THE AVRO ARROW

My Best Regards

Tom Dugelby

A BOOK BY

THOMAS B DUGELBY

CHAPTER 1

This book is dedicated to the four test pilots who made the Avro Arrow what she was.

Janus Zurakowski
Waldek "Spud" Potocki
Jack Woodman
Peter Cope

FOREWORD

I was employed as a Jig and Tool Design Draftsman on the *Avro Arrow* from April 1955 until February 1959 when the project was canceled, whereupon I became a High School Teacher in the subjects of Mechanical and Architectural Drafting, Computer Programing, Computer Assisted Design, Machine Shop Practice and Technical Illustration. I retired in 1963 and have since devoted all my energies into this book.

I first started to think of writing the book on the *Avro Arrow* in 1988 when I was recovering from a cancer operation. My first "port of call" for information was to contact Jim Floyd, who referred me to the National Research Council in Ottawa. The Librarian, Mrs Joan Leonardo, turned out to be very enthusiastic, and could not help me enough in my quest for information. Unfortunately, most of the documents held there were of a CLASSIFIED nature, and I had to apply over the next eight years for declassification. I am now happy to say that all that they possess is now declassified, but only at NRC, not at the DND or anywhere else. This process involved some 1500 documents all told.

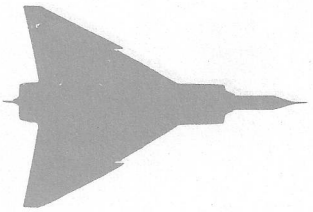
Through my contact with Mrs Leonardo, she referred me to her husband, Ralph, who at the time was a Curator at the National Aerospace Museum at Rockcliffe Airport, Ottawa. Mr Leonardo then introduced me to their *Avro Arrow* collection, which proved most informative.

I contacted several other persons, who are listed in the Acknowledgments, who were more than helpful in my research, and I am very much indebted to them.

During these past few years, the research and writing of the book has been a "labor of love". I have tried as far as was possible, to use the Company's own words in order to keep authenticity at a maximum.

I hope that the reader will gain as much pleasure and insight as I have done, as he or she reads through this and the successive Chapters.

Tom Dugelby
Freelton
Ontario
January - 1997.



ACKNOWLEDGMENTS

First and foremost I wish to thank Mr Ken Barnes of Etobicoke, Ontario for his very great help and access to his files on the Arrow. Without his help, this book would not have been possible in the depth of coverage that has been attained.

The existing files of the former Avro Aircraft Company that are now held at the National Research Council in Ottawa, Ontario, have been invaluable. The co-operation, kindness and help provided to me by the Librarian of the Parkin Library of this Institution, Mrs Joan Leonardo, has been the backbone and very foundation of this book. I cannot thank her enough.

The National Aviation Museum, Rockcliffe Airport, Ottawa, Ontario has also been of very great assistance in allowing me access to their library. In particular I wish to thank Mr Ralph Leonardo, Curator, for his help and friendship.

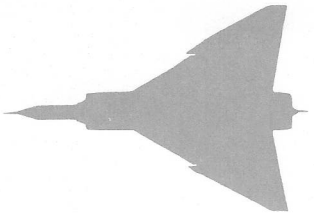
To Mr Les Wilkinson of the "ARROWHEADS" fame who was one of the authors of the "AVRO ARROW", published by Boston Mills Press in 1980, I extend another special thanks for his help in the provision of documents.

To Mr James C. Floyd, who can be said to be the "father of the Arrow", I wish to extend a special thank you for his support and guidance in the many hours of conversation held over the past few years. .

To Mr Palmiro Campagna, the author of "Storms of Controversy", published by Stoddart in 1992, I also extend an appreciation for his help and friendship in the pursuit of information.

To Mr James Cook of Freelton, who provided information.

This would not be complete without a thanks to the 14,000 former employees of Avro Aircraft, who made this whole thing possible. I was a very small part of that team, and take pride in the fact that I was a part of a project that for a short time only, enabled Canada to lead the world.



ABBREVIATIONS USED IN THE TEXT

RCAF - Royal Canadian Air Force.

NACA - National Advisory Committee for Aeronautics.

DRP - Defence Research Board.

NAE - National Aeronautics Establishment.

RAE - Royal Aeronautical Establishment.

T/C - Thickness - Chord Ratio.

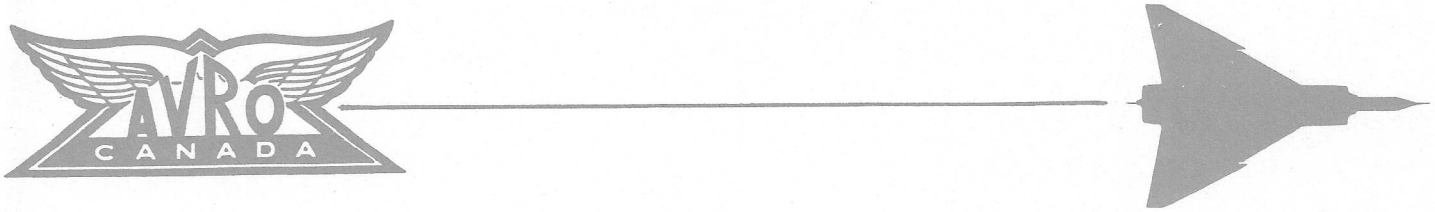
FFAAR - Folding Fin Air-to-Air Rockets.

M - Mach number.

EAS - Estimated air speed.

CARDE - Canadian Armament Research Development Establishment.

DDP - Defence Department of Production.



INTRODUCTION

It was in 1951, that both the R.C.A.F. and Avro Canada recognized the fact that the CF-100 fighter would have to be replaced at a future date in order to keep pace with the development of long-range bombers in the then Soviet Union.

To this end, the Long Range Projects department at Avro started work on such a replacement using the following references as guides:-

1. Handbook of Instructions for Aircraft Designers. AMC 80-1 1951.
2. U.S.A.F. Model Spec. MIL-1-6252 Oct 18 1950.

Much work had been carried out by such notables as Prof.B M Jones in the UK who was able to show in 1929 that nearly all contemporary aircraft had two or three times the drag due to their design. Prandtl of Germany proposed the concept of boundary layer in 1904, though in the UK literature the term does not appear until 1925. The use of sweepback to reduce drag at supersonic speeds was first proposed by Busemann (a German Aerodynamicist) at the Volta Congress for High Speed Flight in Rome in 1935 and in 1939 Albert Betz of Switzerland, another aerodynamicist, had shown the sweepback could be used to delay the onset of compressibility problems in transonic flight. Dr Alexander Lippisch of Messerschmitt AG in Germany during World War 2, applied all this on delta and swept wing designs in high speed flight. The swept wing clearly demonstrated the delay of drag rise at high supersonic speeds. The British, on May 15th 1946, were the first to capitalize on this research with the DeHavilland 108 "Swallow", and were followed by Sweden with the SAAB J29 in September 1948, the first production swept wing fighter in Western Europe, preceded World Wide only by the Americans and the Russians. The Americans produced such successful designs as the North American F-86 Sabre and the Convair F-102 Delta Dagger, the Russians built the MIG-15 and the British in 1948 had three swept wing designs, the Avro 707, the Hawker P1052 and the Supermarine Type 510/517 and were beginning to realize the properties of a Delta configuration.

Avro therefore used this information as a starting point for the new design, and in June of 1952, issued two brochures, C/104/1 for a single-engined design and C/104/2 for a twin engined one. Both were intended to perform the same task, namely to intercept and destroy any long-range bombers of the highest performance which were likely to be available to an enemy during a five to ten year period. Guided missiles and air-to-air rockets were specified as the main offensive armament, the target tracking, aiming and fire control being automatically computed by airborne electronic equipment working in conjunction with ground signals. The C/104/2 with a two man crew became the basis for the initial new design.

In May of 1953, the R.C.A.F. specification AIR 7-3 was issued to cover the

development of such a replacement aircraft, now named the C-105. Avro then undertook to design the aircraft to this specification and after many false starts and design changes due to engine availability, R.C.A.F. demands, aerodynamic problems and material specifications, the R.C.A.F. in 1954 issued an updated specification, AIR 7-4 to cover the new design, the CF-105.

The resulting aircraft, named in 1957, was the Arrow Mk1 using Pratt and Whitney J-75 engines, and five aircraft were built and flown. With the Iroquois engine becoming available, the first Mk2 Arrow was completed in February 1959 and was scheduled to commence flight tests in March of that year, but the entire project was canceled and terminated on February 20 1959 with all aircraft, tools, drawings and photographs ordered destroyed by the Canadian Government.

The tables of events etc., are taken from the original Avro writings of which the CF-105 "Engineering Chronology" was the result of considerable sifting of the multifarious data relating to the CF-105 project between the time of the inception of a 'High Performance All-Weather Fighter' in 1948, and the concept as it became to RCAF Spec. AIR 7-4.

This 'Chronology' is based on correspondence, meeting minutes, schedules and internal memoranda. It is primarily restricted to engineering fact, recommendation and decision, though it does contain a certain amount of the contractual and fiscal data. It includes test programs, weight progress, drag assumptions and the highlights of the configurations which evolved through the design period.

It is important to remember that during project study years (1948 - 1953), the CF-103 and C-104 were separate entities in so far as design concept. The CF-103 was essentially developed from the CF-100, whereas the C-104 was an entirely new design.

Moreover, these tables are presented so that the reader can progress through all these stages as they happened at the time.

Most of the illustrations in the text, are directly from the originals, but there are several which have had to have been redrawn as they were incapable of being reproduced. In all cases, accuracy to the original has been observed.

This treatise is presented in the form of reports in a similar manner to the way that such information was presented at Avro, in order to give the reader a feeling of "being there".

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TO DEFEND A NATION 1

CF-100 DEVELOPMENT

That the reader should fully understand the reason for being of the Avro Arrow aircraft, it is necessary to define the geographical and environmental conditions that prevail in Canada.

To this end, there is no better description than that presented by James C Floyd in his lecture to the Royal Aeronautical Society in London, England, on October 9, 1958 entitled "The Canadian Approach to All-Weather Interceptor Development".

> " Canada's chosen role in military air power is one of defence, and Canada does not maintain any bombing or tactical Air Force. Environmentally, while our geographic proximity to the United States obviously influences the choice of systems and armament to ensure reasonable compatibility with the complex USAF North American defence system, and the traditional association with the RAF in the United Kingdom again influences the basic establishment and strength of the RCAF, there are unique requirements and conditions in maintaining an adequate air defensive system in Canada which have led the RCAF to establish requirements for an aircraft particularly suited to these conditions.
>
> Canada's northern frontier is a vast unpopulated expanse which, from coast to coast, is second in length only to that of Soviet Russia. Air defence bases are of necessity, few and far between. Our defence interceptors must be capable of long range operation by day or by night, in any weather. The climate is anything but temperate, varying from near tropical conditions to sub-zero temperatures, and our fighters must have a very high reliability in this relatively abnormal environment.
>
> Since Northern Canada is the first line of defence for the North American continent, our aircraft must be equipped with an automatic fire control system which will ensure the maximum probability of kill on the first pass, and the most potent airborne weapons available.
>
> Canada learned a hard lesson in World War 2, when she depended upon other sources for her front line aircraft. To quote the Chief of Staff at the time of decision to proceed with "home brew": "In the early days of fighting, Canadian squadrons operating overseas were low on the list for equipping with the latest types, and on occasion, even Canadian built Hurricanes, sorely needed by home based squadrons to meet a Japanese threat in the Alutions, were alloted to Russia". In a sense, this is quite understandable, since it is like expecting a neighbor, in the middle of a fire in his own house, to hand over one of his insufficient number of fire extinguishers so that you may prevent fire spreading to yours. However, it

gave Canada a "loneliness complex", the cure for which I believe has turned out very well.

When, in 1946, the RCAF made the decision to re-equip its front line fighter squadrons with a two-place twin-engined day and night all-weather interceptor with a particularly long range capability, a team of RCAF officers visited aircraft factories in the United Kingdom and the United States to ascertain whether there was an aircraft on the drawing boards which was likely to fill their requirement. Apparantly there was not, and they persuaded the Canadian Government to take the momentous step of financing the design and development of a suitable aircraft in Canada. The CF-100 all-weather fighter was the result.

The outcome of this joint decision must be judged on a basis that, in addition to being the standard Canadian all-weather fighter for many years, the CF-100 is now in service with the RCAF Air Division in NATO, and was recently chosen in keen competition with other available types to re-equip the Belgian Air Force. The RCAF CF-100 squadrons are also now an integral part of the North American Air Defence system under NORAD".

CF-100 TYPE DETAILS.

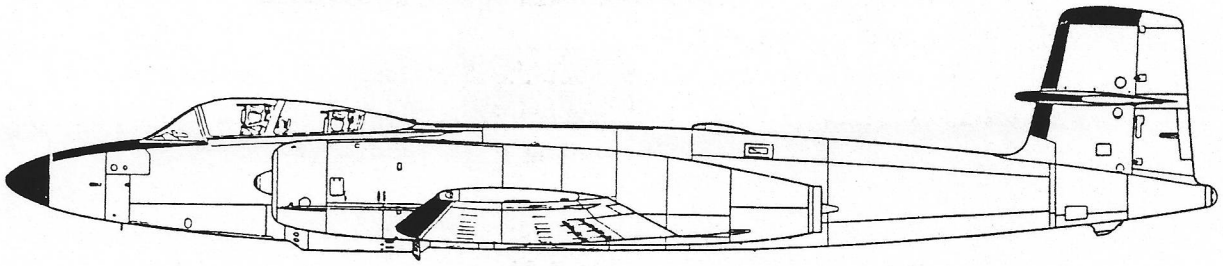
1. CF-100 Mk3.

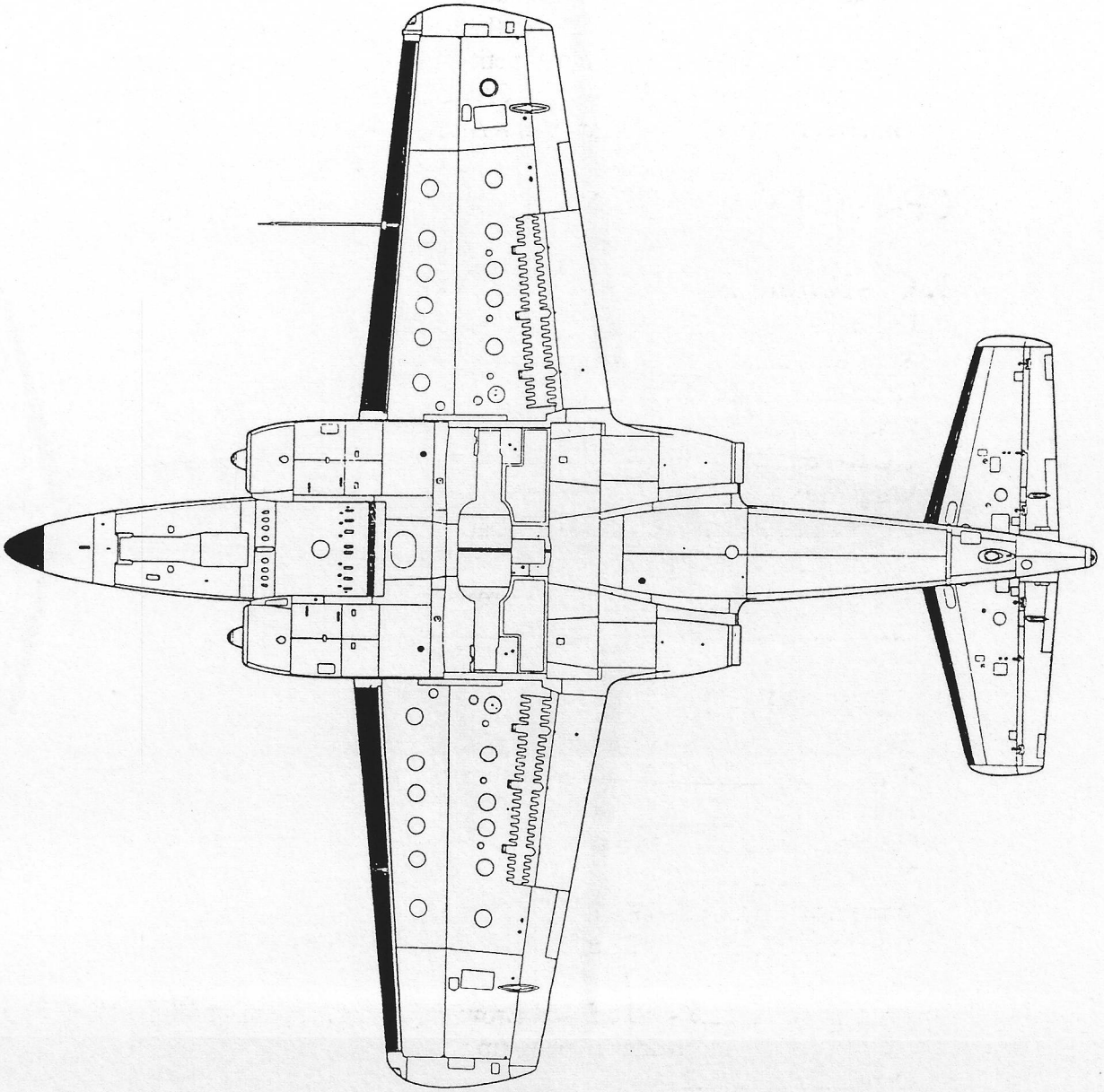
Engines.....2 - Orenda 8
Span.....52 ft. 0 in.
Length.....52 ft. 6 in.
Height.....15 ft. 1 in.
T/C Ratio.....10%
Wing Area.....540 sq. ft.
Weight.....27,000 lbs. (combat)
Radar.....APG 33
Armament.....8 - .50 cal. M3 Browning machine guns.
Crew.....2

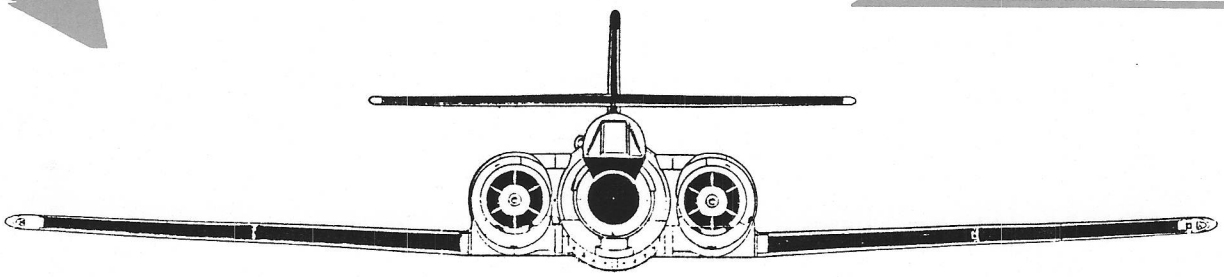
2. CF-100Mk4B.

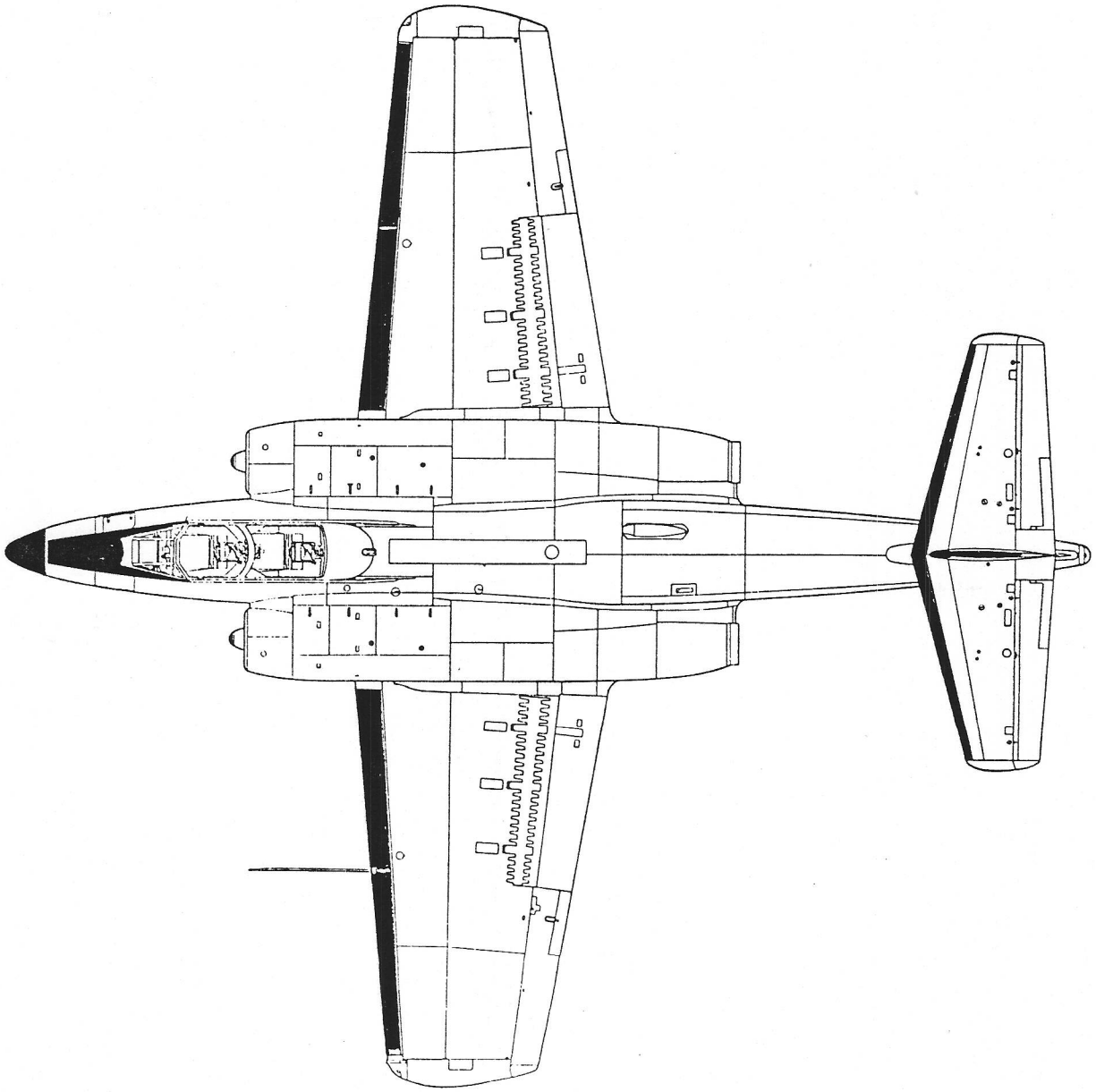
Engines.....2 - Orenda 11
Span.....57 ft. 5.5 in. (with tip tanks)
Length.....54 ft. 2 in.
Height.....14 ft. 6 in.
T/C Ratio.....10%
Wing Area.....540 sq. ft.
Weight.....36,500 lbs.
Radar.....MG 2
Armament.....8 - .50 cal. M3 Browning machine guns or 58- 2.75" rockets in wing-tip pods.
Crew.....2

AVRO CANADA









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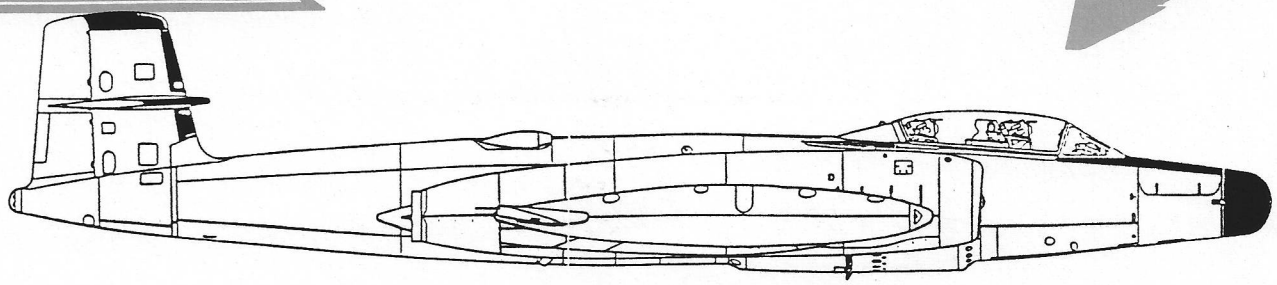
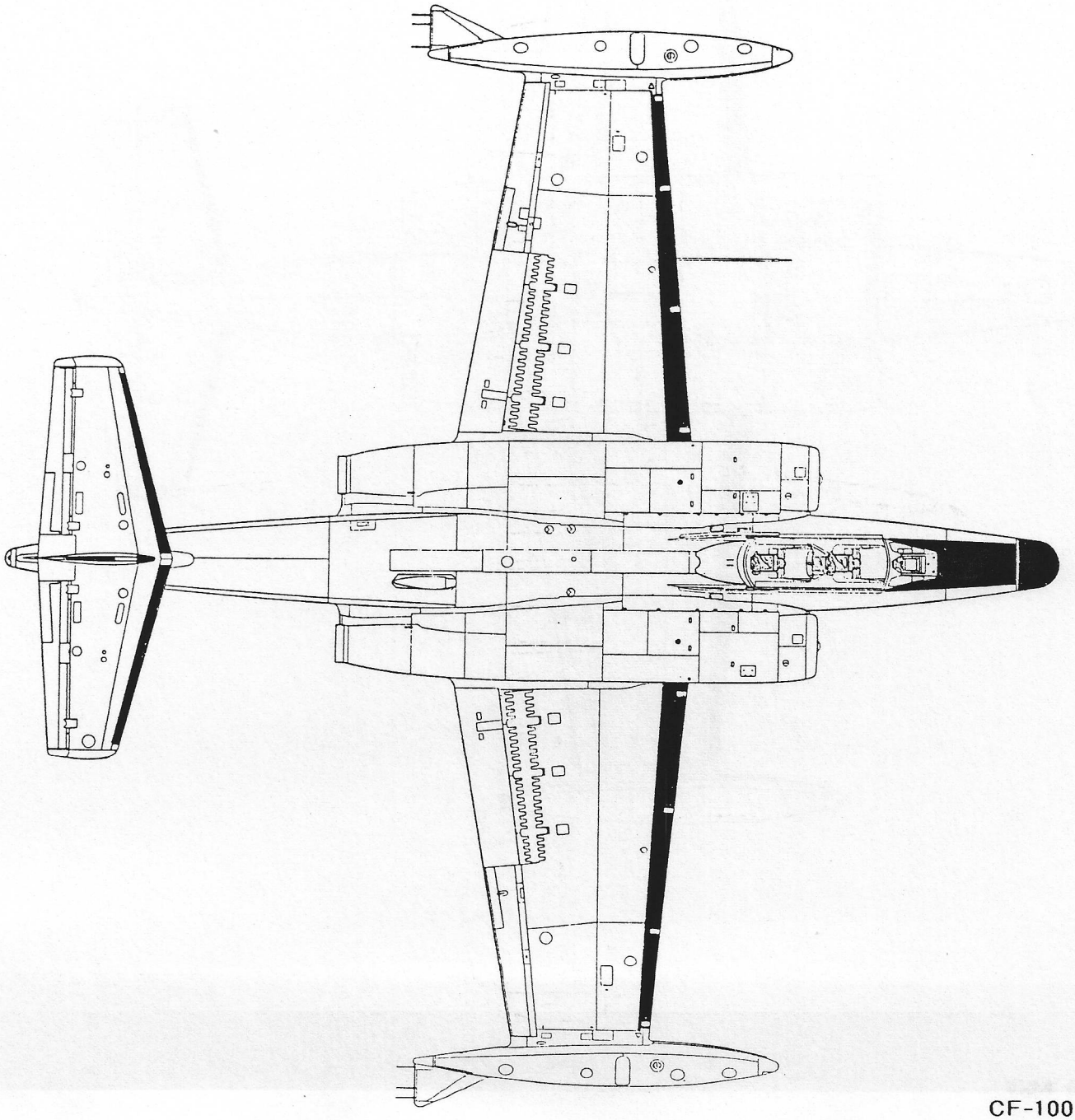
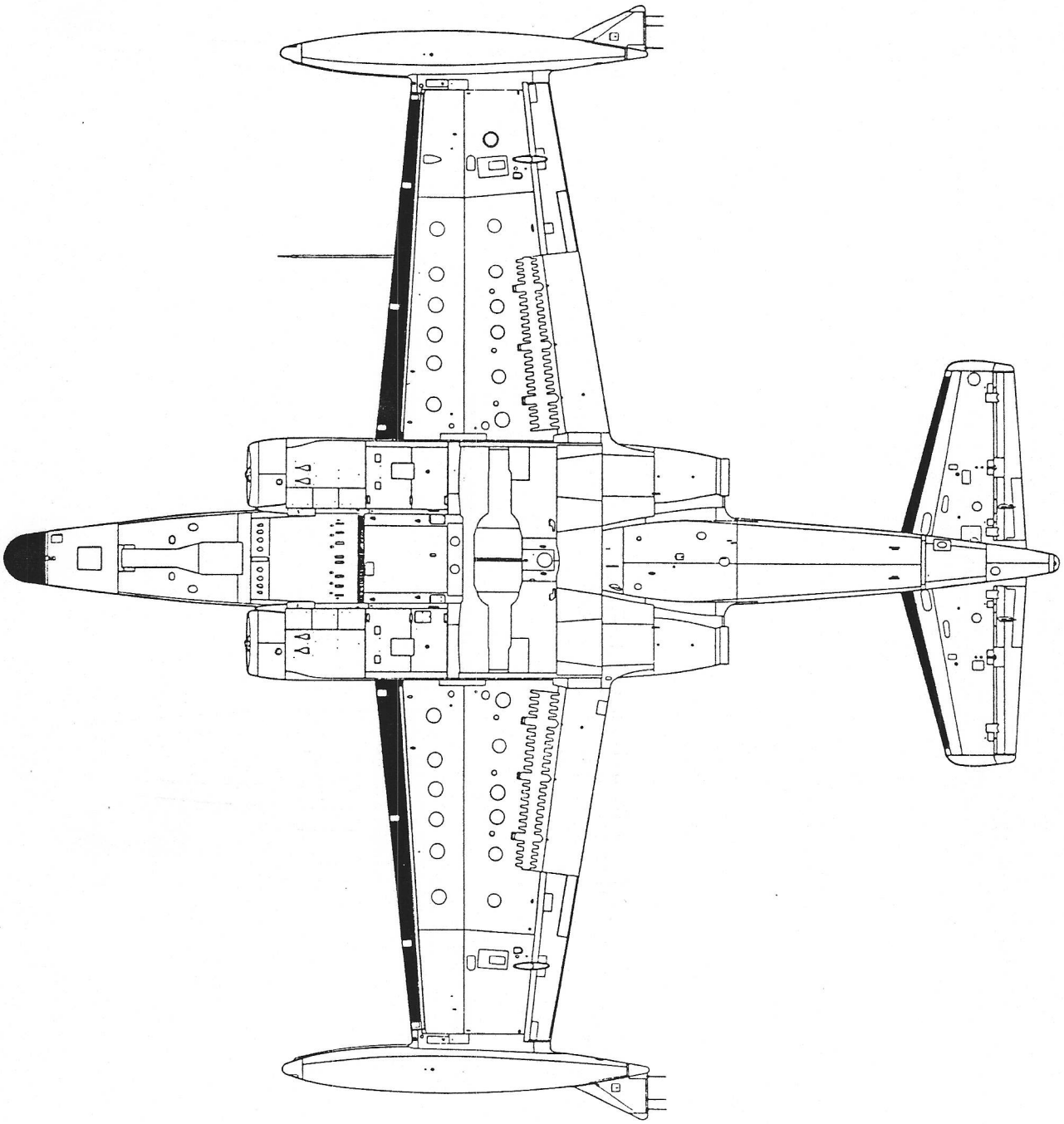




CF-100 Mk4



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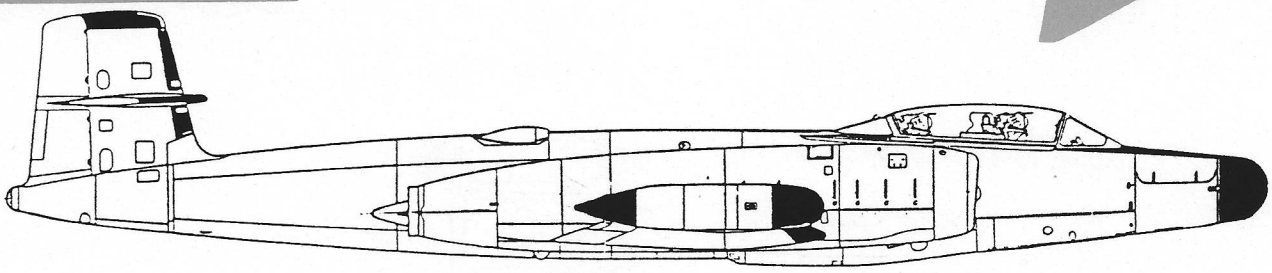
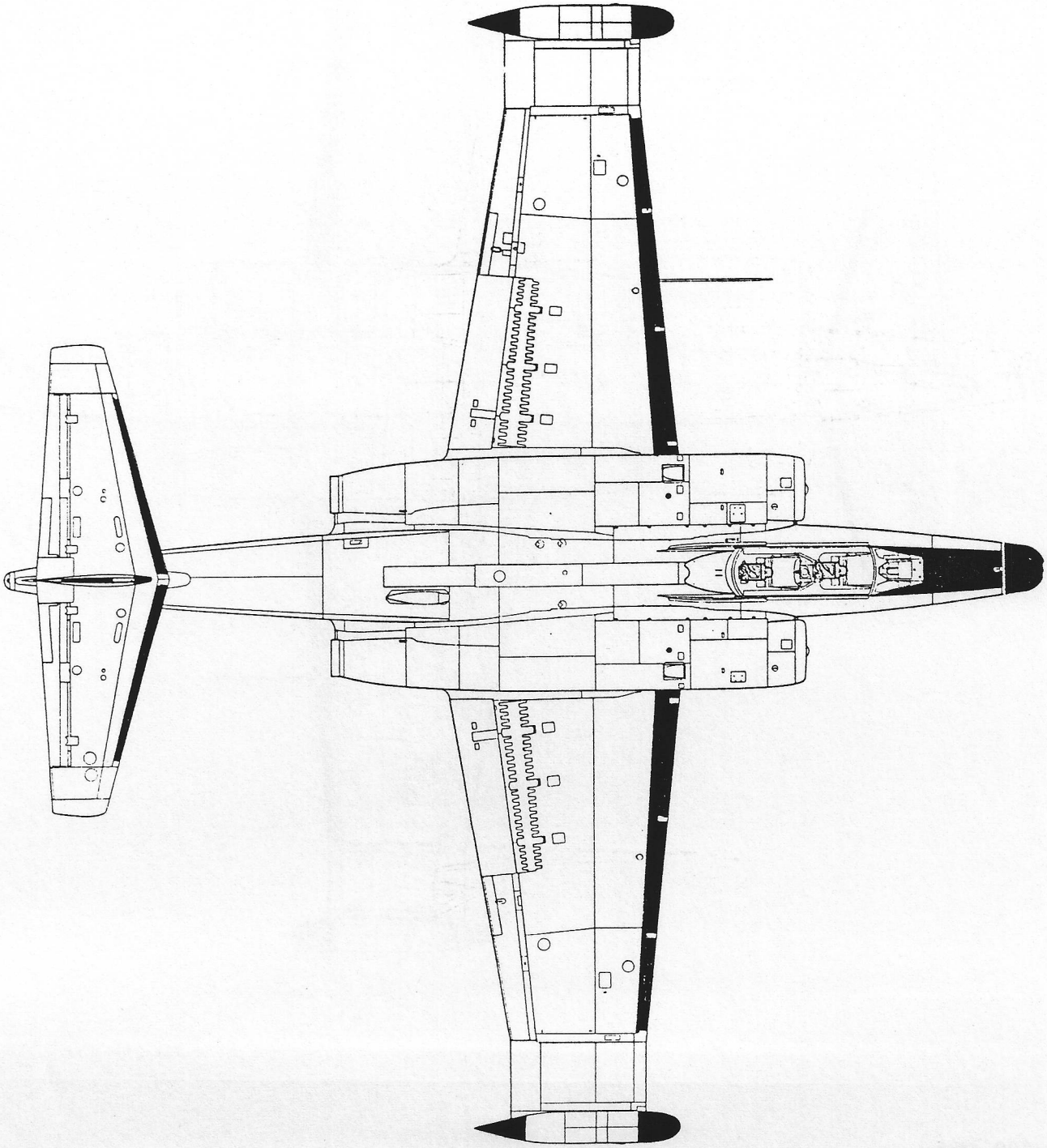
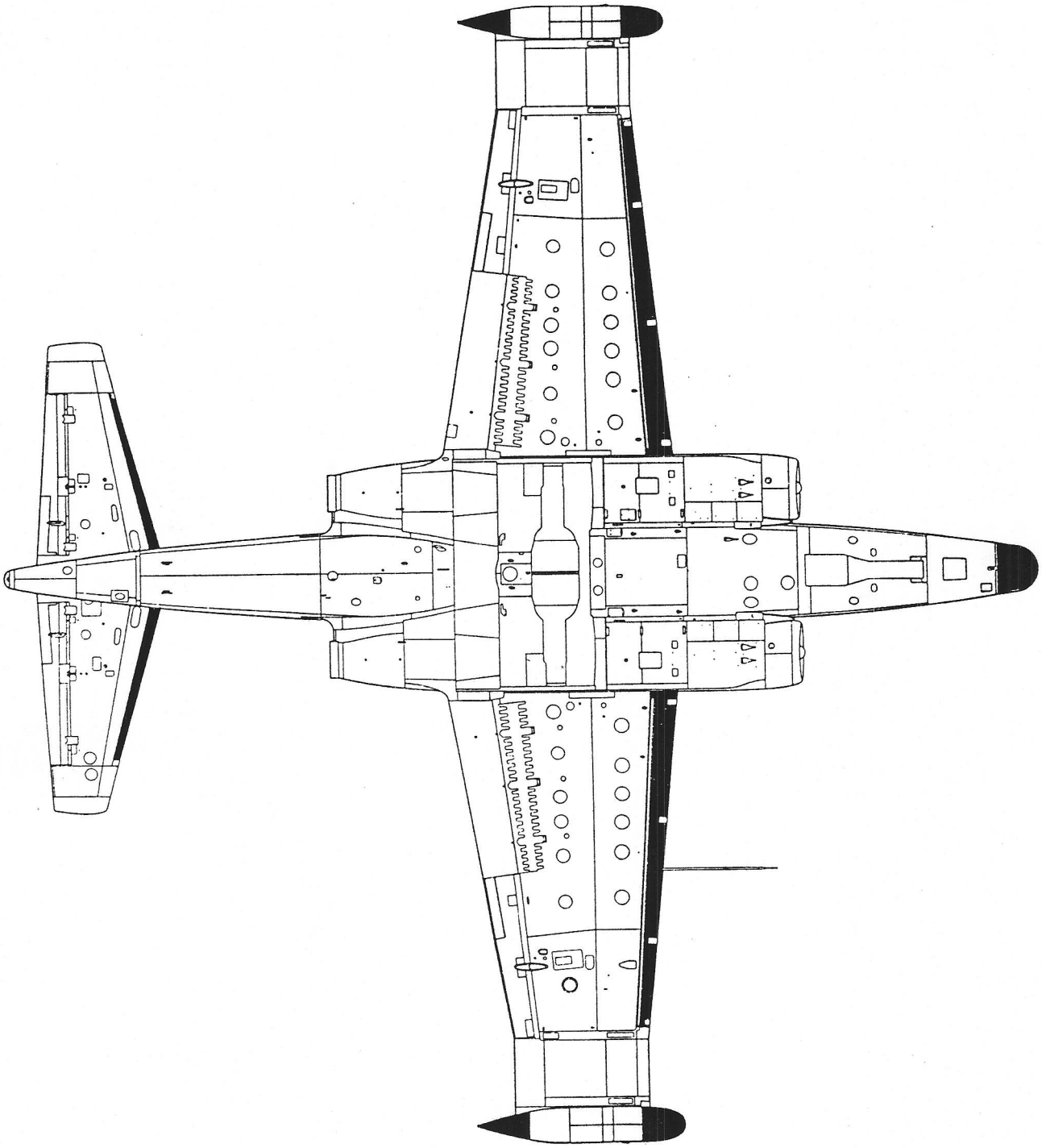
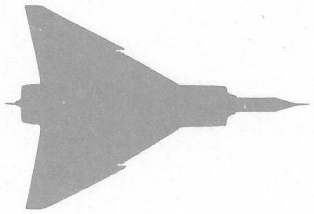








3. CF-100 Mk5.

Engines.....2 - Orenda 14
Span.....60 ft. 10.25 in.-Tailplane to 25 ft.
Length.....54 ft. 2 in
Height.....14 ft. 6 in.
T/C Ratio.....10%
Wing Area.....592 sq. ft.
Weight.....29,000 lbs.
Radar.....MG 2
Armament.....24 - 2.75" rockets
Crew.....2

CF-100 REPLACEMENT.

Due to the number and complexity of dates and events, the following tabulations lay out the development of designs from July 1948 until June 1952 which led to the C-104/1 and C-104/2 which became the genisis for design of the C-105 through to the Arrow itself. In order to give the reader a complete progression of events leading up to the C-105, the entire table of design studies leading to the CF-105 is presented below:

1. July/48 Aircraft type.....C-100-S

Engines.....2-TR9
Span.....52 ft. 0 in.
Length.....51.25 ft.
Height.....13 ft. 0 in.
T/C ratio.....9%
Wing area.....624 sq. ft.
Weight.....32,930 lbs.
Radar.....British Mk9-A1
Armament.....Guns and rockets as CF-100
Crew.....2

Modified CF-100 fuselage and nacelles with 35 degree swept low wing with fixed tailplane on top of fin. Became C-103 in 1951.

2. July/49 Aircraft type.....C-100-D

Engines.....2-TR9 + A/B
Span.....50 ft. 0 in.
Length.....67.6 ft.
Height.....22 ft. 0 in.
T/C ratio.....6.58%
Wing area.....850 sq. ft.

Weight.....40,610 lbs.
Radar.....AN/APS-19A
Armament.....4-Aden 30mm cannon
Crew.....2

43 Degree swept low-wing with fixed tailplane. Became the C-104. Major changes from C-100-S, buried engines in fuselage and flush intakes.

3. Nov/49 Aircraft type.....C-104

Engines.....2-TR9 + A/B
Span.....49.5 ft.
Length.....68.5 ft.
Height.....21 ft. 0 in.
T/C ratio.....6.58%
Wing area.....888 sq. ft.
Weight.....41,000 lbs.
Radar.....AN/APS-19A
Armament.....4-Aden 30mm cannon
Crew.....2

43 Degrees swept low-wing with fixed tailplane. Major changes from C-100-D, wing root intakes and buried engines side-by-side.

On December 19th, 1949, Avro Aircraft issued a preliminary brochure on a "Proposed Long-Range All-Weather Fighter". The complete study for this fighter as it was seen then, is presented here as a beginning of the Arrow project.

INTRODUCTION

"It was thought worth while to investigate the potentialities of the long-range, all-weather fighter which could be expected to be realized, utilizing recent aerodynamic developments and anticipating engine developments. For this purpose the specification on which the CF-100 is based is used as a starting-off point. This was on the assumption that the basic requirements against which this aircraft was designed would meet Canadian conditions for some time to come. In order to make a worth while advance on the CF-100, the high-altitude, high-speed, long-range bomber which can be expected in the next four or five years was taken as the tactical datum and an endeavor was made to design a fighter which would be able to attack such a bomber effectively. It has been assumed that suitable ground-to-air, and air-to-air search radar will be available in conjunction with appropriate aircraft armament.

GENERAL DESCRIPTION

This study describes a long-range, high-altitude, all-weather search fighter of advanced design. Alternative arrangements are shown in the drawings. From these drawings it can be seen that the aircraft is a two-place, mid-wing monoplane, powered by twin gas turbines, each of 8,000 lbs. static thrust.

The wing is of swept-back plan form having a quarter chord sweep-back of 43 degrees and an aspect ratio of 2.76. A similar swept-back tailplane has been retained on this aircraft as it is felt that this is desirable in order to achieve adequate manoeuvring.

In addition to the gas turbine engines, rocket motors are also provided in the tail for providing up to 6,000 lbs. of additional thrust under high altitude combat conditions. The armament may be either four 30 mm cannon or, probably later on, long range, large calibre guns firing shells with proximity fuses.

The tankage of the airplane will enable a normal range of over 1.500 miles to be achieved while ultimately additional tankage can be provided for the second rocket motor fuel. This will enable the aircraft to be developed for flight at supersonic speeds. In addition, after-burners are provided for the gas turbine engines to assist in take-off, climb and in combat.

With the provisions described the aircraft can, therefore, climb to the approximate height of the bomber, say 45,000 ft. at which height it can patrol at a moderately high cruising speed. On making contact by radar with the bomber it can go into the attack using the rocket engines which will give the aircraft a short duration performance substantially superior to that of the bomber. The rocket engines will enable the aircraft to climb to 60,000 to 70,000 ft., if necessary with a speed differential of at least 200 mph. This should give ample margin for manoeuverability and getting into position for the attack.

It is felt that the study as outlined suggests an aircraft which basically is of normal design but which has considerable potential development in it, in so far as it can utilize its supersonic possibilities by the addition of the rocket engines, in due course, when this superior performance is required operationally.

Under short range conditions the aircraft would be an extremely effective Interceptor Fighter having a sea level rate of climb with reheat of say 24,000 ft. per minute, with ample manoeuverability."

The three aircraft submitted in the study were the XC-104, Version A, Version A with tip tanks and Version B.

The basic data on the similar sized aircraft is as follows:

Aircraft type.....C-104 A and B

Engines.....2-Orenda engines plus 2-rockets
Span.....49.5 ft
Length.....64.0 ft
Height.....20.0 ft (over fin)
T/C Ratio.....6.38%
Wing Area.....888 sq ft
Weight.....48,000 lbs
Radar.....Unspecified
Armament.....Initially 4-30 mm cannons
Crew.....2

Illustrations of each type are provided.

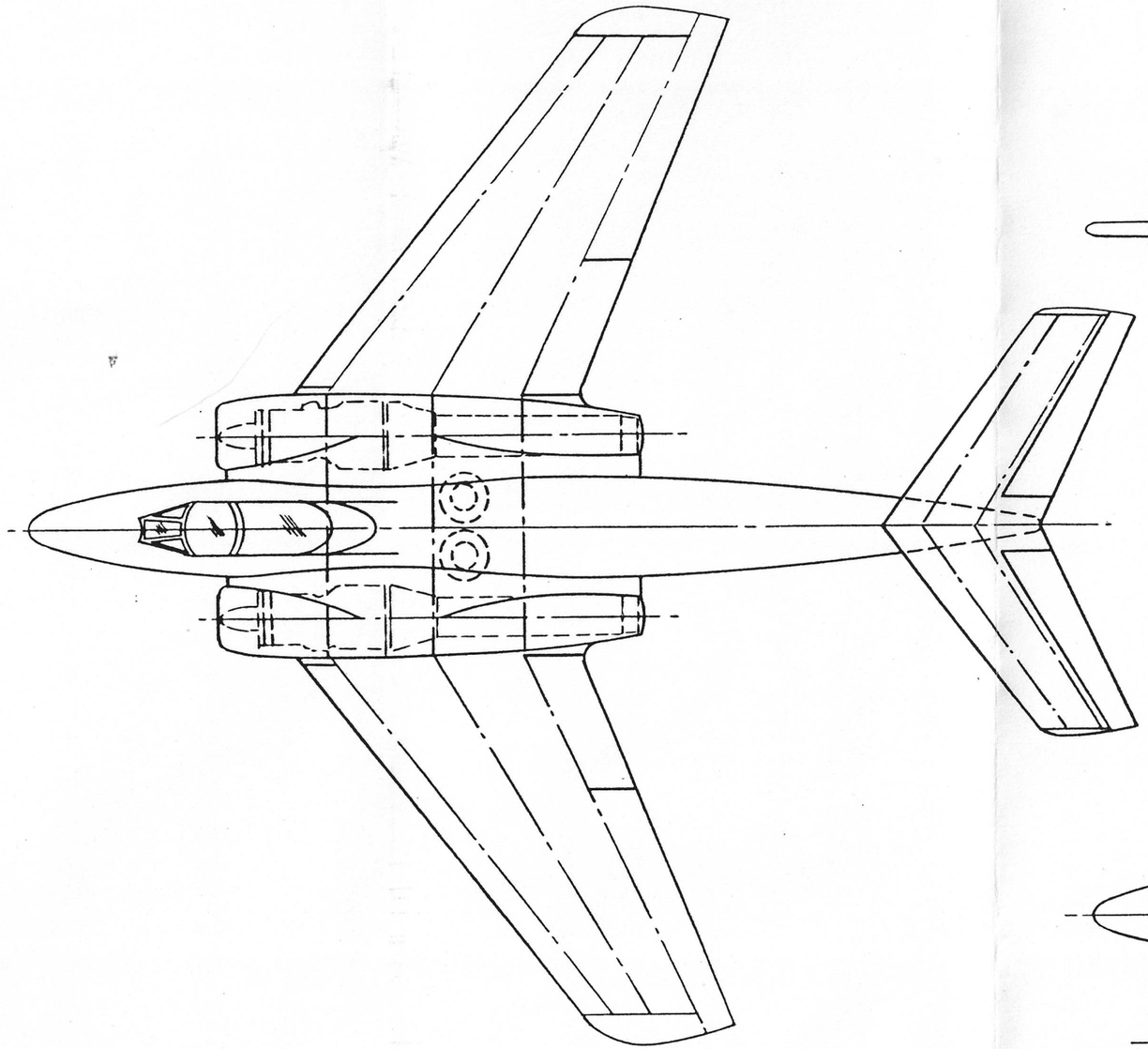
4. July/50 Aircraft type.....C-104

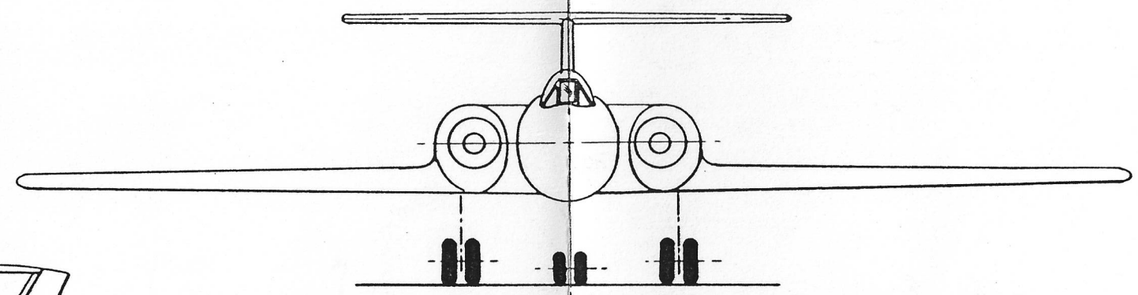
Engines.....2-TR9 + A/B + 2-rocket engines
Span.....49.5 ft.
Length.....67 ft. 0 in.
Height.....20.5
T/C ratio.....6.58%
Wing area.....888 sq. ft.
Weight.....48,000 lbs.
Radar.....AN/APS-19A
Armament.....Armament bay for 18 small missiles
Crew.....2

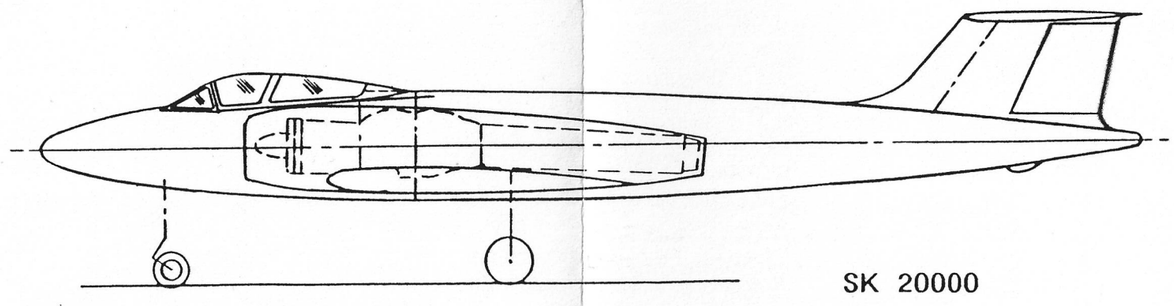
43 Degree swept mid-wing with fixed tailplane. Major changes from C-104 of Nov/49, fuselage nose intake, mid-wing, armament bay and engines over each other.

5. Jan/51 Aircraft type.....C-103

Engines.....2-TR9 + A/B
Span.....50.5 ft.
Length.....54.25 ft.
Height.....17.6 ft.
T/C ratio.....8%
Wing area.....800 sq. ft.
Weight.....46,670 lbs.
Radar.....AN/APS-19A
Armament.....T-160 cannon plus rocket pack
Crew.....2







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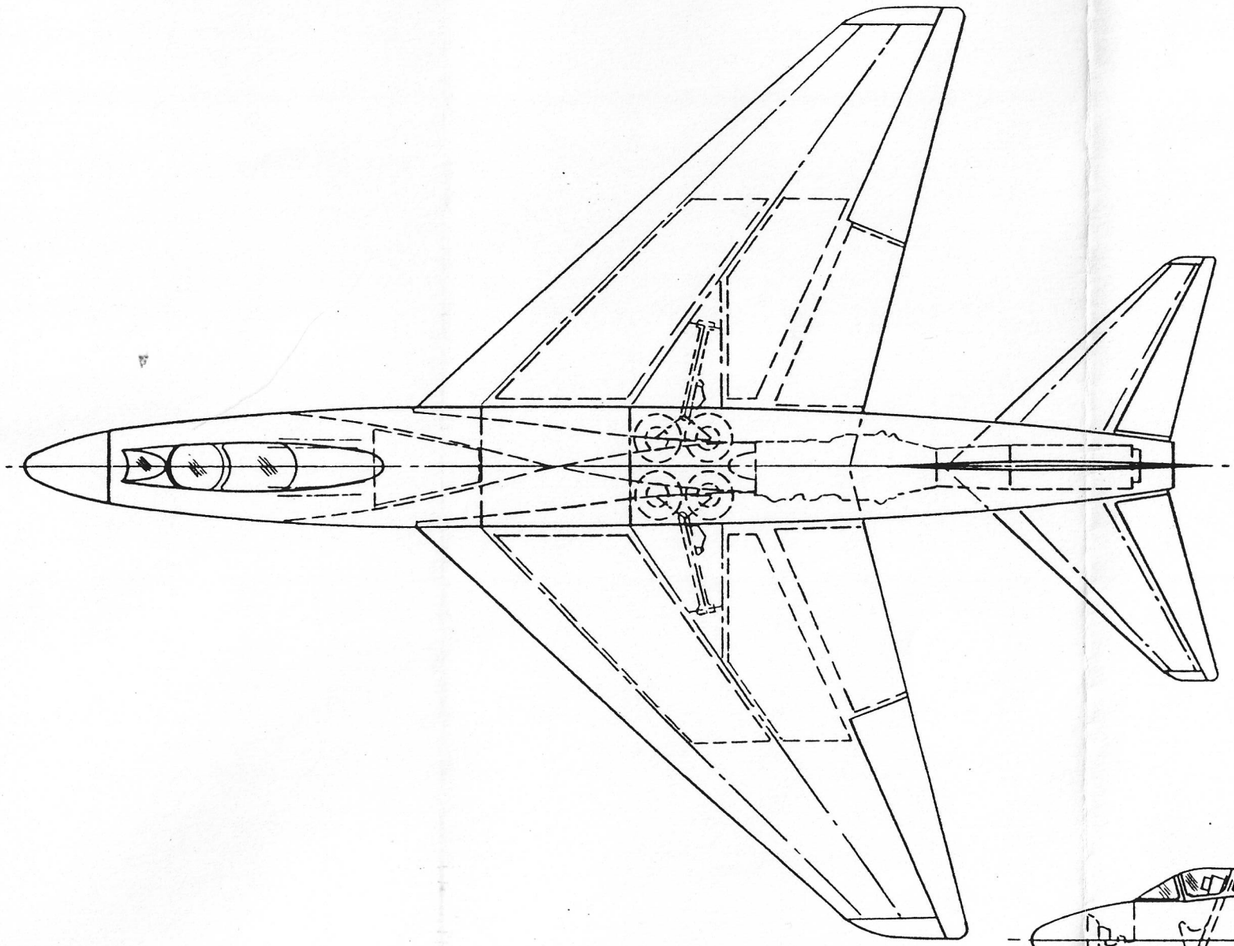
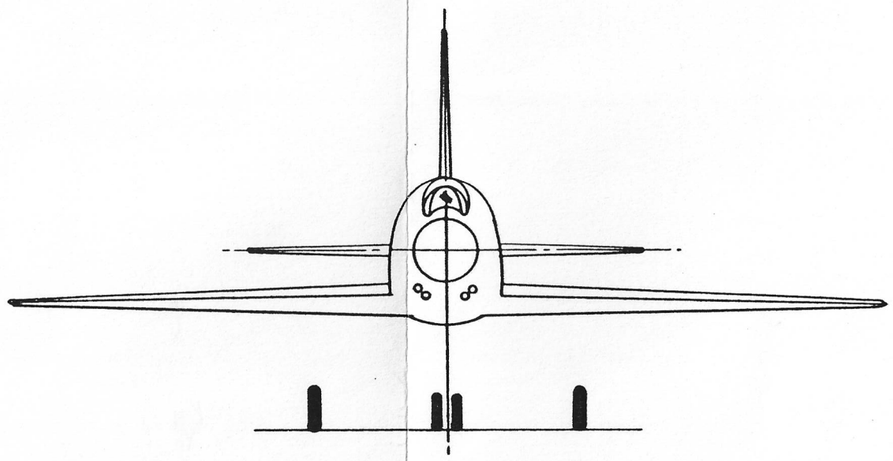
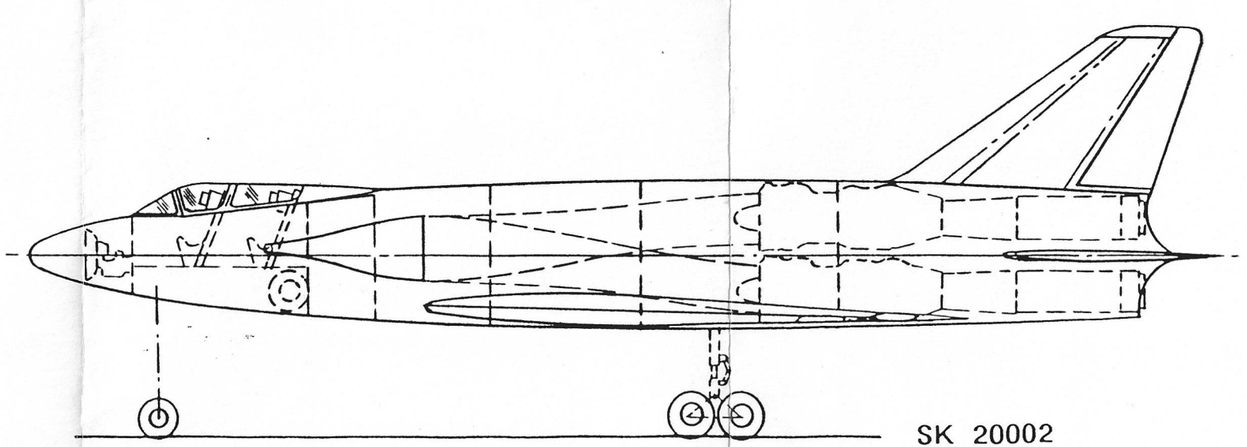
C/100S/TR9. JULY 1948.







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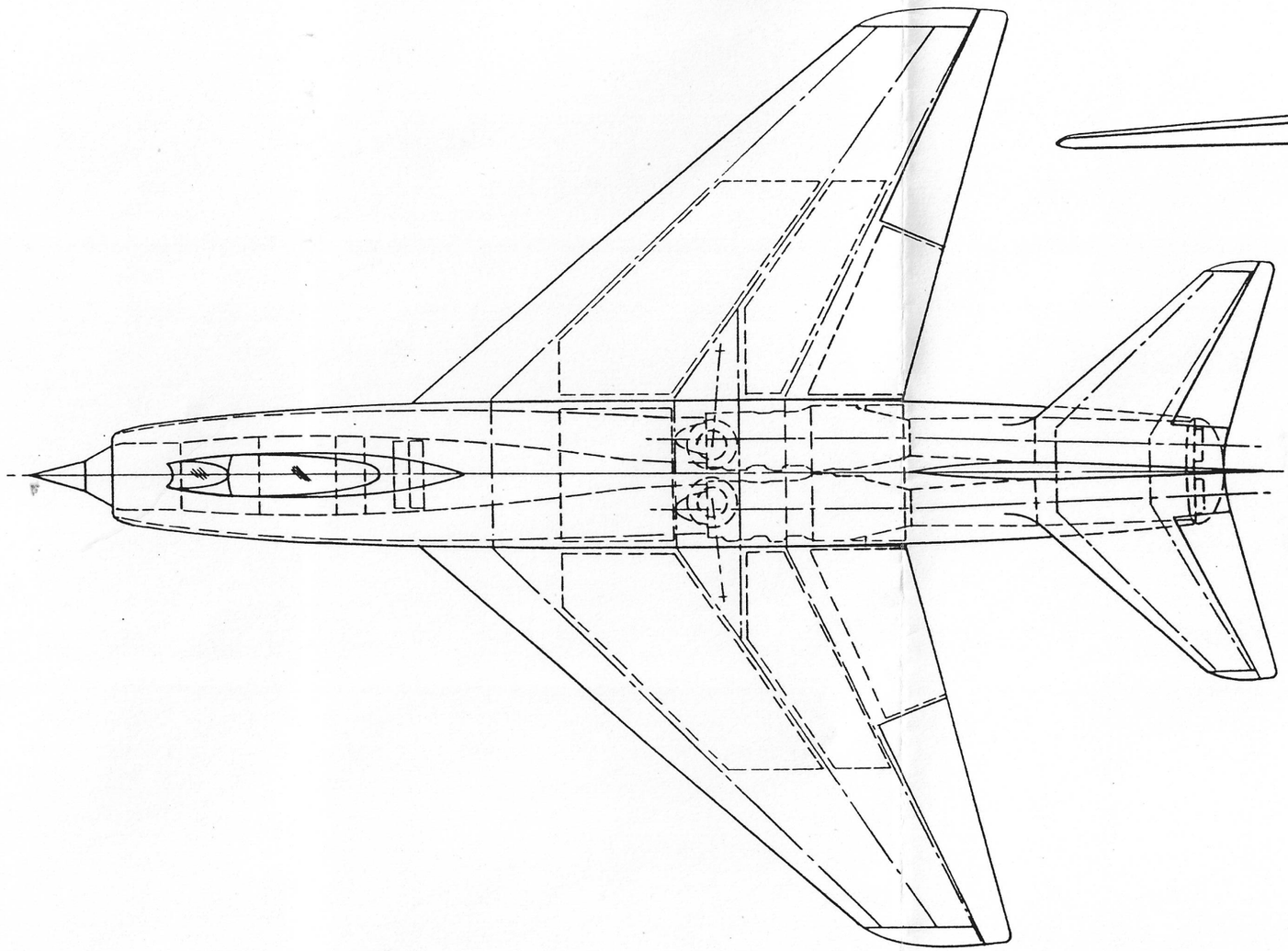
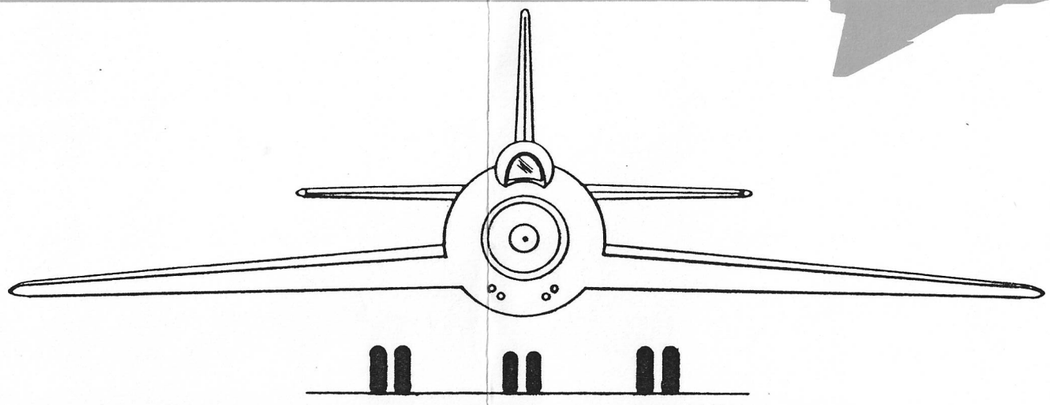
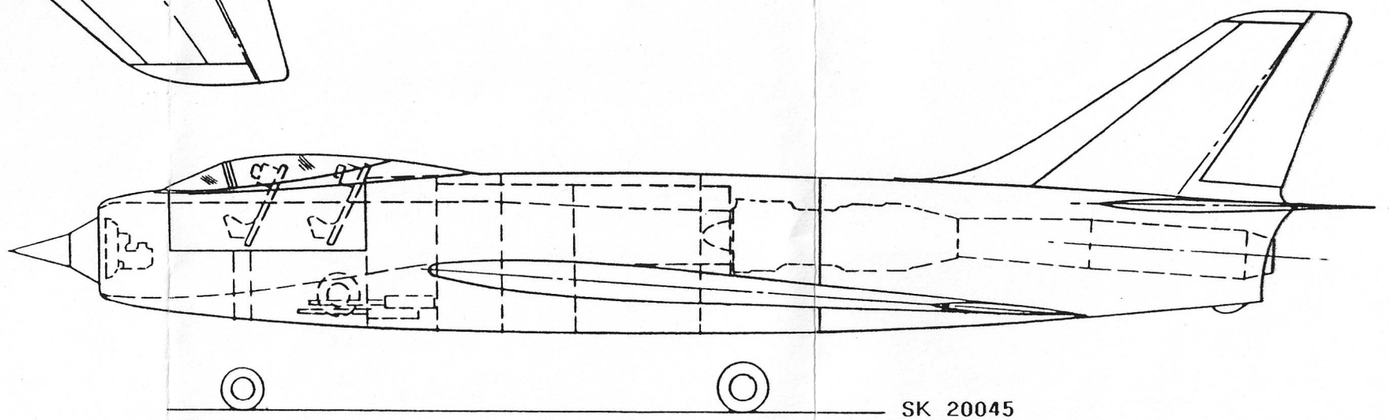
C/100D/TR9. JULY 1949

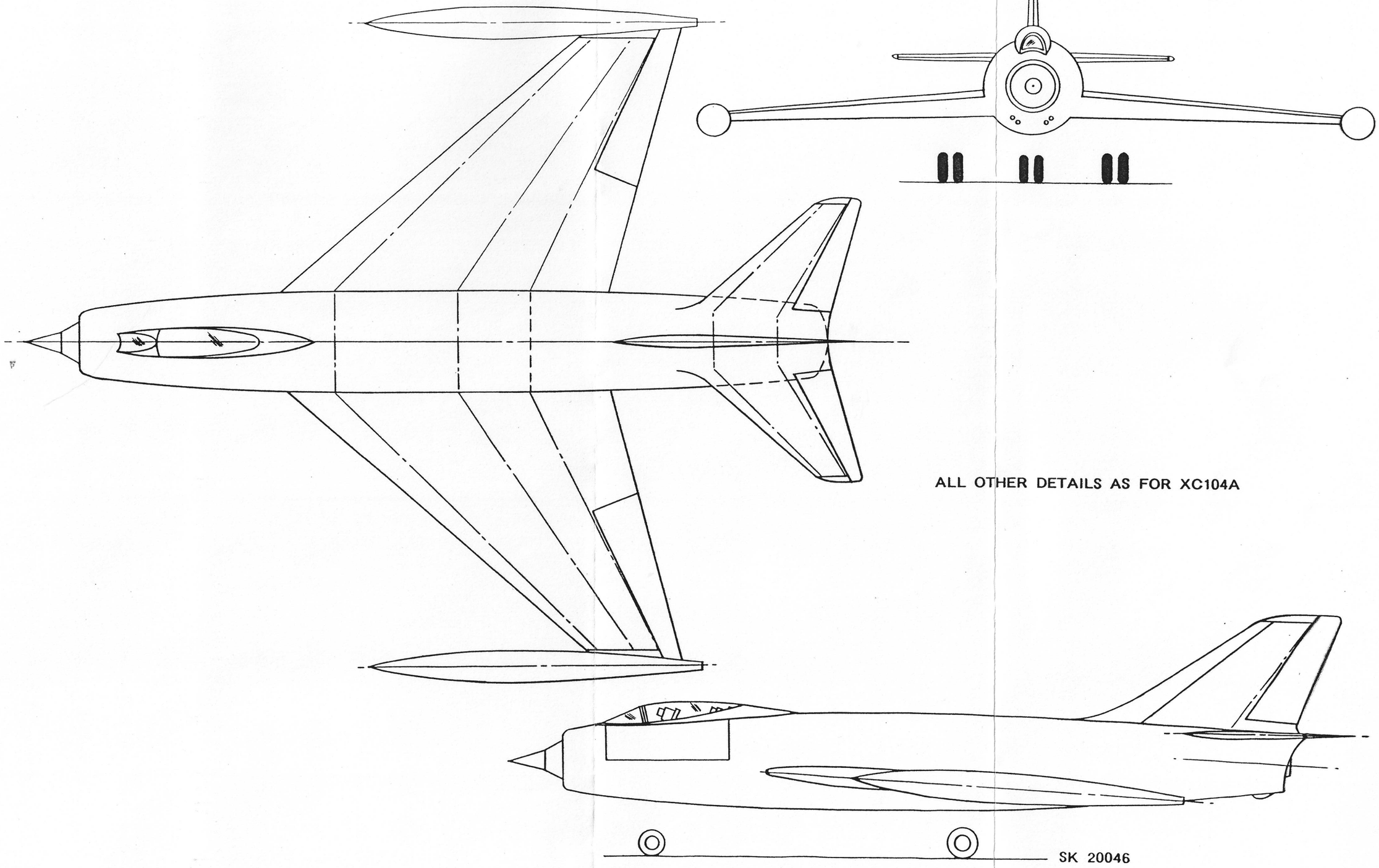






SK 20045

XC/104A. DECEMBER 1949.

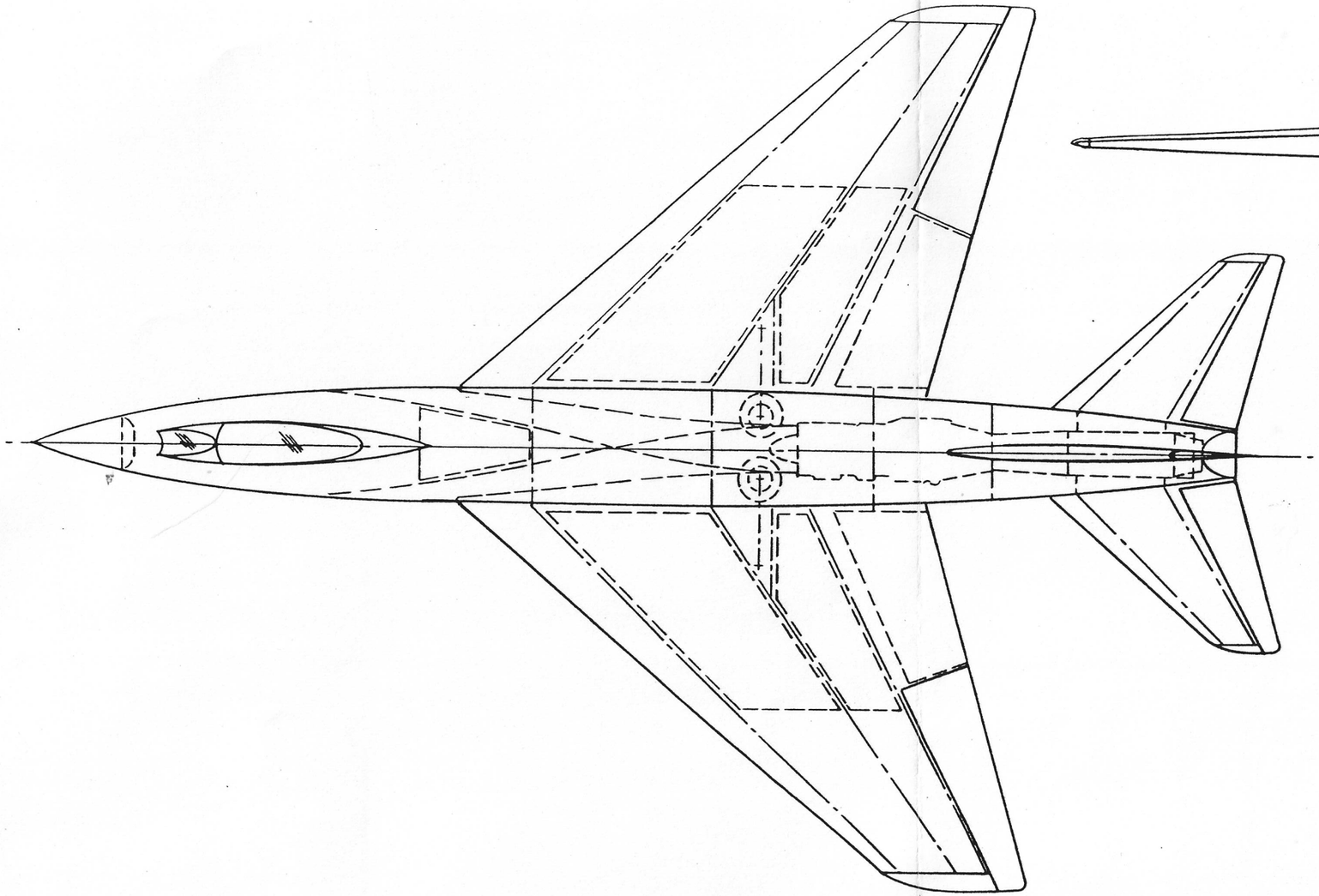


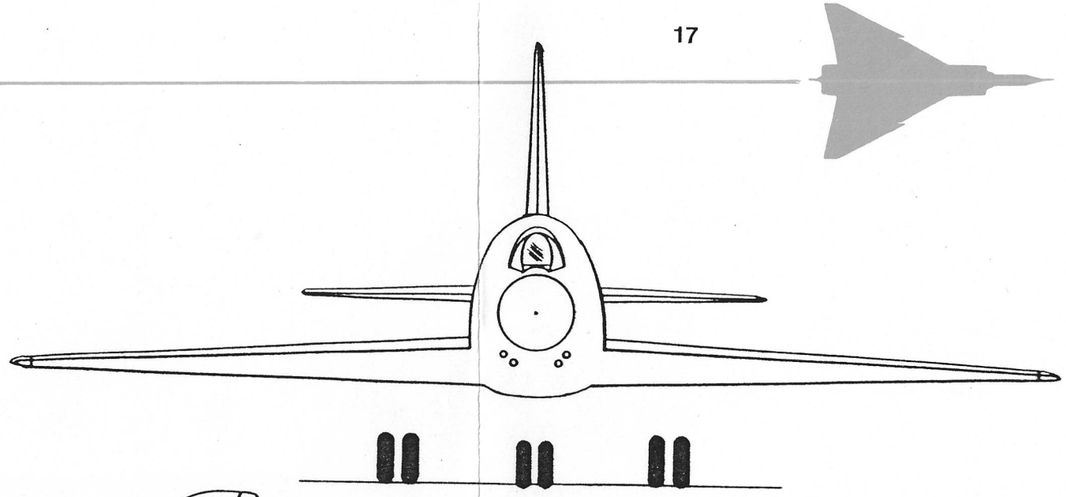
ALL OTHER DETAILS AS FOR XC104A

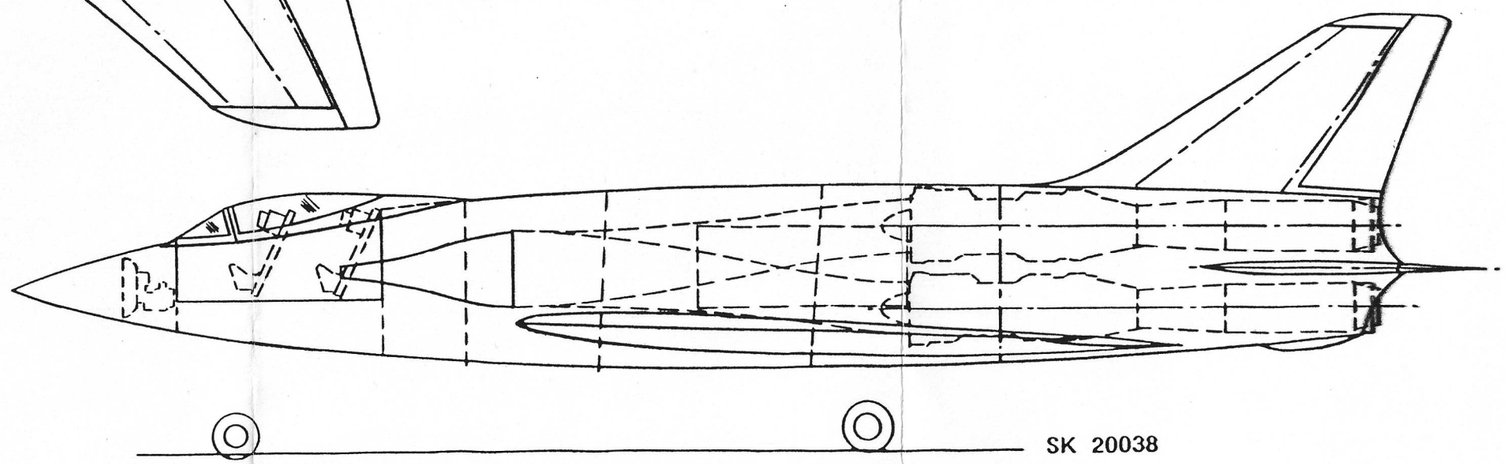
SK 20046

XC/104A. WITH TIP TANKS. DECEMBER 1949

AVRO CANADA

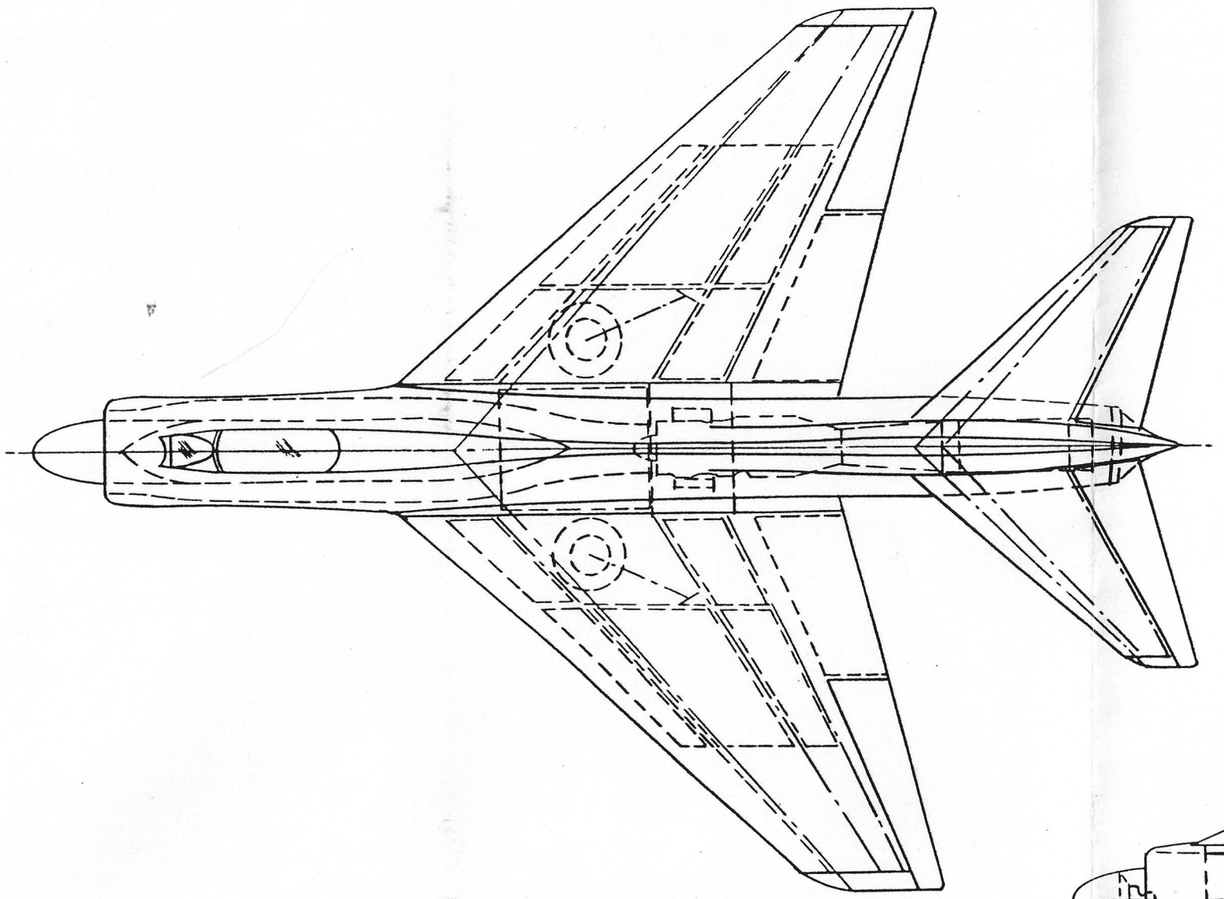


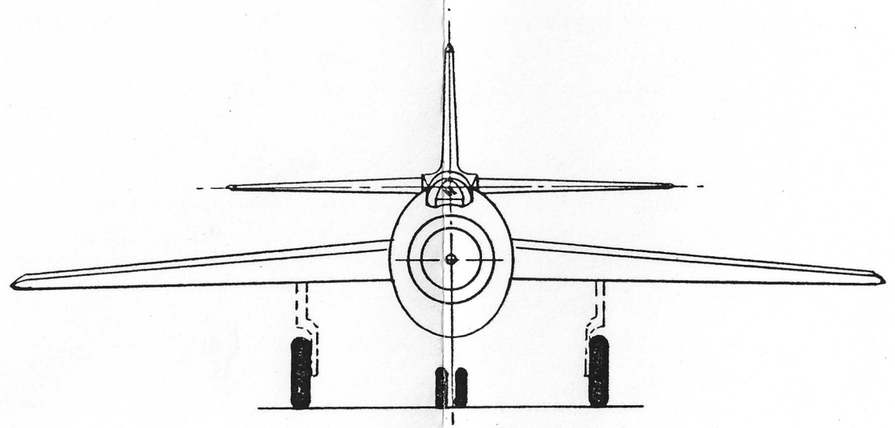


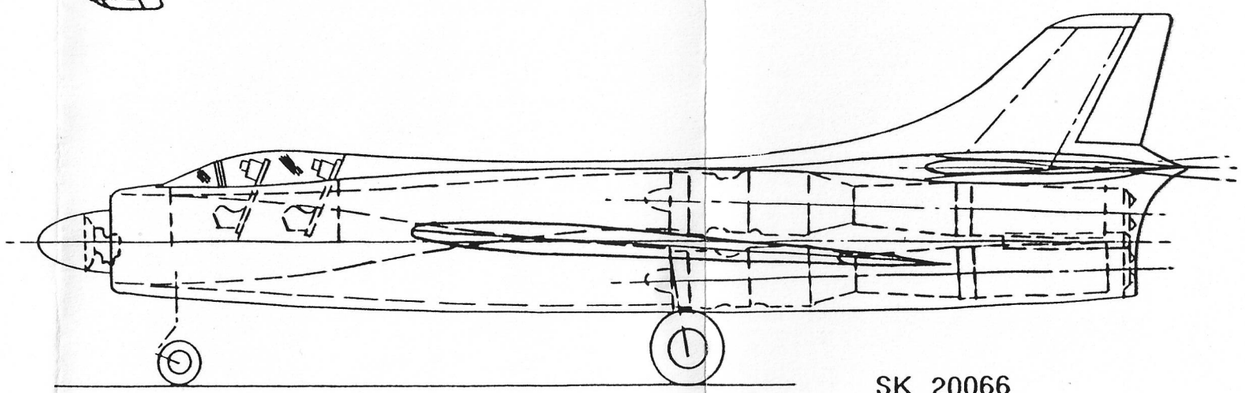


SK 20038

XC/104B. DECEMBER 1949







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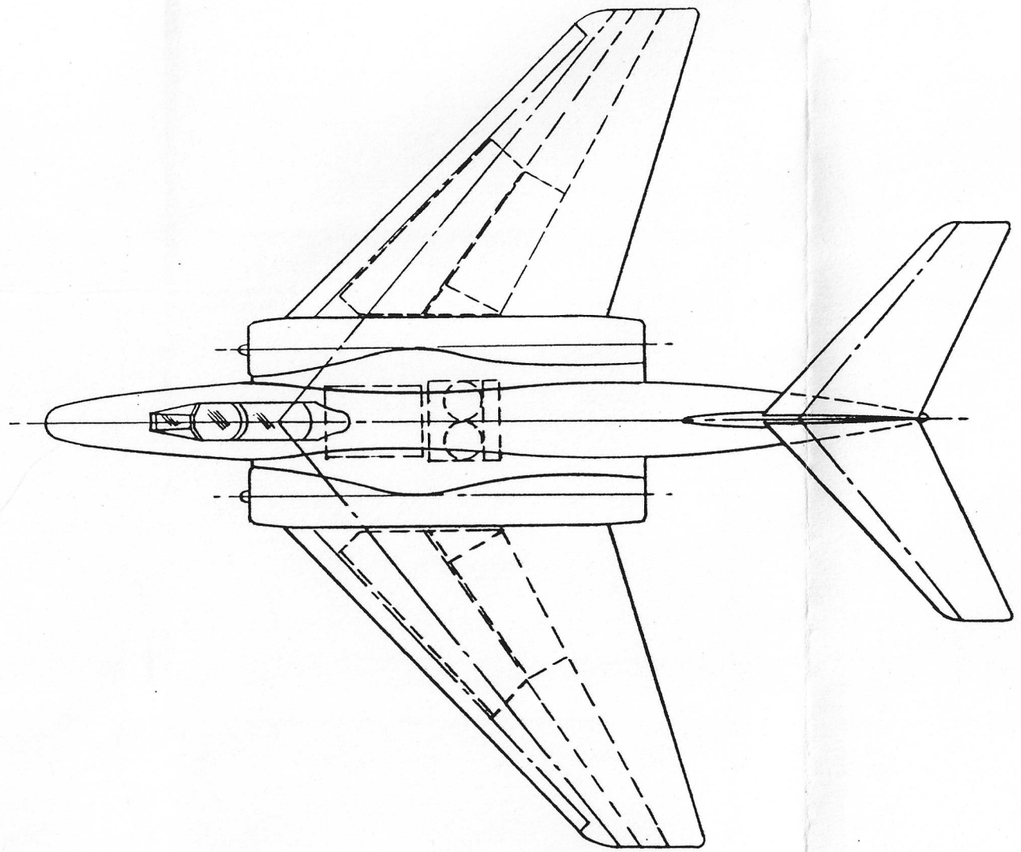

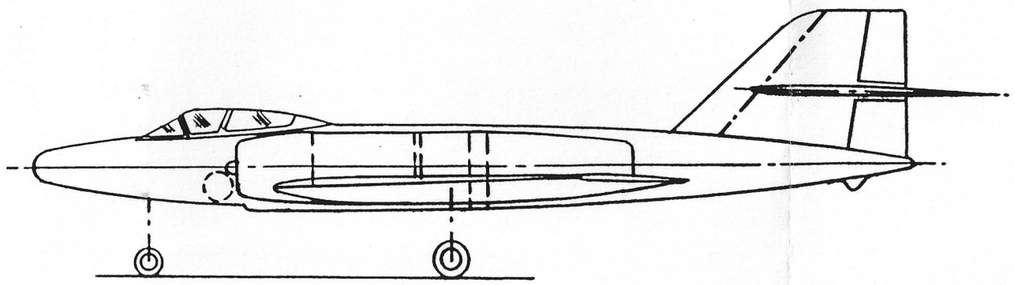

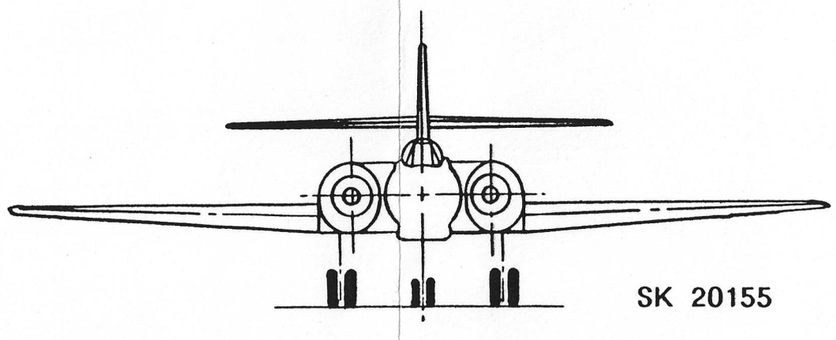

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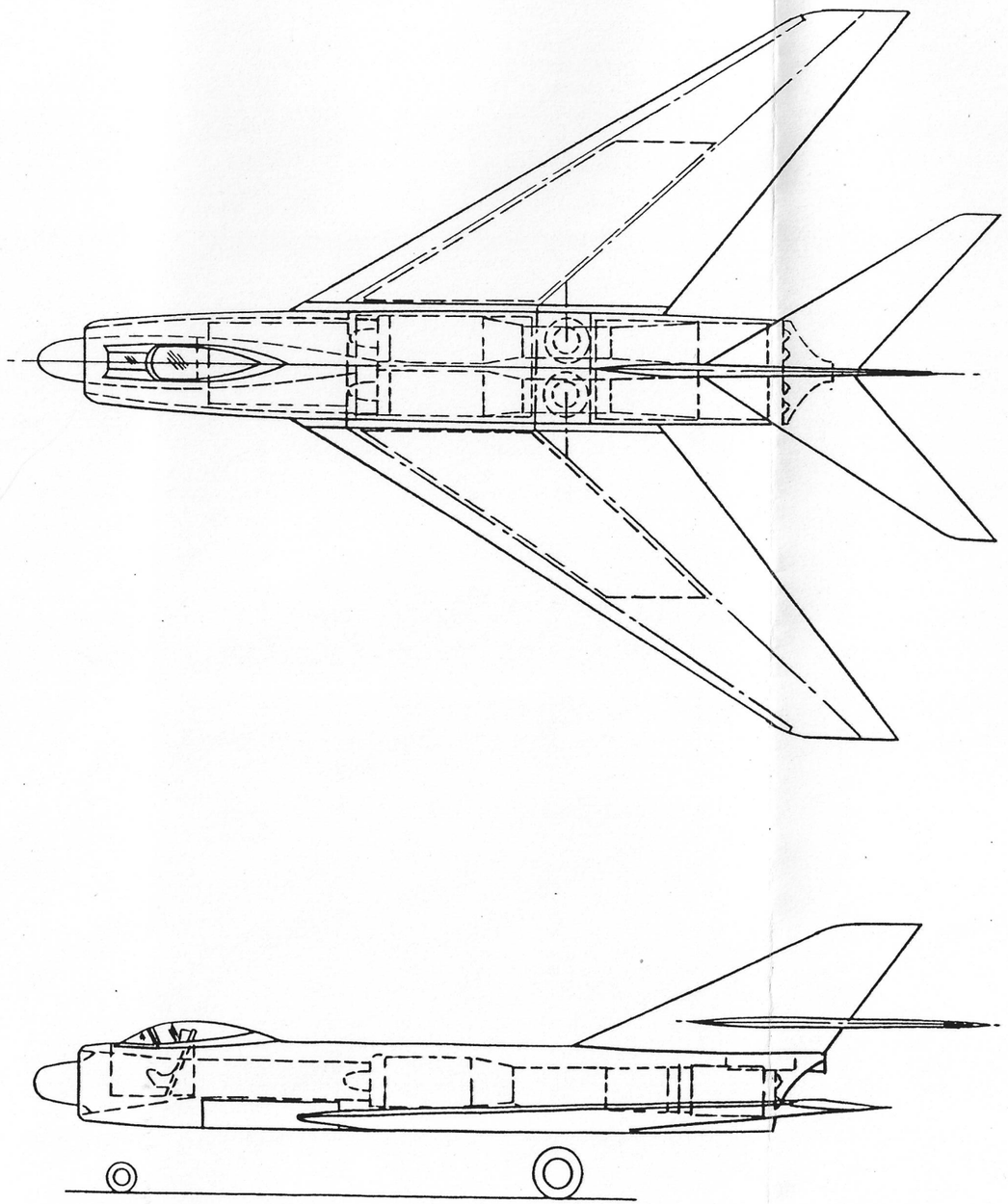
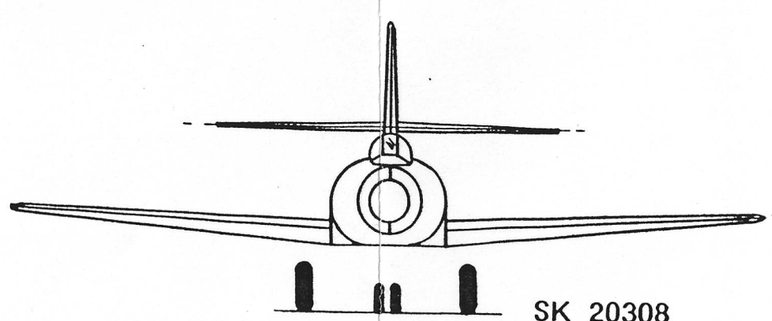
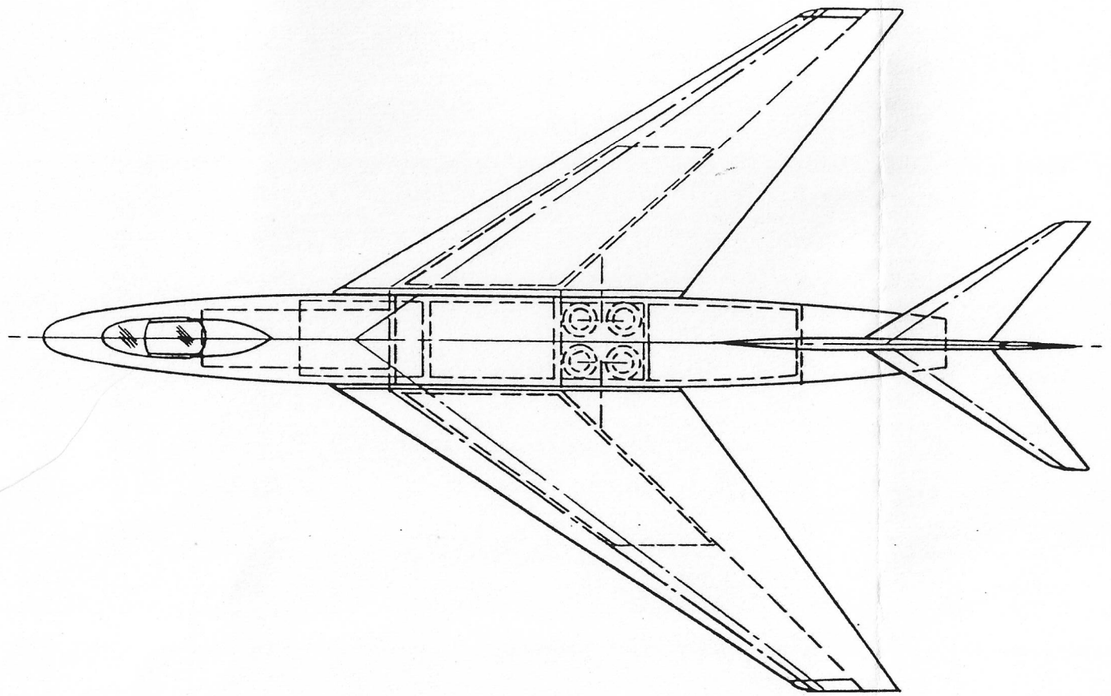
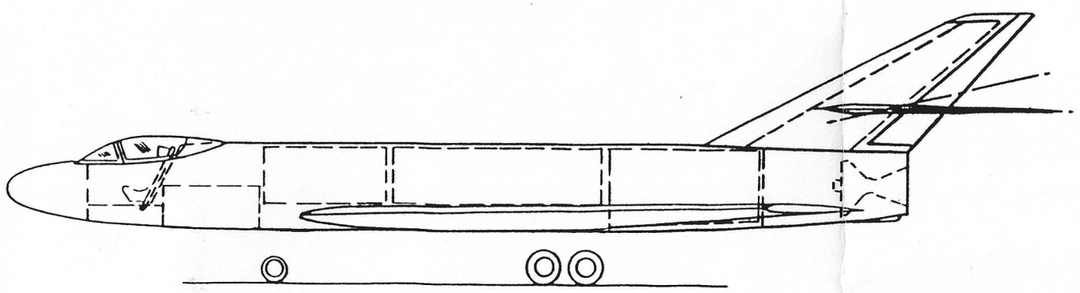


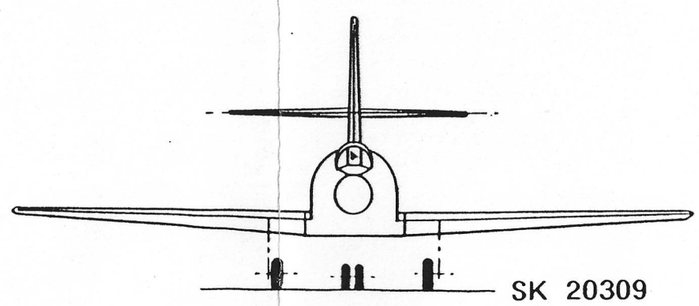


SK 20308

C/104/Sa4. AUGUST 1951

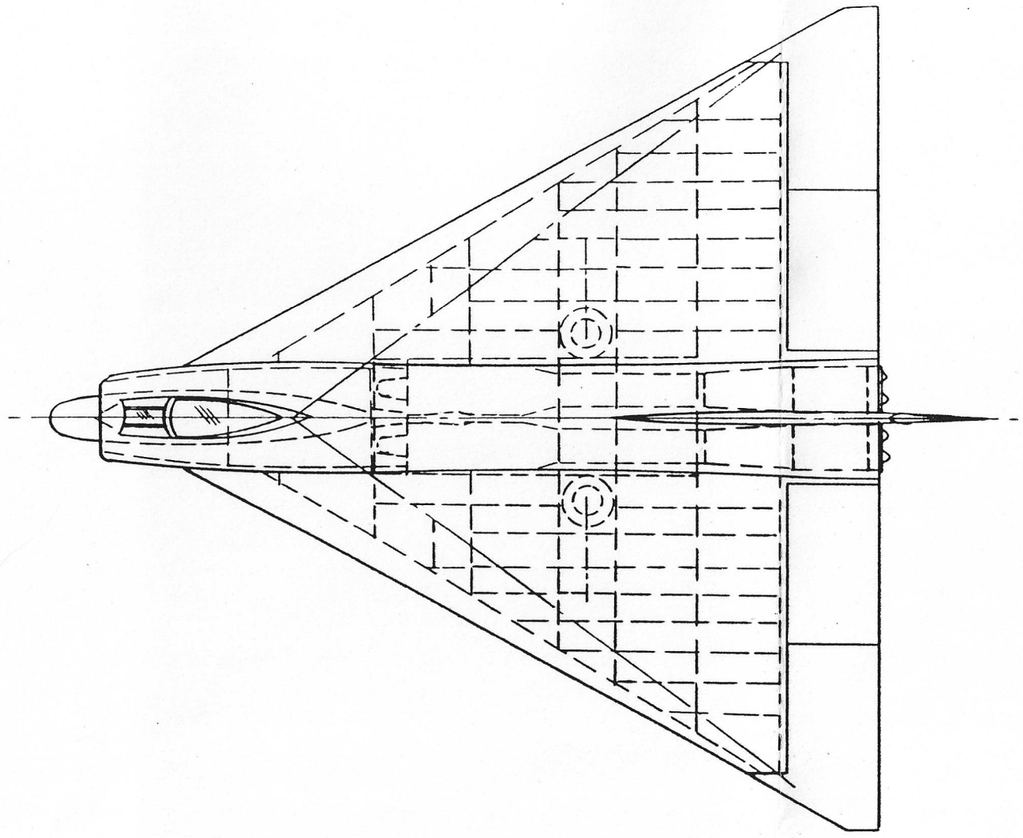


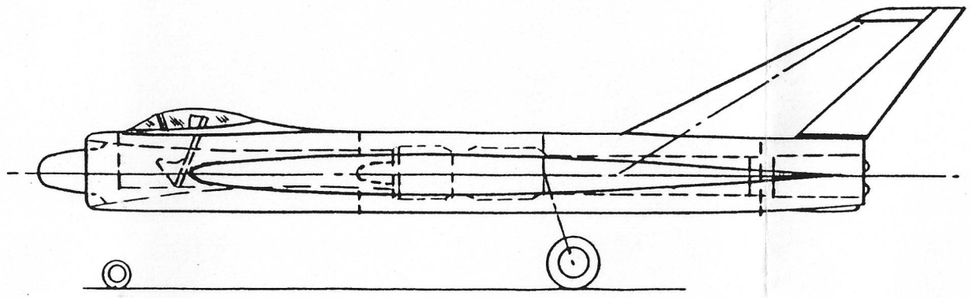


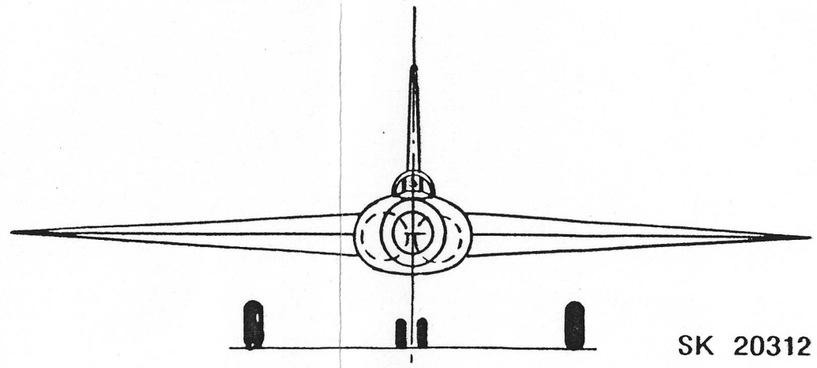


SK 20309

C/105 ROCKET. AUGUST 1951







SK 20312

C/104/Sa4. SEPTEMBER 1951

40 Degree swept low-wing with fixed tailplane. Developed from C-100-S with 5 degrees more sweep and redesigned tailplane.

6. Aug/51 Aircraft type.....C-104

Engines.....2-Sapphire-4 + rocket engine
Span.....46.5 ft.
Length.....61 ft. 0 in.
Height.....17 ft. 0 in.
T/C ratio.....6.5%
Wing area.....770 sq. ft.
Weight.....38,400 lbs.
Radar.....APG
Armament.....Provision for missiles-rockets
Crew.....1

55 Degree swept low-wing with flying horizontal tailplane. Major changes from C-104 of July/50, sweep increased to 55 degrees and number of crew to one.

7. Aug/51 Aircraft type.....C-105

Engines.....Rocket engines (30,000 lbs.)
Span.....41 ft. 0 in.
Length.....63 ft. 0 in.
Height.....16 ft. 0 in.
T/C ratio.....6.5%
Wing area.....600 sq. ft.
Weight.....50,580 lbs.
Radar.....APG 37
Armament.....Provision for missiles-rockets
Crew.....1

55 Degrees swept low-wing with flying horizontal tailplane. Proposed as lower cost airplane with limited endurance. Combat radius 104 naut.mi.

8. Sept/51 Aircraft type.....C-104. Sa.4.

Engines.....2-Sapphire-4 A/B + 5,000 lb. rocket engine
Span.....48 ft. 0 in.
Length.....56 ft. 0 in.
Height.....16.75 ft.
T/C ratio.....6%
Wing area.....1,200 sq. ft.
Weight.....40,000+ lbs.
Radar.....APG 37
Armament.....Provision for missile bay
Crew.....1

First Delta configuration developed from C-104 Aug/51.

9. Oct/51 Aircraft type.....C-104

Engines.....2-TR9 + 5,000 lb. rocket engine
Span.....48 ft. o in.
Length.....54 ft. 0 in.
Height.....17 ft. 0 in.
T/C ratio.....6% at body side 3% T.J.-tip
Wing area.....1,200 sq. ft.
Weight.....52,050 lbs.
Radar.....APG 37
Armament.....Provision for missile bay
Crew.....1

Delta configuration. Main changes from C-104 Sept/51, wing t/c reduced from transport joint to tip to 3%. Orenda TR-9 engines specified.

10. Nov/51 Aircraft type.....C-104

Engines.....2-TR9 + A/B + 5,000 lb. rocket engine
Span.....48 ft. 0 in.
Length.....56.25 ft.
Height.....14.5 ft.
T/C ratio.....3%
Wing area.....1,200 sq. ft.
Weight.....52,050 lbs.
Radar.....APG 40
Armament.....5-Falcon missiles
Crew.....2

Main changes from C-104 Oct/51, 3% wing throughout, high-wing, crew of two, increased sweep to 50 degrees and intakes in fuselage side.

11. Dec/51 Aircraft type.....C-104

Engines.....2-TR9 + A/B
Span.....48 ft. 0 in.
Length.....59.5 ft.
Height.....16 ft.
T/C ratio.....3%
Wing area.....1,185 sq. ft.
Weight.....51,980 lbs.
Radar.....APG 40
Armament.....5-Falcon missiles
Crew.....2

Main changes from C-104 Nov/51, low-wing (part of general low/high-wing studies) and rocket engine deleted.

12. June/52 Aircraft type.....C-104/1

Engines.....(a)-1-TR9 + A/B
(b)-1-Bristol OL.3 + A/B
(c)-1-Curtiss-Wright J 67 + A/B
Span.....32.5 ft.
Length.....58.8 ft.
Height.....18.5 ft.
T/C ratio.....3%
Wing area.....617 sq. ft.
Weight.....28,200 lbs.
Radar.....MX 1179 I.E.S.
Armament.....6-Falcon missiles + 24-2.75" FFAAR
Crew.....1

Subject of study submitted to RCAF for All-Weather High Performance Fighter. Main changes from C-104 Dec/51, single engine, single crew and introduction of MX 1179 I.E.S. light-weight.

13. June/52 Aircraft type.....C-104/2

Engines.....(a)-2-TR9 + A/B
(b)-2-Bristol OL3.
(c)-2-Curtiss-Wright J 67 = AB
Span.....48 ft. 0 in.
Length.....70.25 ft.
Height.....21.25 ft.
T/C ratio.....3%
Wing area.....1,189 sq. ft.
Weight.....52,000 lbs.
Radar.....MX 1179 I.E.S.
Armament.....6-Falcon missiles + 24-2.75" FFAAR
Crew.....1

Subject of study submitted to RCAF for All-Weather High Performance Fighter. Submitted in conjunction with C-104/1 June/52.

14. Mar/53 Aircraft type.....C-104/2

Engines.....2-Curtiss-Wright 67 + A/B
Span.....50 ft. 0 in.
Length.....73.14 ft.
Height.....19.75 ft.
T/C ratio.....3%
Wing area.....1,225 sq. ft.
Weight.....54,000 lbs.
Radar.....MX 1179 I.E.S.
Armament.....6-Falcon missiles + 48-2.75" FFAAR
Crew.....1

Development of C-104/2 submitted to RCAF. Introduction of electronics crate, "V" windshield and ramp with boundary bleed.

15. Aug/53 Aircraft type.....C-105

Engines.....2-Rolls-Royce R 106 + A/B
Span.....50 ft. 0 in.
Length.....73.14 ft.
Height.....19.75 ft.
T/C ratio.....3%
Wing area.....1,225 sq. ft.
Weight.....56,865 lbs.
Radar.....MG3/E9
Armament.....6-Falcon missiles + 50-2.75" FFAAR
Crew.....2

Major changes from C-104/2 Mar 53, re-arrangement for two man crew capable of conversion to single man crew when complete integrated electronic system MX 1179 becoming available. Meanwhile, E9 fire control. Introduction of 0.75% negative camber and the Rolls-Royce RB 106 engine.

16. May/54 Aircraft type.....C-105

Engines.....2-Curtiss-Wright J 67 + A/B
Span.....50 ft. 0 in.
Length.....73.14 ft.
Height.....20.75 ft.
T/C ratio.....3.5% body side-T.J. 3.8% tip
Wing area.....1,225 sq. ft.
Weight.....65,393 lbs.
Radar.....MG3/E9
Armament.....8-Falcon E missiles
Crew.....2

Major changes from C-105 Aug/53, increase in wing t/c to 3.5% between body side and transport joint, and 3.8% tip. Fin t/c increased to 3.5% at root to 3.8% at tip. Curtiss-Wright J 67 engine and deletion of avionics crate and FFAAR.

17. Nov/54 Aircraft type.....C-105

Engines.....2-Curtiss-Wright J 67 + A/B
Span.....50 ft. 0 in.
Length.....75.95 ft.
Height.....21.3 ft.
T/C ratio.....3.5% body side-T.J. 3.8% tip
Wing area.....1,225 sq. ft.
Weight.....67,730 lbs.
Radar.....MX 1179 modified
Armament.....8-Falcon GAR-1A or 3 Sparrow 2 missiles.
Crew.....2

Major changes from C-105 May/54, introduction of 5% notch, 10% leading edge extension of outer wing, 15% increase in fin area, large nose for increased size radar antenna (38" diameter scanner) and fin t/c increased to 4%. 3 Sparrow missiles added.

18. June/55 Aircraft type.....CF-105

Engines.....2-Pratt and Whitney J 75 + A/B
Span.....50 ft. 0 in.
Length.....75.95 ft.
Height.....21.25 ft.
T/C ratio.....3.5% body side-T.J. 3.8% tip
Wing area.....1.253 sq. ft.
Weight.....68,196 lbs.
Radar.....MX 1179 modified
Armament.....8-Falcon GAR-1A or GAR-1C missiles
or
4-Sparrow 2 missiles
Crew.....2

Major changes from C-105 Nov/54, introduction of leading edge droop, area rule modifications and J-75 or P.S.13 engines.

PROJECT STUDY STAGE. July/48 - Mar/52.

July/1948

- Avro submited proposal to the RCAF for a swept wing CF-100, later to become the CF-103.

July/1948-49

- Priority development of the CF-100 and the C-102. (Jetliner).

July/1949

- First meetings between RCAF HQ, DRB and NAE to consider an advanced fighter.

- Proposal submitted for C-100 D, later to become one of the C- 104 family.

July-June/49

- Investigation into C-104 swept wing aircraft featuring fixed and flying tail-planes, engines internally stowed in fuselage or in CF-100 type nacelles, flush NACA type intakes or fuselage pitot intakes, a crew of two and cannons as principal armament.

- RCAF HQ, DRB and NAE investigations proceeding simutaneously. NAE report on "Fighter Project Investigations" based on estimate of threat in 1956.

Aug/1949
- First flight of C-102. (Jetliner)

Jan/1950
- First flight of CF-100 Mk1.

July/1950
- First flight of second CF-100.

- Department of Trade and Commerce requested by the RCAF to authorise Avro to commence design studies on an advanced fighter. Cost to be charged to CD-87 (CF-100).

- Preliminary brochure on C-104. Three schemes for "Long Range All-Weather Fighter". (Dec 1949), swept wing, twin Orenda engines (8000lb.) plus rocket motors (6000 lb.), crew of two and t/c = 6.58%.

Sept/1950
- Outbreak of Korean war.

Dec/1950
- Swept wing C-100 submitted to RCAF, designated CF-103, two Orenda engines (8000 lb.), rockets and guns, crew of two, low wing, 800 sq.ft., 40 degree sweep. The Company was authorised to proceed with this aircraft.

Jan-Aug/51
- Priority given to CF-103 development. Only slight progress with C-104 due to heavy commitment on CF-100 and CF-103 programmes.

Feb/1951
- CF-103 detail design commenced.

March/1951
- CF-103 wind tunnel testing commenced.

June/1951
- CF-103 Jig and Tool manufacture commenced.

August/1951
- Proposal for C-105 rocket aircraft. Lower cost, short range (120 Naut.mi. rad.), project using 30,000 lb. rocket thrust, 600 sq.ft., t/c 6.5% with 55 degree sweep.

Aug-Sept/51

- First Delta configuration of C-104. Two Sapphire 4 engines plus one rocket engine, 1,200 sq.ft.,t/c 6%, crew - one, APG 37 radar, missile bay and mid-wing.

Sept/51

- Avro submit to RCAF, at their request, three studies of an advanced supersonic fighter with a view to establishing a specification for this type of aircraft. Project designs between July and Sept/51:

(a) CF-103 swept wing development for short range interceptor (C-104 SR) 220 St.mi.rad. Auxiliary rocket, 55 degree sweep, single crew, t/c 6.5%, 770 sq.ft. wing area.

(b) CF-103 swept wing development for long range search and interceptor aircraft (C-104 LR) 350 st.mi. rad. Auxiliary rocket or 760 st.mi. with afterburners only, 55 Degree sweep, crew of two, t/c 6.5%, 900 sq.ft. wing area.

(c) Delta version - C-104 having similar performance to the short range version, single crew, t/c 6%, 1200 sq.ft. wing area.

Sept-Oct/51

- C-104 investigate t/c reduction from 6% to 3% crew of two vs one, Falcon missiles introduced, two Orenda TR-9 engines plus one rocket engine, radar changed from APG 37 to APG 40, 1155 sq.ft. wing area.

Oct-Nov/51

- First CF-100 (Mk2) delivered to RCAF.

- C-104 investigate engine removal, mid-wing to high-wing, engine intakes from fuselage pitot to fuselage side, t/c fixed at 3%, 5-Falcon missiles, two Orenda TR-9 engines plus after-burners plus one rocket engine and crew of two.

Dec/51

- CF-103 project canceled. Performance and delivery incompatible with threat.

Dec/51-Mar/52

- C-104 - Further studies comparison high/low wing, undercarriage with outriggers, engine intakes now at fuselage side, 24 - 2.75" FFAAR plus 6-Falcon missiles.

Jan/52

- C-104 Performance summarized. 450 naut.mi.rad. with 10 mins. combat at 50,000 ft. at 1.4 M.N. and reserves. General outline of C-104 Advanced Fighter Project.

- Avro Manchester comment on "Proposed Supersonic Fighters" brochure issued

Sept/51 to RCAF. Three versions of C-104: C-104/LR, C-104/SR, C-104 Delta.

Avro Manchester suggest:

(a) Aircraft too large therefore too heavy.

(b) T/C too high. Suggest 4% maximum.

(c) Intake bullet too blunt. Low intake efficiency.

(d) Dubious advantage of rocket motors.

Mar/52

- All Weather Interceptor Requirements received from RCAF:

(a) Combat performance with internal armament installed.
Combat speed M = 1.5. Combat load factor n=2.
Combat altitude H = 50,000 ft.

(b) Combat performance with external armament installed.
Combat speed M = 1.2. Combat load factor n=2. Combat altitude H = 50,000 ft.

(c) Reach 50,000 ft. and combat speed from rest at S.L. in 6 mins.

(d) Capable of 5 mins. combat at 200 naut.mi.rad., supersonic cruise out. Capable of 5 mins. combat at 300 naut.mi.rad.,subsonic cruise out.

(e) Capable of operation from 6,000 ft. runways.

(f) Internal Armament. 6 - Missiles of Falcon size plus 50 FFAAR 2" calibre rockets.

(g) External Armament. 2 - Missiles of 600 lb. weight, Meteor dimensions or 4 - Missiles of 300 lb. weight, Velvet Glove dimensions.

(h) Design diving speed M = 2, but less than 700 kts. E.A.S.

(j) Design load factor 7.33, ultimate 11.0.

THE AVRO "THINK TANK" 1948-50.

Due to developments in both the United States, the United Kingdom and Soviet Russia with swept wing designs, the Long Range Projects department at Avro had been looking at a swept wing version of the CF-100 even before the prototype had flown. One such outcome of this was the C-100-S, (later to become the CF-103), in July 1948 with two Turbo research (later to be called Orenda Engines) TR9 engines

and in July 1949 was followed by the C-100-D, (later to begin the C-104 family), supposedly capable of supersonic speed.

AVRO SUBMISSION IN 1950.

The Company had submitted a swept wing version of the CF-100 design to the Government in December 1950, as an interim weapon, thus keeping pace with Soviet developments. The aircraft was designated the CF-103 and the Department of Trade and Commerce was requested to authorize Avro to proceed with the construction of two prototypes and one static test aircraft.

CF-103 FAILURE.

On paper, the CF-103 had indicated supersonic performance and the use of the existing CF-100 fuselage made it a logical development and therefore a good interim aircraft between the CF-100 and the designated C-104 advanced fighter (then under contemplation). By February 1951, detailed design and tooling were well under way and wind tunnel testing had begun at Cornell Aeronautical Laboratories in Buffalo, New York as no high-speed wind tunnels were available in Canada.

The first flight of the CF-103 was scheduled for July 1952 and manufacture of jigs, tools and parts was begun in June of 1951. Meanwhile, due to the pressure of the Korean war, priority was given to the CF-100 Mk3 and Mk4 aircraft and the first flight of the CF-103 was set ahead to June 1953. The wind tunnel tests were completed and analyzed by November 1951 where it was found that the aircraft would probably not exceed the speed of sound in a dive and that it would not achieve its projected top speed due to aerodynamic limitations and further wind tunnel work was required. These delays would mean that the aircraft would be obsolete by the time any refinement was done, therefore it was canceled in December of 1951.

RCAF OPERATIONAL REQUIREMENT ORI/1-63

The priority in design was then focussed on the C-104 advanced fighter. The Long Range projects group at Avro had produced several designs of both delta and swept wing configurations and thus were keeping in step with the "state of the art".

We again refer to the words of James C Floyd:-

> "In the fall of 1952, The RCAF decided that because of the increase in the threat, they would have to replace the CF-100 within a specified time by a supersonic all-weather fighter, and an evaluation team was again sent out to the countries in the Western Alliance who might have a suitable interceptor, and it was again decided that none of these countries had a project either in design or contemplated, which fully met the Canadian

requirement. Once again, the decision was taken to design, develop and produce in Canada. This decision was not taken on the basis that there happened to be an established aircraft industry in Canada, although this obviously had some influence on the decision. However, the Chief of Air Staff at that time, Air Marshall Slemon, made it quite clear that Canada was not in a position to undertake the development of a new aircraft if a suitable type was being designed, developed or produced in either the United States or the United Kingdom, and the decision to design and develop in Canada was taken entirely because of the peculiar Canadian defence requirements which had already been established by the Canadian aircraft industry".

ROLE OF THE NEW DESIGN.

To intercept and destroy any long-range bombers of the highest performance which were likely to be available to an enemy during a five to ten year period and beyond. Guided missiles and air-to-air rockets were specified as the main offensive armament, the target tracking, aiming and fire control being automatically computed by airborne electronic equipment operated with a two- man crew; the pilot and the navigator.

PROJECT DESIGN STAGE. June/52 - May/53.

Mar-June/52

- C-104 - Designs to Interceptor Requirements of March/52. Issue brochures, C-104/1 and C-104/2 to RCAF, June/52. Basically the C-104/1 was a single engine as against twin, wing area 617 sq.ft. as against 1189 sq.ft. and gross design weight 28,200 lb. as against 52,000 lb.

- Both aircraft had a crew of two and carried 6 missiles and 24 - 2" FFAA rockets. C-104/2 was computed to have slightly better performance, twin engine reliability, more range, more "stretch" and the better buy! ("Comparison of C-104/1 and C-104/2 Supersonic Fighters" by J.C.Floyd and J.A.Chamberlin, Dec 1, 1952).
- Bristol OL.3 and Curtiss-Wright J.67 now considered along with Avro TR-9 with Solar after burner. MX 1179 integrated electronic fire control system included in design proposal.

June-Oct/52

- Development work on single seat C-104/1 version.

Sept/52

- Hughes confirm proposed launching arrangement for Falcon missiles from C-104 is satisfactory.

Oct/52
- First flight T.I. CF-100 Mk4.

- NAE report received on analysis of C-104/1 and C-104/2 proposals. They are broadly in agreement on the analysis of the aircraft but recommend that the C-104/2 is unsuitable on the grounds of excessive weight and expense. However, C-104/2 features were preferable to those of the C-104/1 and NAE recommended that Avro evolve from C-104/1 all the features of the larger aircraft for no appreciable increase in size, weight or expense. NAE recommend the use of hypothetical 10,000 lb. engines of approximately 30" diameter for study. Avro receive requirement changes for All-weather Interceptor Fighter concept from the RCAF. Primarily the combat altitude is increased from 50,000 ft.-60,000 ft.

Oct/52-Jan/53
- Study using 2 x 30" diameter engines per NAE suggestion in NAE report LR-38. Study changed altitude requirement.

Nov/52
- Avro receive RCAF Operational Requirement OR1/1-63 "Supersonic All-Weather Interceptor Aircraft"- first issue.

Dec/52
- Results of investigation into meeting increased altitude requirement indicate that unless a rocket engine is used there would not be too much gain in altitude by modifying the plan-form in terms of wing area or span which would theoretically contribute a lower wing loading and would reduce excessive drag to lift at high altitude.

- Critical review of engine situation for C-104. The basic requirement is for an engine giving at least 21,000 lb. with afterburner at sea level. Even then the 'g' performance will not be entirely satisfactory. The most suitable engines are as follows:

(a) Bristol Olympus OL.3

(b) Curtiss-Wright J.67

(c) Rolls-Royce R.A. 17

(d) Pratt and Whitney J.57/75

Concluded that the Olympus 3 is the most suitable engine with respect to thrust, timing and availability.

- Estimated completion date of the first Prototype C-104 is January 1956.

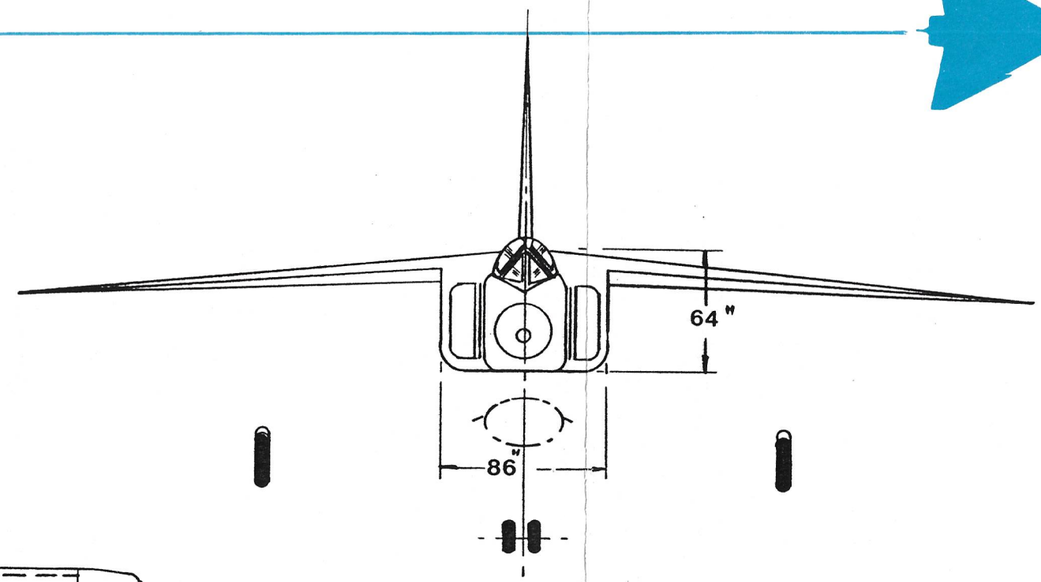
Jan/53

- Avro complete appraisal of NAE report LR-38, including 30" diameter engines. NAE concede C-104/1 and C-104/2 performance realistic. Philosophy rejected since no such engines under development and the use of this size of engine restricts the flexibility relative to the C-104/2.

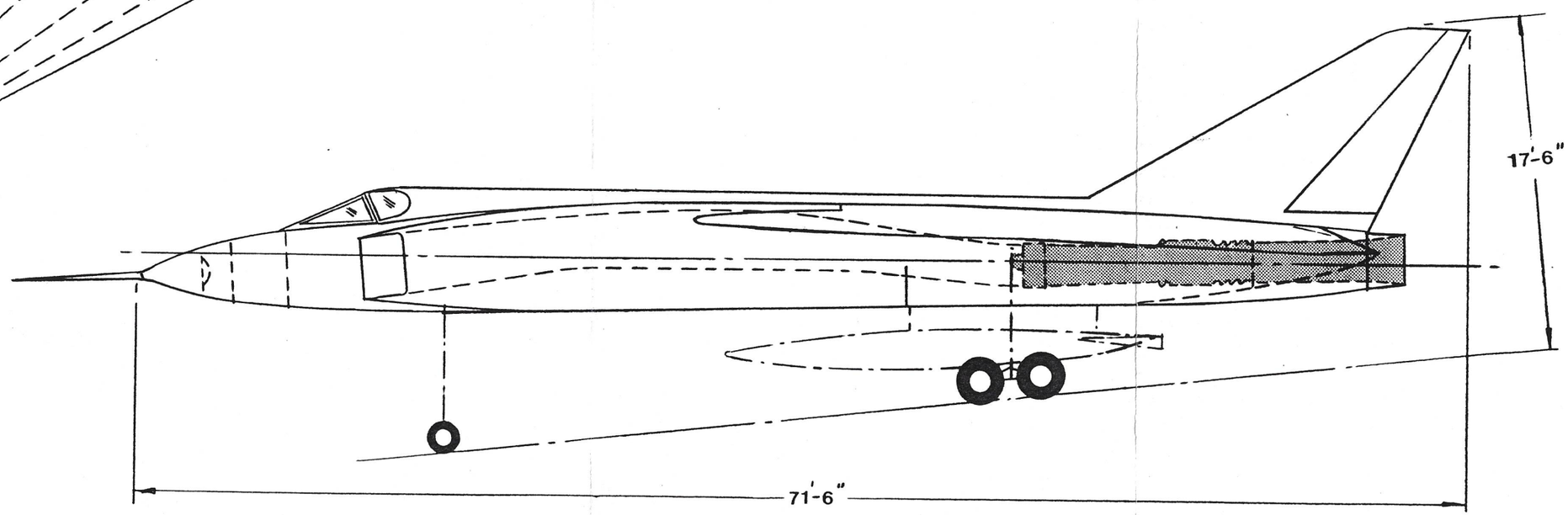
In October of 1952, the NAE suggested to Avro that two engines of 30" diameter and generating 10,000 lbs. of static thrust might be considered in view of the indeterminate availability of other engines, such as the Rolls-Royce RB-106.

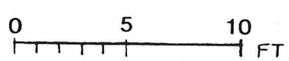
A study was undertaken and a report written by Jim Chamberlin was filed on July 29th. 1953, which stated:-

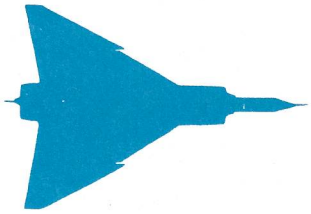
> "In the search for a method of obtaining a lighter version of the C-105, the use of engines of 30" diameter but developed to the same state as the larger engines specified in AIR 7-3 has been suggested.
>
> This proposal has been investigated along the lines followed in the Design Study Report P/C-105/1 for the engines specified in the RCAF Specification AIR 7-3. It has been assumed that an engine with a 30" overall envelope diameter has characteristics similar to the Rolls-Royce RB 106 engine, but with 2/3 of the thrust. Since the Rolls-Royce engine is regarded as an exceptionally ambitious project from the point of view of thrust per unit frontal area, it is felt that assuming that an engine can get 2/3 of the thrust with 51% of frontal area is very optimistic to say the least.
>
> Since the flight conditions are much more severe, it was felt that the weight of the engine could not be reduced substantially below the weight of the Orenda. The afterburner with convergent divergent nozzles and the attendant control system would undoubtably weigh somewhat more than the equivalent simple system for the Orenda. A total installed weight of 3,500 lbs. for each engine has accordingly been assumed. While it is felt that this weight is realistic, it may be argued that savings could be made. It is however, exceedingly hard to believe that these could exceed 500 lbs. at the outside. In view of the magnitude of the design problem of getting the thrust from an engine of this size, savings of this order are regarded with great skepticism. However, if they prove possible, they are not sufficient to alter the overall picture materially. An airframe similar to those studied in P/C-105/1 was tailored as closely as possible around the small engines, and the weights and performances for three wing areas were studied. From this, it appears that 1,000 sq.ft. wing area is about the best compromise."



C-105. 1,000 sq.ft. WING WITH 2-30" DIAMETER ENGINES OF 10,000 lbs. THRUST.







In the final analysis, it was stated that as there were no engines of this type either being contemplated, designed or manufactured and would not be available for the prototype aircraft. Therefore the whole idea was dropped and other solutions considered.

Feb/53

- RCAF and Avro decide to proceed with CF-100 Mk6.

Mar/53

- Avro request use of CARDE facilities for aerodynamic testing. (Considered premature by RCAF since no specification issued for C-105.)

Jan-Mar/53

- C-104/2 - Development of Project. Introduction of Curtiss-Wright J.67 engine, air intake investigation resulting in fixed ramp and boundary layer bleed, "V" windshield incorporated and removable electronics crate considered. Wing area 1225 sq.ft. (The overall shape and design of the windshield and canopy were very similar to that of the F-102 and the Avro Manchester 720. This was a design to the (British) OR.301 and the specification F.137D numbers. Powered by "Viper" turbo-jet and a "Screamer" rocket engine. Scrapped after mock-up stage.)

Apr/53

- Avro receive advance notice of RCAF Specification AIR 7-3, Issue 2, "Design Studies of Prototype Supersonic All-Weather Interceptor Aircraft".

- C-104 - Exhaustive minimum weight study of C-104 project to attempt to find the minimum weight of airplane required to meet RCAF Spec. AIR 7-3. Principally the investigation involved:

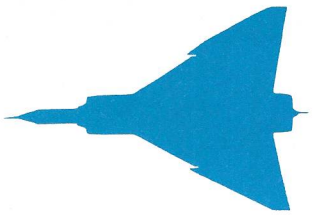
(a) Reduction of fuel weight to exactly that required to meet the specified range.

(b) The use of 0.75% camber to reduce drag and hence fuel for mission.

(c) The use of lower stressing weight which is obtained by taking into account the above savings.

(d) The use of an ultimate load factor of 10 at the half fuel weight in place of 11 at the take-off weight as specified in AIR 7-3, para. 5.02.01.

The resulting weight saving under these headings was 5,500 lb. Aircraft size was investigated for wing areas 1,225, 1,100 and 1,000 sq.ft., 3% t/c, cambered and adjustments to fuselage for balance. A further 2,000 lb. could be saved using a reduced wing area, but with certain disadvantages and risks dependent upon the weight growth of the airplane and uncertainties of drag estimation.



- Meetings with the RCAF to discuss minimum weight airplane on the basis of AIR 7-3. RCAF agreed to major concessions to permit Avro to design an optimum configuration. RCAF appreciate design problems and realize high design weight unavoidable if the stringency of AIR 7-3 is to be satisfied. Avro anticipate an ultimate design gross weight of 48,500 lb. Agreed that RCAF issue contract request to DDP for $200,000 to be allocated to Avro for further design work. RCAF will issue new specification. Avro asked to submit complete details of minimum weight investigation.

As stated above the Long Range Projects Group at Avro had produced several designs in both Delta and Swept-wing configurations to meet the RCAF Operational Requirement OR1/1-63. Two of these designs were submitted for consideration.

The C/104/1.

The details of the C/104/1, from the Avro brochure of June 1952, are as follows:-

Service model designation.....Supersonic all-weather fighter
Designer's name and Model No.....A.V.Roe Canada Ltd, C/104/1
Number of crew.....One (Pilot)
Number and kind of engine.....One A.V.Roe Canada turbo-jet engine - TR9
or
One Bristol Engine Co. turbo-jet - OL3 (fighter version)
or
One Curtiss-Wright turbo-jet engine - J67

Note: Each type of engine would have been fitted with an afterburner.

Design information

Length-max.....58 ft.10 in.
Height-max.....18 ft.6 in.
Wing span.....32 ft.6 in.
Airfoil section.....NACA-0003-63 (modified)
Root chord.....35 ft.
Tip chord (basic)...3 ft.
Total wing area.....617.5 sq.ft.
Elevon area.....43.8 sq.ft.(each)
Vertical tail area....81.6 sq.ft.
Rudder area.....21.1 sq.ft.
Main wheel size.....29 x 7.7
Nose wheel size.....18 x 5.5
Dihedral.....1 deg. 45 min.
Performance.....959 kts. at 50,000 ft. 926 kts. at sea level.
Max. ceiling.....52,800 ft.
Combat radius.....200 Naut.mi.
Max. range.....300 naut.mi.

ARMAMENT OPTIONS.

The projected armament for the C/104/1 was 6 - Falcon guided missiles and 24 - 2.75 in. air-to-air rockets. These rockets were intended to be fired at altitudes below 10,000 ft. as at heights up to this figure, ground echoes interfered with the guidance system which was to have been the Hughes MX 1179 integrated electronic system which provided for:-

(a) Automatic navigation.
(b) Interception.
(c) Fire control.
(d) Return to base.

The basic feature of this system, was that data from all relevant sources was fed

into a single high-speed digital airborne computer which then, successively supplied the information to the airplane controls required for navigation and fire control.

OPTIONAL ARRANGEMENTS.

A trainer version of the basic airplane was designed and designated the C/104/1/T. It was envisaged that the conversion from the basic airplane to the trainer was to have been accomplished simply by unbolting the cockpit section of the fuselage forward of the transport joint bulkhead to which the nose gear was attached and replacing it with the longer trainer cockpit version. (It should be noted here that this version could have been a two-man crew model - pilot and navigator.)

The C/104/1 was designed around and only for the armament system described, and any deviation from this would have necessitated a complete re-design of the entire aircraft.

ALIGHTING GEAR - DESCRIPTION.

The alighting gear was of the conventional type, very similar to that of the CF-100. It consisted of a nose wheel, main gear and a retractable tail skid, (to cater for the high angle of incidence of the airplane when landing.)

CONTROL SURFACES.

Neither elevators or horizontal stabilizers were to be fitted to this aircraft. Instead of elevators, elevons were to be fitted. As this was the only design to have possessed elevons, they are worthy of a full description. A rudder was also provided.

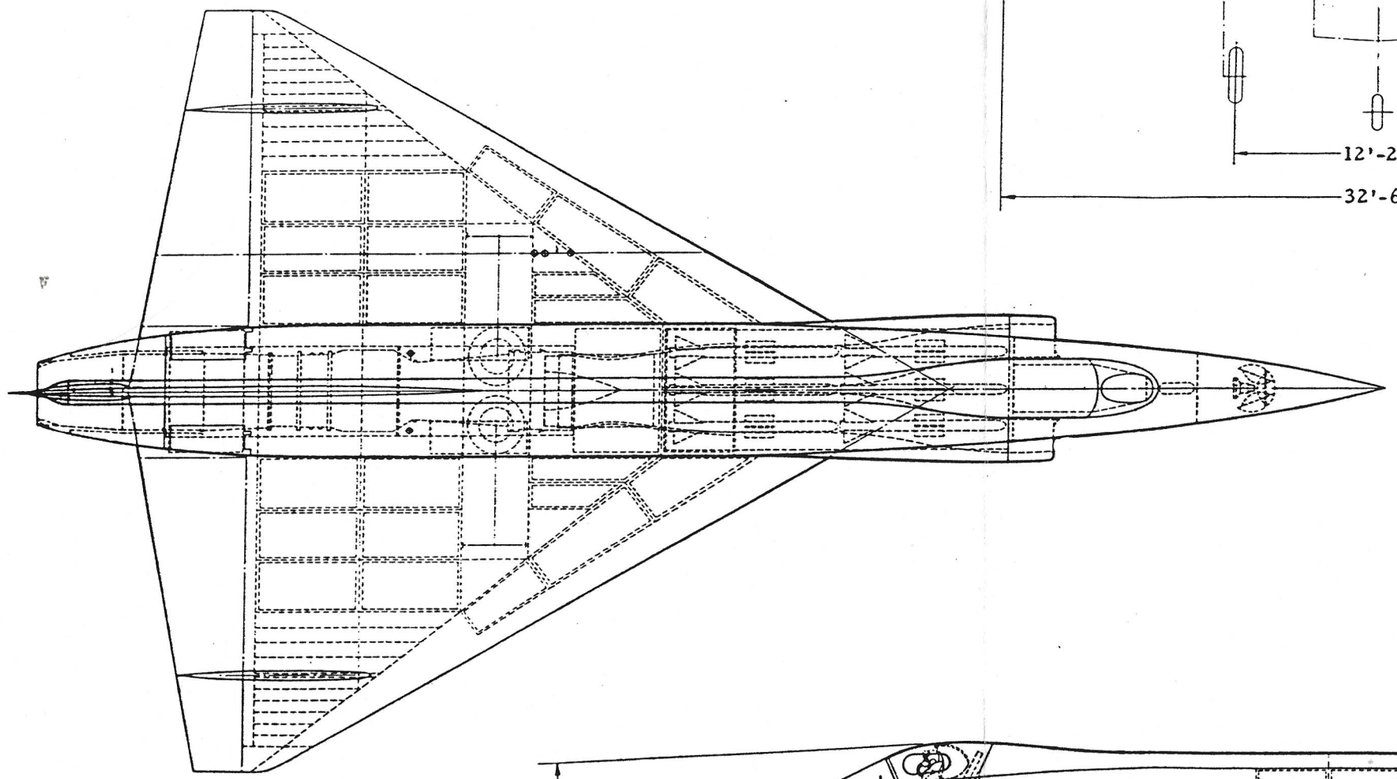
ELEVON CONSTRUCTION.

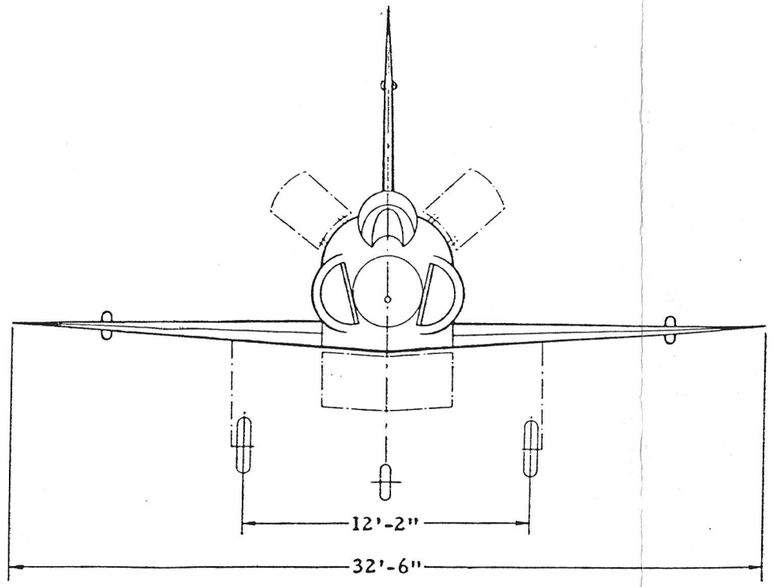
The elevons which combine elevator motion with aileron motion, are full span plain flaps extending from the fuselage sides to the wing tips and were to be fully power-operated by hydraulic jacks. The motion is as follows:-

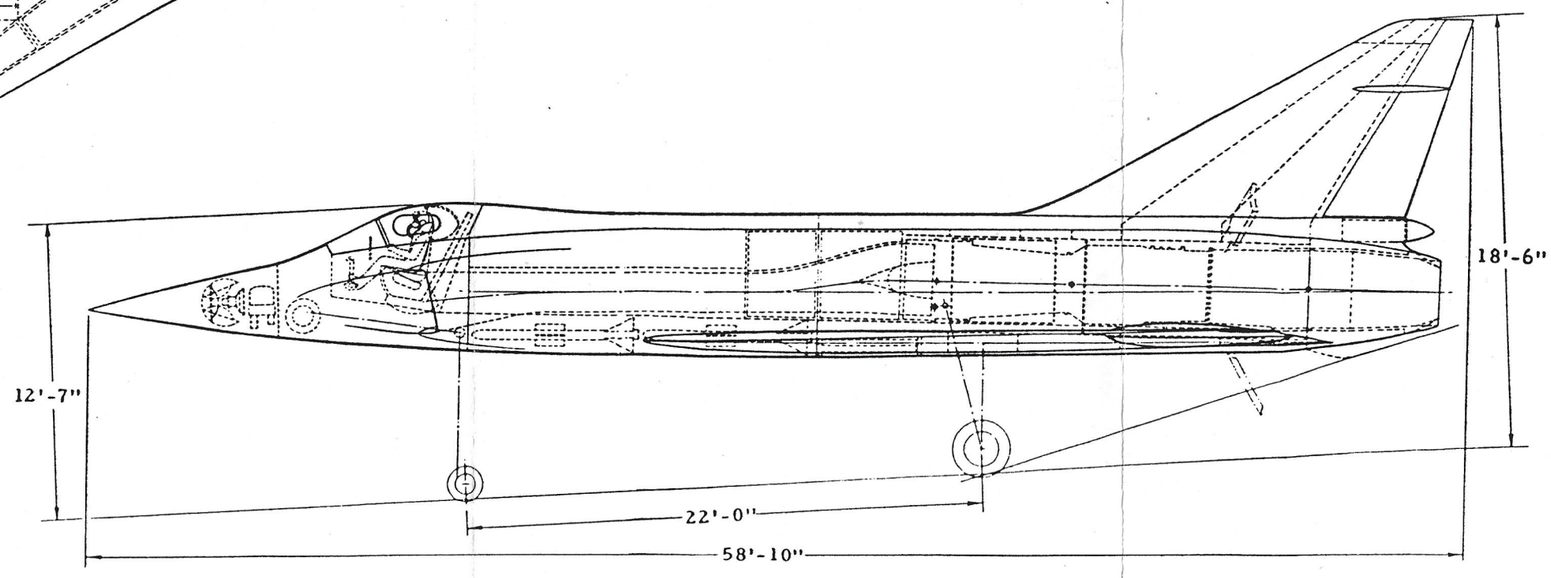
a. Elevator - 20 degrees up and down.
b. Aileron - 7 degrees up and down.

The aileron motion was superimposed on the elevator motion so that the maximum angular motion of the elevons was 27 degrees up and down.

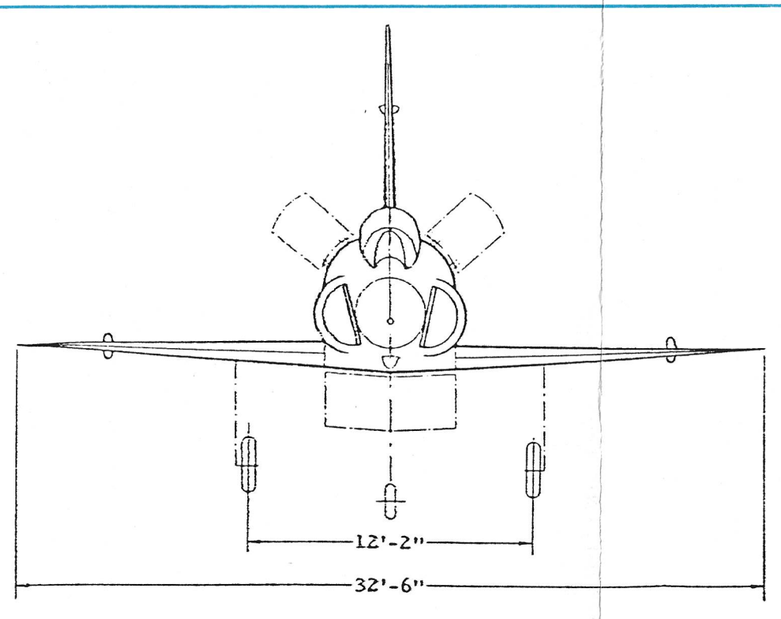
The elevons were attached to the wing rear spar by six hinges. The hinge line was at right angles to the airplane centre line; this was necessary because, due to the extremely thin airfoil section, the elevon operating horns protruded into the airstream and it was hence necessary to shroud them and the driving mechanism with fairings which were in line with the airstream. Each elevon was actuated by two sets

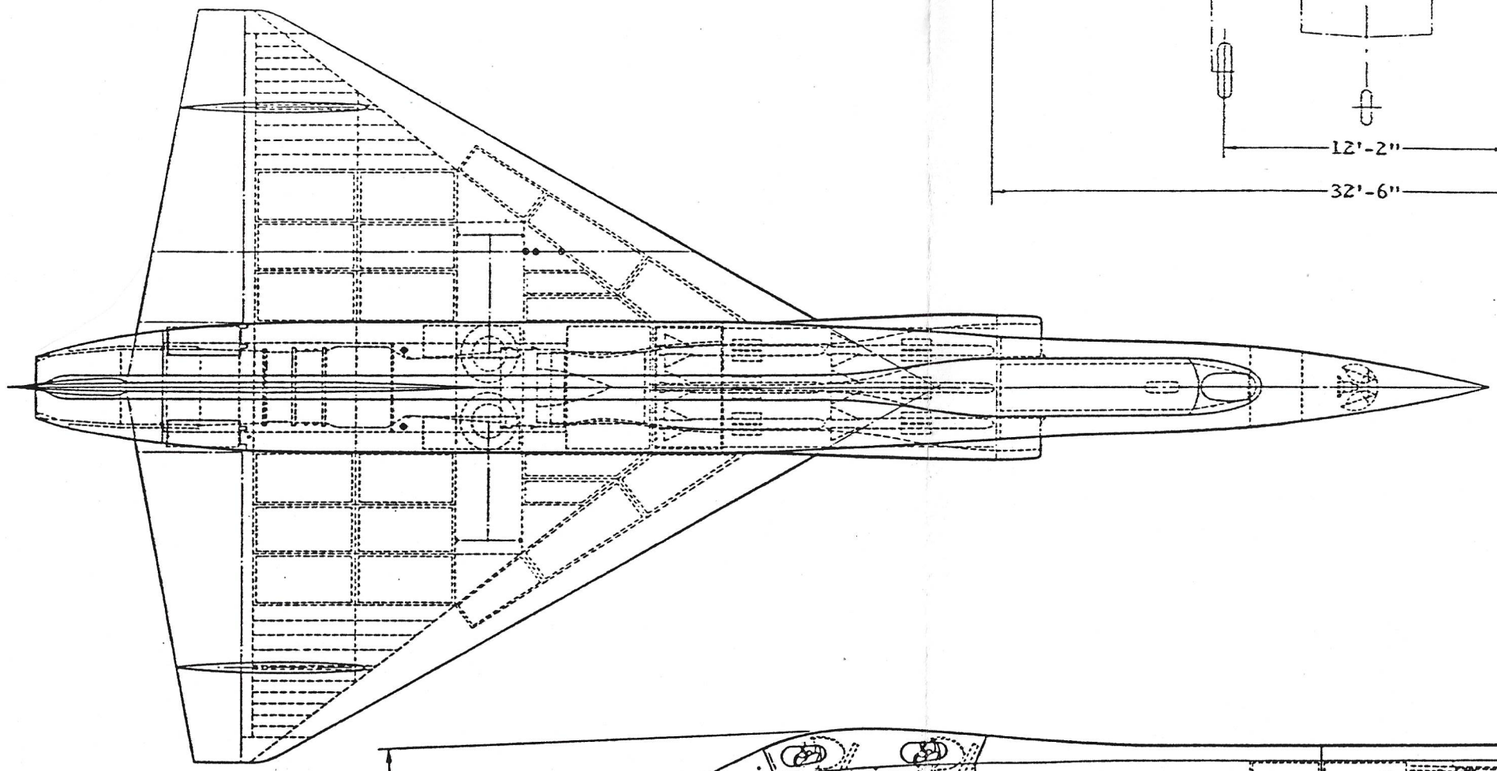


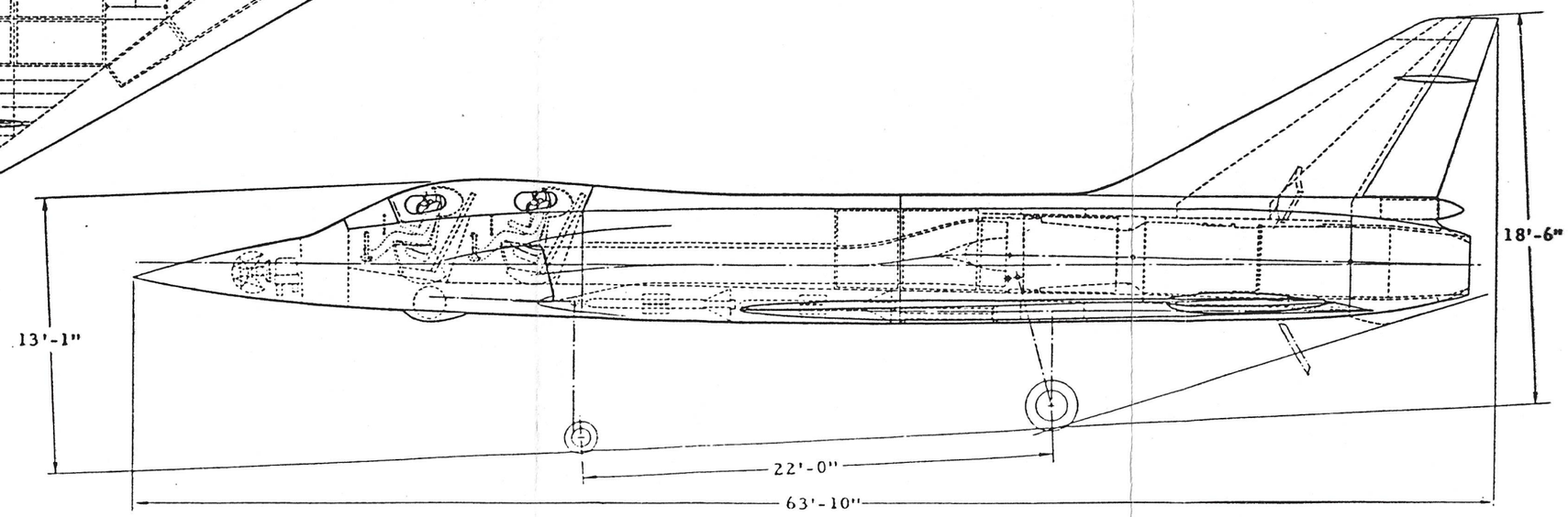




THREE VIEWS OF THE SINGLE SEAT C/104/1.



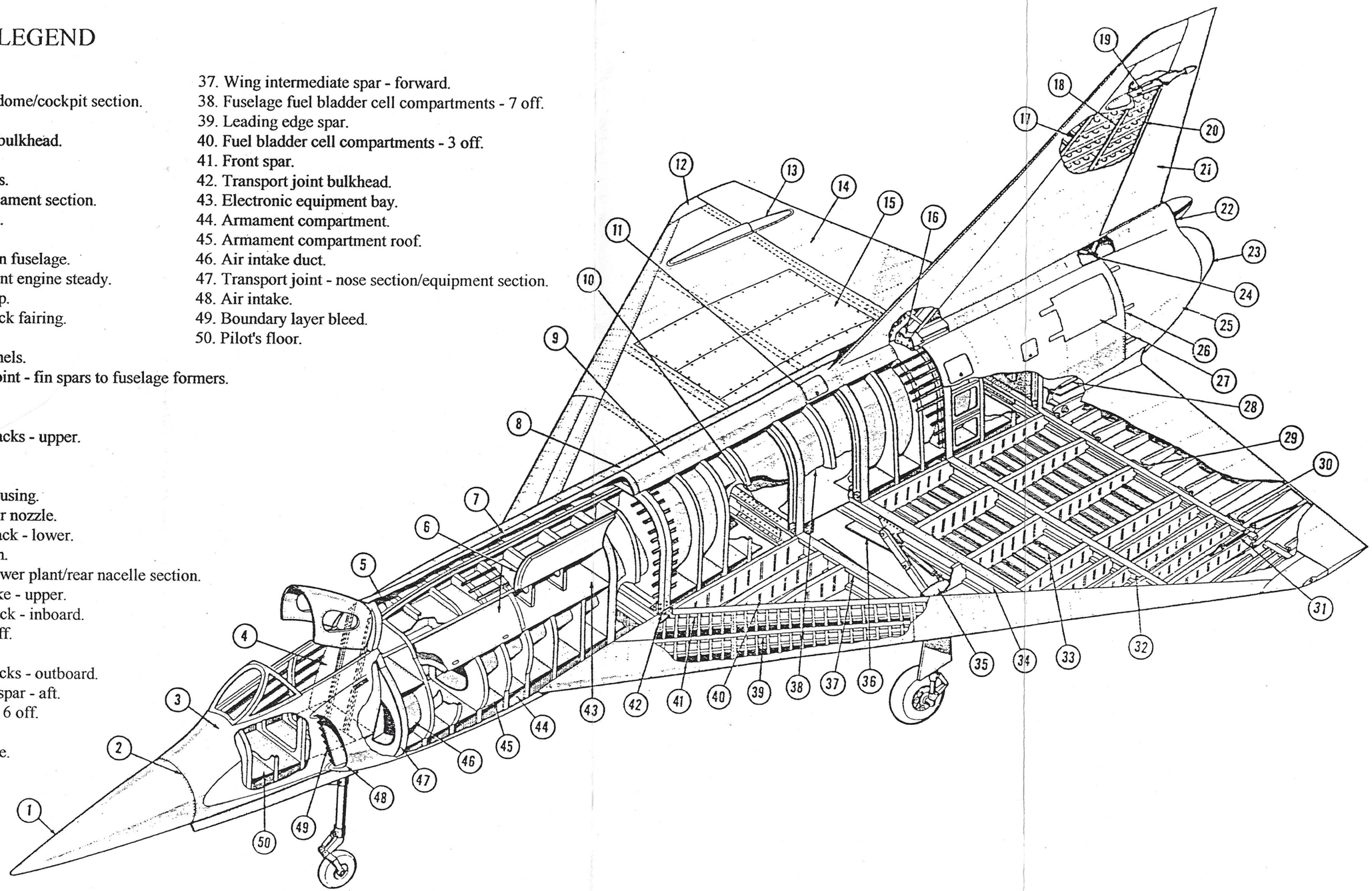


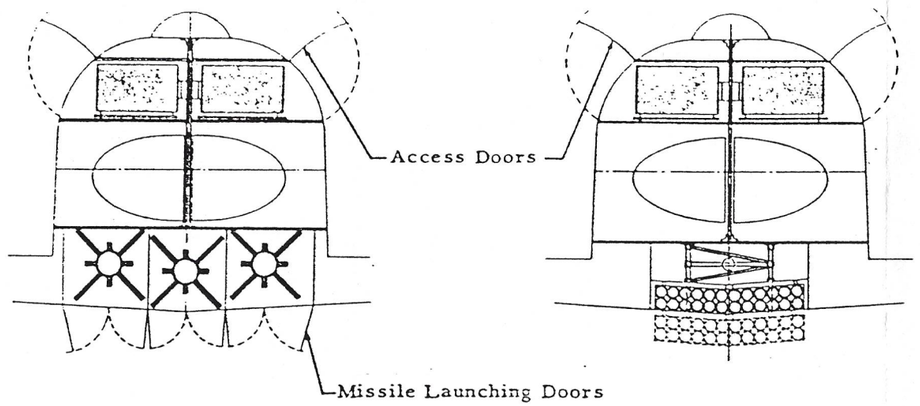


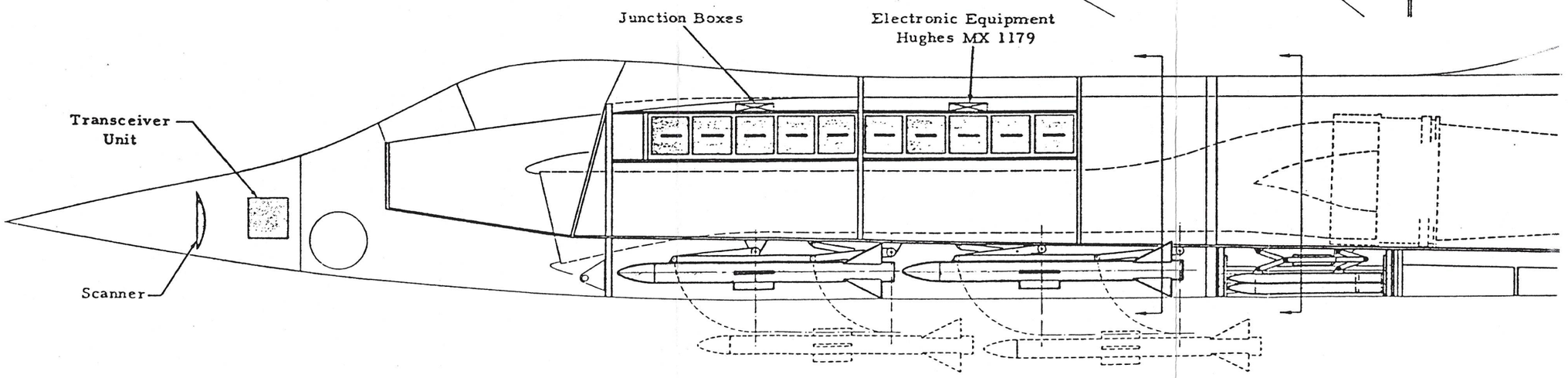
THREE VIEWS OF THE TWO SEAT C/104/1T.

LEGEND

1. Radome.
2. Transport joint - radome/cockpit section.
3. Cockpit section.
4. Pilot's seat/sloping bulkhead.
5. Central beam.
6. Hinged access doors.
7. Equipment and armament section.
8. Power plant section.
9. Control trough.
10. Typical spar joint in fuselage.
11. Access panel to front engine steady.
12. Detachable wing tip.
13. Elevon outboard jack fairing.
14. Elevon.
15. Fuel cell access panels.
16. Typical transport joint - fin spars to fuselage formers.
17. Fin front spar.
18. Fin centre spar.
19. Rudder operating jacks - upper.
20. Fin rear spar.
21. Rudder.
22. Brake parachute housing.
23. Variable afterburner nozzle.
24. Rudder operating jack - lower.
25. Rear nacelle section.
26. Transport joint - power plant/rear nacelle section.
27. Fuselage speed brake - upper.
28. Elevon operating jack - inboard.
29. Elevon hinges - 5 off.
30. Wing rear spar.
31. Elevon operating jacks - outboard.
32. Wing intermediate spar - aft.
33. Integral fuel tanks - 6 off.
34. Wing centre spar.
35. Main gear pivot axle.
36. Main gear bay.
37. Wing intermediate spar - forward.
38. Fuselage fuel bladder cell compartments - 7 off.
39. Leading edge spar.
40. Fuel bladder cell compartments - 3 off.
41. Front spar.
42. Transport joint bulkhead.
43. Electronic equipment bay.
44. Armament compartment.
45. Armament compartment roof.
46. Air intake duct.
47. Transport joint - nose section/equipment section.
48. Air intake.
49. Boundary layer bleed.
50. Pilot's floor.







C/104/1 ARMAMENT AND ELECTRONIC EQUIPMENT INSTALLATIONS

of two jacks. The inboard jacks were installed in tandem within the fuselage contour while the outboard jacks were mounted externally on either side of the surface at 70% of the elevon span and were covered by fairings. The elevon structure was a simple monocoque, using thick skin, a leading edge spar and a small number of ribs. A blunt trailing edge was used which consisted of a light alloy extrusion; the reason for this is that a blunt trailing edge will improve the torsional stiffness considerably and, from the aerodynamic point of view, a blunt trailing edge will not cause additional drag at supersonic design speed. (This feature was to be retained and incorporated in the Arrow development). All bearings were of the roller type. No mass balance or aerodynamic balance were incorporated and no tabs were fitted.

The rudder was constructed in a similar manner.

CONSTRUCTION.

Basically, the aircraft was to be of conventional construction. The wings, the essential part of any aircraft, were to have been made of the following materials;-

All skin panels.....24ST clad Aluminum.
Sparboom extrusions.....75ST Aluminum.
Spar Webs.....75ST Aluminum.

SPEED BRAKES.

Two brakes were fitted to the upper rear side of the fuselage and one large flap fitted to the rear underside of the fuselage. They were of conventional aluminum alloy construction.

The C/104/2

The details of the C/104/2 from the Avro brochure of June 1952 are as follows:-

Service model designation.....Supersonic all-weather fighter
Designer's name and model No...A.V.Roe Canada Ltd. C/104/2
Number of crew.....One (Pilot)
Number and kind of engine.....Two A.V.Roe Canada turbo-jet engines - TR9
or
Two Bristol Engine Co. turbo-jet engines - OL3 (Fighter version)
or
Two Curtiss-Wright turbo-jet engines - J67

Note: Each type of engine would have been fitted with an after burner.

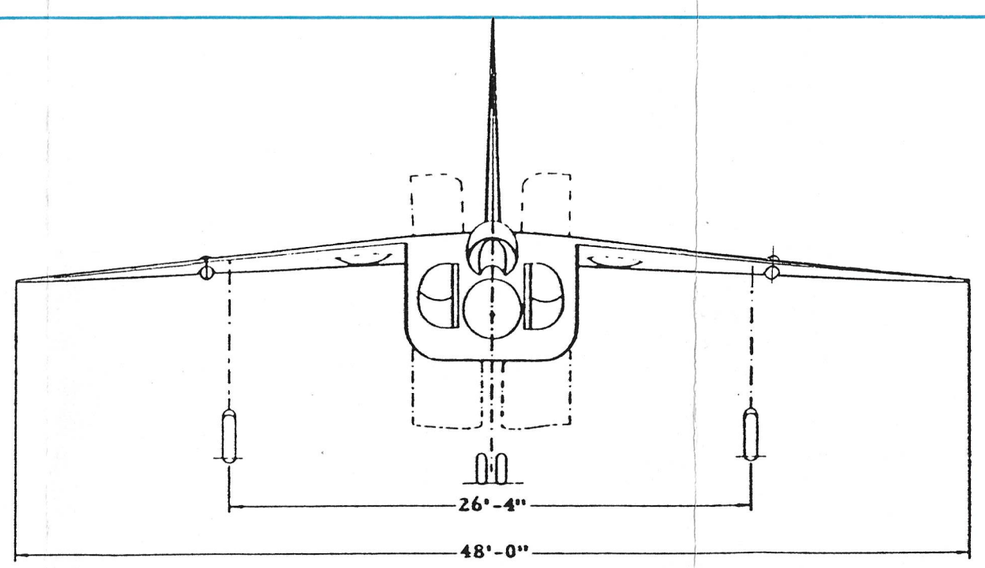
Design information

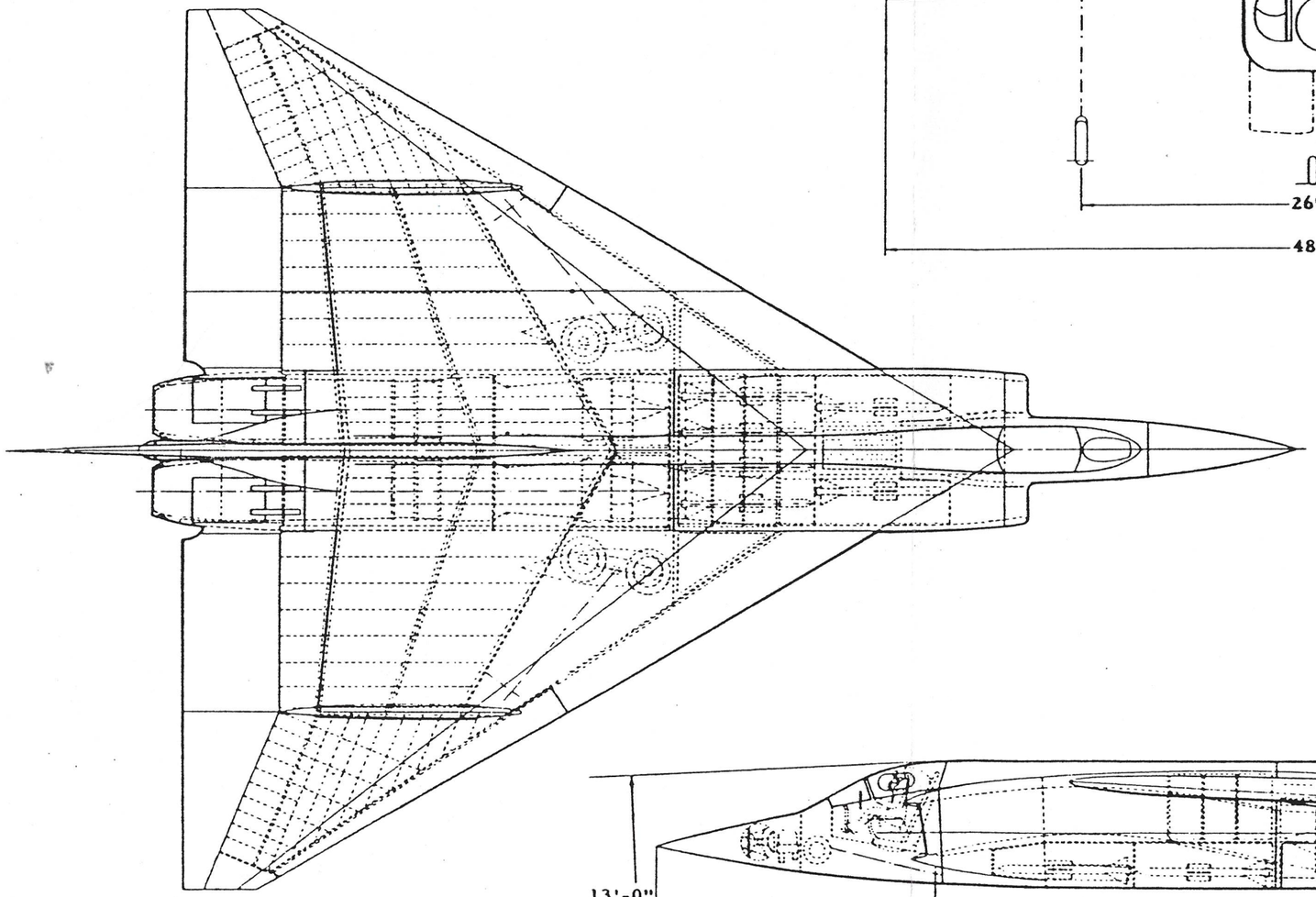
Length-max.....70 ft. 3 in.
Height-max.....21 ft. 3 in.
Wing span.....48 ft. 0 in.
Aerofoil section....NACA-0003-63 (modified)
Root chord.....45 ft. 7 in.
Tip chord (basic). 4 ft. 0 in.
Total wing area....1189.4 sq.ft.
Elevator area.....51.55 sq.ft. (each)
Aileron area.....30.25 sq.ft. (each)
Vertical tail area...155 sq.ft.
Rudder area.....33 sq.ft.
Main wheel size....29 x 7.7
Nose wheel size....18 x 5.5
Anhedral.....3 deg. 0 min.
Performance.....1,140 kts. at 50,000 ft.1,100 kts. at sea level
Max. ceiling.....55,000 ft.
Combat radius.....242 naut.mi. at 50,000 ft.
Max. range.....390 naut.mi.

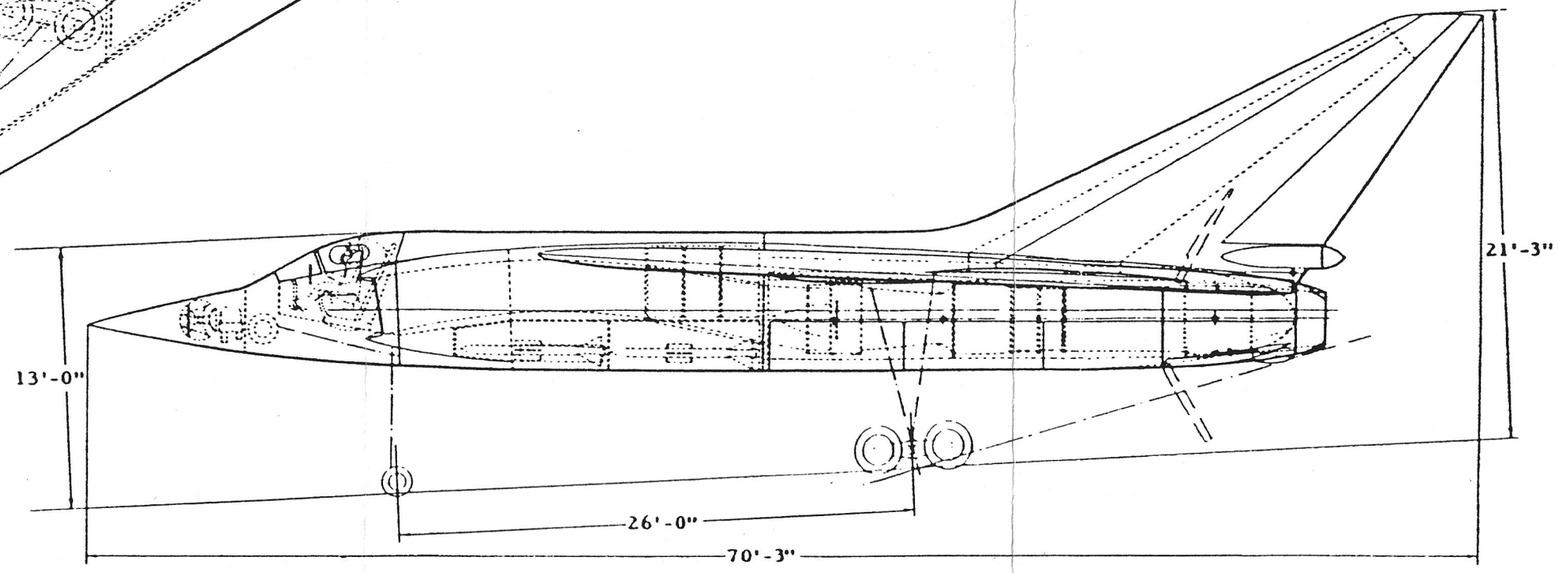
ARMAMENT OPTIONS - (PROJECTED).

C/104/2.
- 6 - Falcon guided missiles and 24- 2.75 in. rockets.

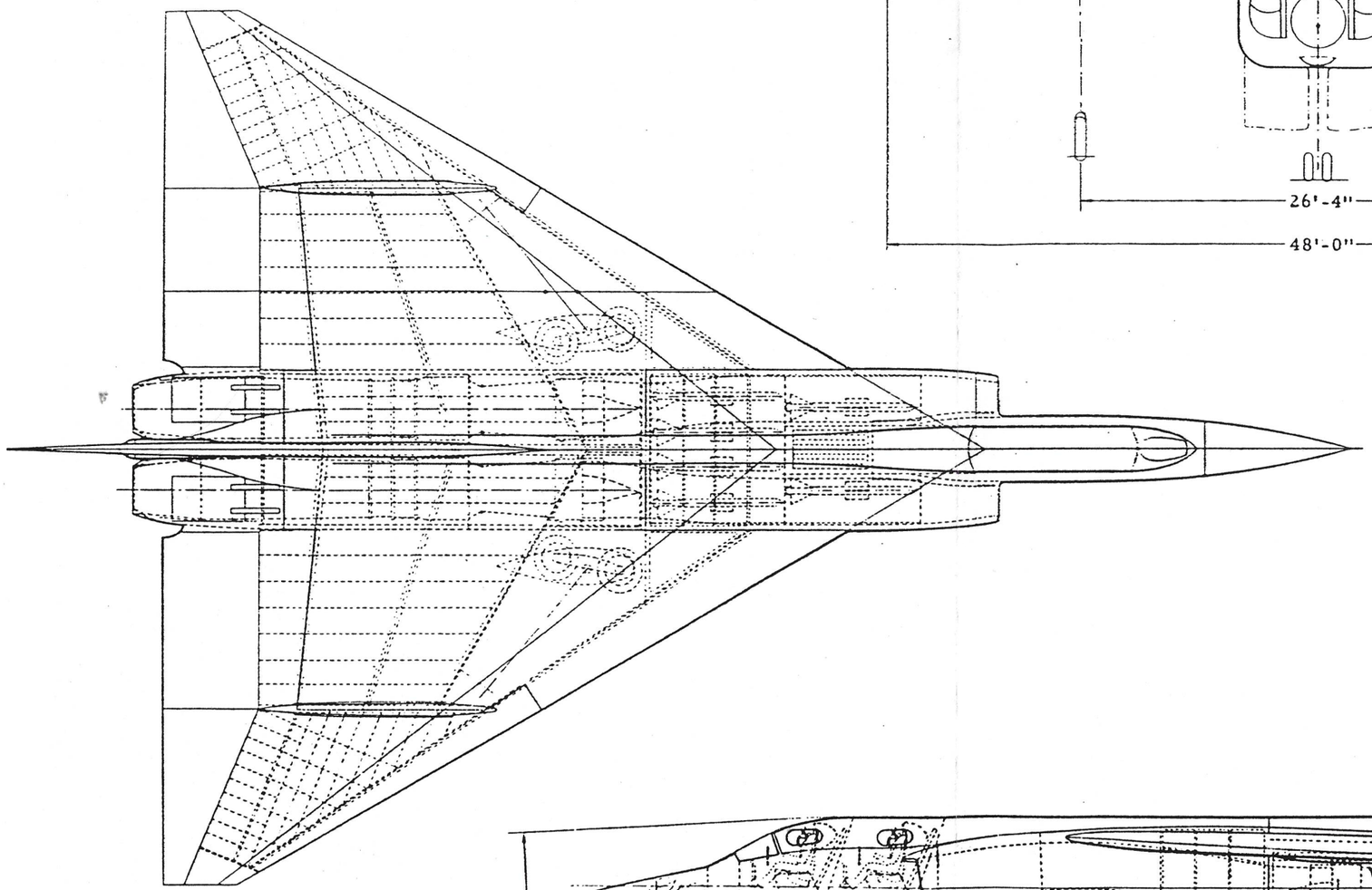
C/104/2A.
- 4 - CARDE (Velvet Glove) guided missiles.

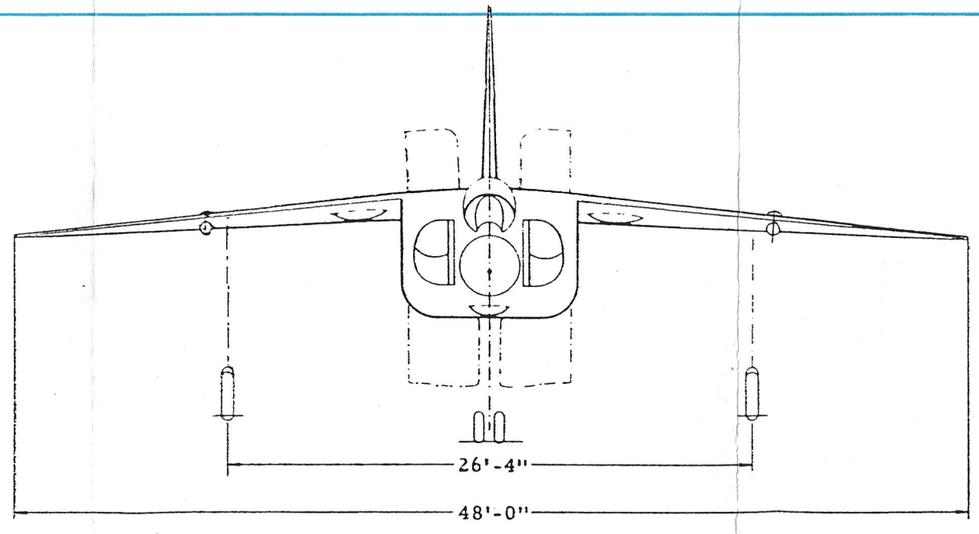


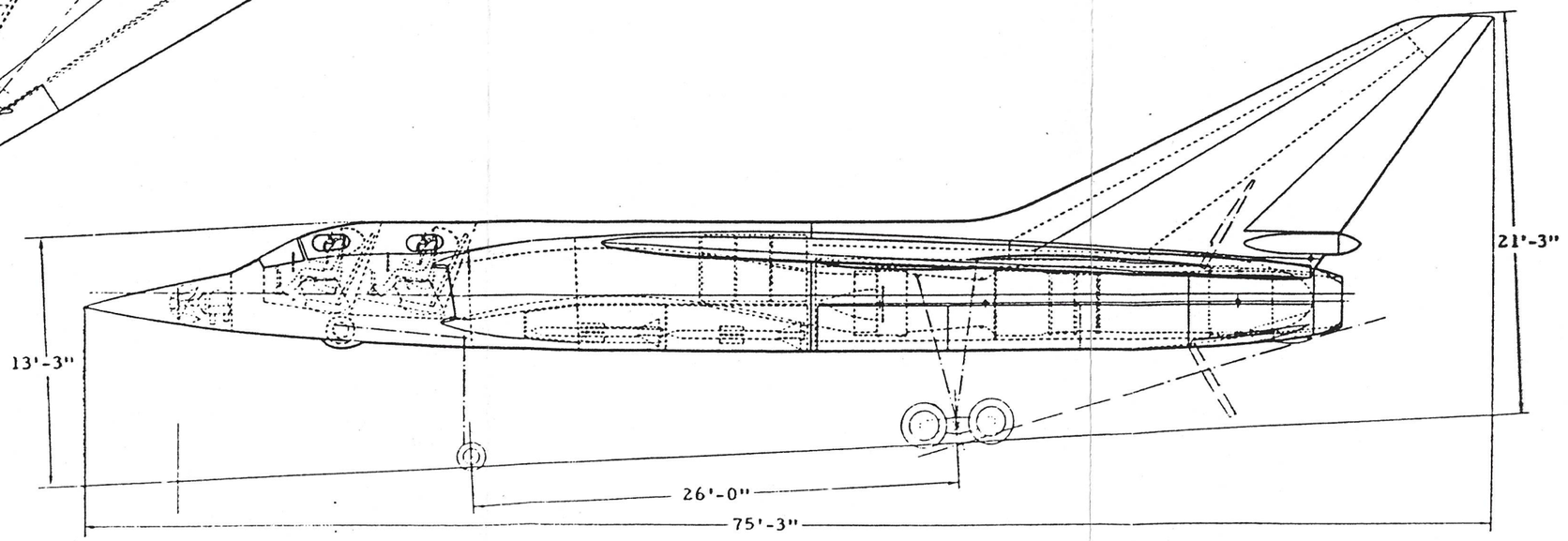




3 VIEWS OF THE SINGLE SEAT C/104/2





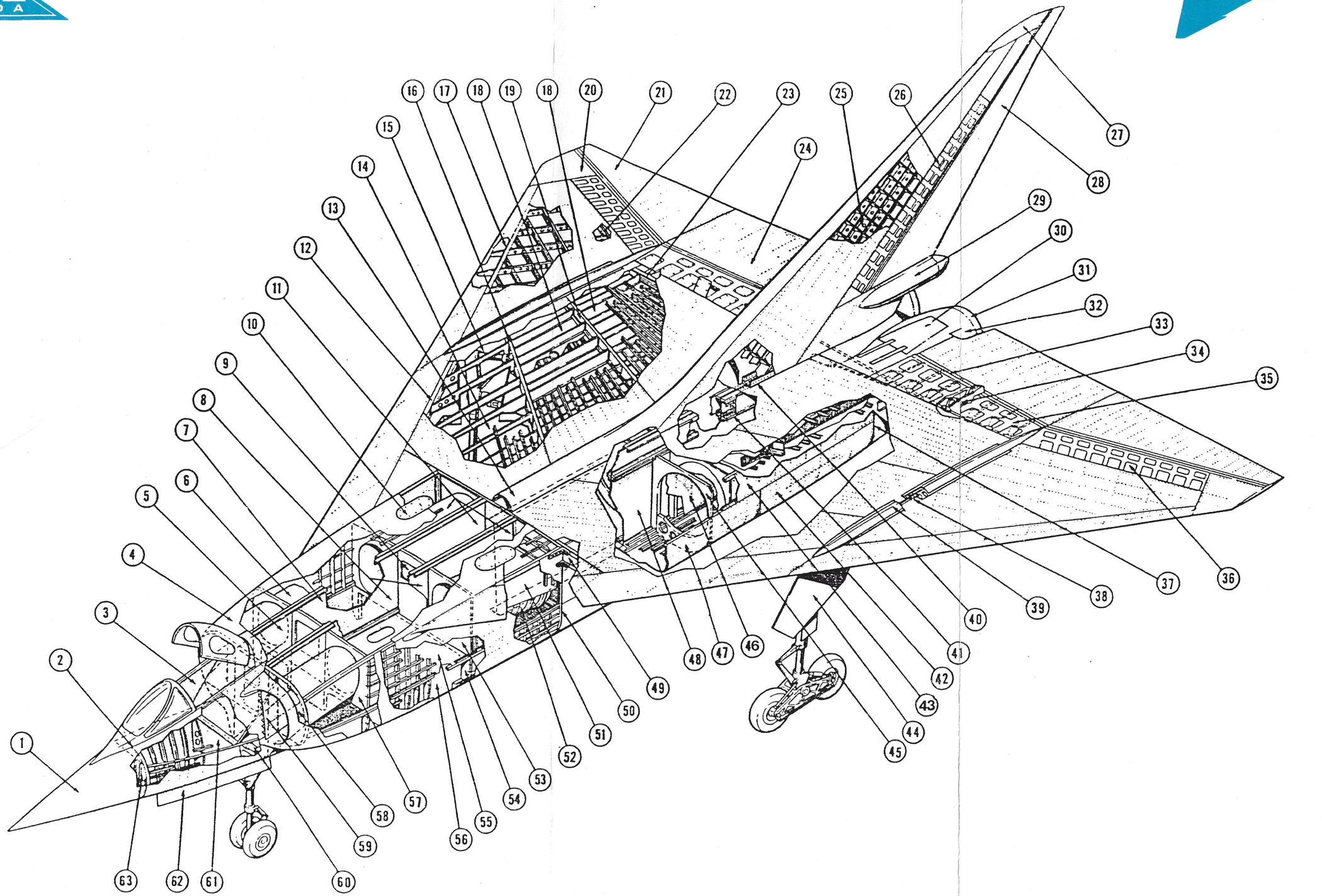


3 VIEWS OF THE TWO SEAT C/104/2D

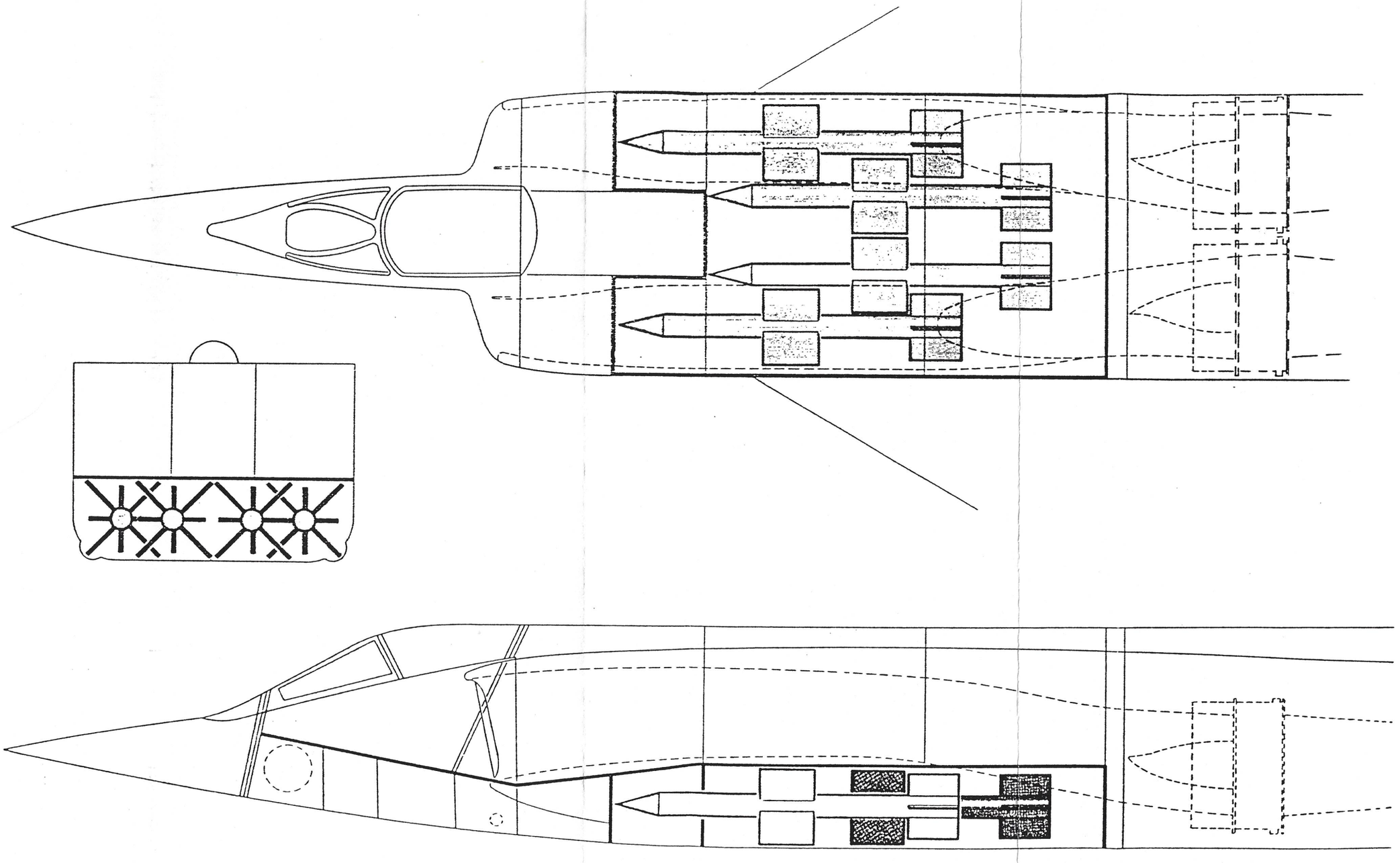
LEGEND

1. Radome.
2. Radome/cockpit section transport joint.
3. Cockpit section.
4. R.H.Engine air intake.
5. Electronic equipment compartment.
6. Air intake structure.
7. Hydraulic and pneumatic equipment compartment.
8. Longtitudinal diaphragms.
9. Access aperture to main fuel cells.
10. Access panels - Main fuel cells.
11. Fuel cell compartments.
12. Inner wing - leading edge spar.
13. Control trough.
14. Main undercarraige retracting bay.
15. Main undercarraige pivot axle.
16. Intermediate wing spar - forward.
17. Outer wing - leading edge spar.
18. Fuel cell compartments.
19. Intermediate wing spar - aft.
20. Detachable wing tip.
21. Aileron.
22. Outer wing - rear spar.
23. Inner wing - rear spar.
24. Elevator.
25. Multi-cell fin structure.
26. Fin casting - trailing edge.
27. Detachable fin tip.
28. Rudder.
29. Brake parachute housing.
30. Fuselage speed brake - upper.
31. Variable afterburner nozzle.
32. Rear nacelle section of fuselage.
33. Elevator hinge - piano type.
34. Elevator control linkage.
35. Inner wing - trailing edge casting.
36. Outer wing - trailing edge casting.
37. Transport joint - power plant section/rear nacelle section.
38. Transport joint - inner wing/outer wing.
39. Transport joint shroud.
40. Fin structure attachment to wing transport joint.
41. Wing transport joint - centre line of aircraft.
42. Hinged access doors - engine compartment - aft.
43. Side walls - engine compartment.
44. Main undercarraige fairing door.

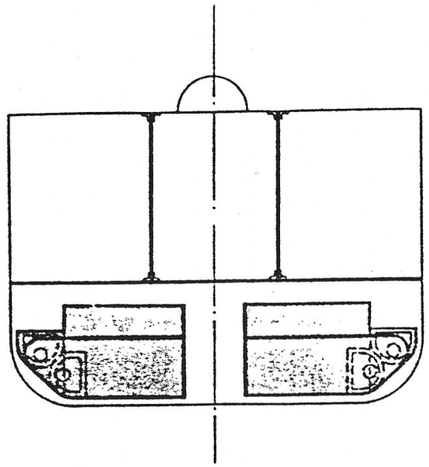
45. Formers - engine compartment.
46. Shroud - engine compartment.
47. Hinged access doors - engine compartment - centre.
48. Longtitudinal keel structure.
49. Front spar - lateral wing section attached to fuselage transport joint.
50. Transport joint - equipment section/power plant section.
51. Air intake shroud.
52. Air intake duct.
53. Lateral bulkhead - equipment/fuel cell compartments.
54. Lateral bulkhead - armament compartment.
55. Floor structure - equipment compartment.
56. Armament and electrical equipment compartment.
57. Lateral bulkhead forming aft wall of electronics compartment.
58. Transport joint - cockpit section/equipment section.
59. Boundary layer bleed - air intake.
60. Nose undercarraige pivot axle.
61. Cockpit floor structure.
63. Bulkhead - cockpit/radome section.

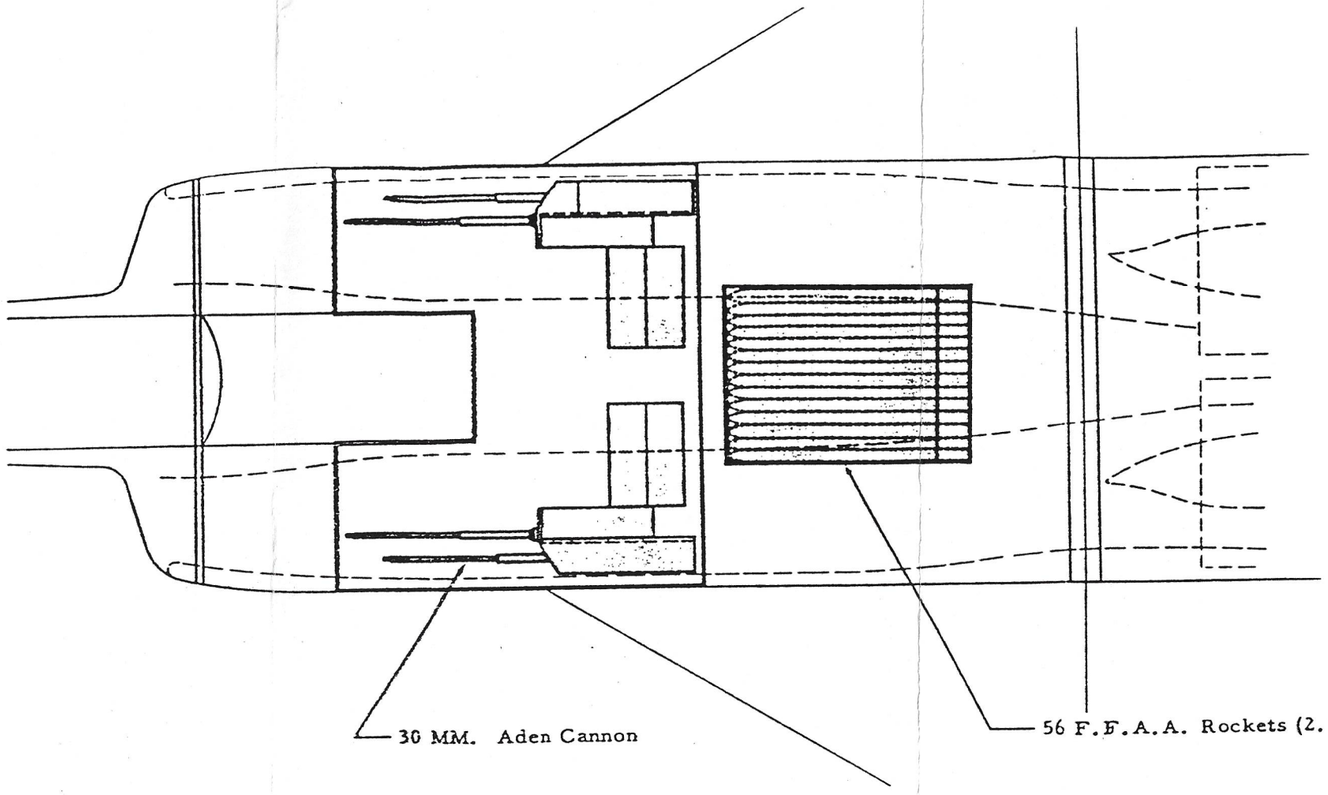


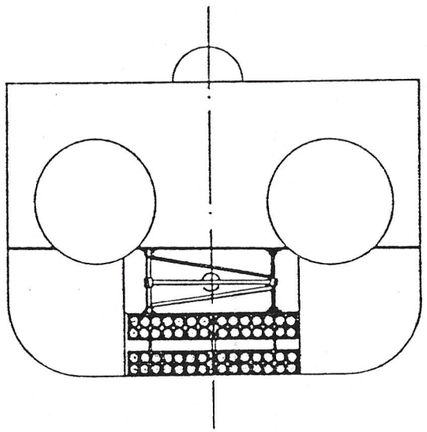
C/104/2 STRUCTURE

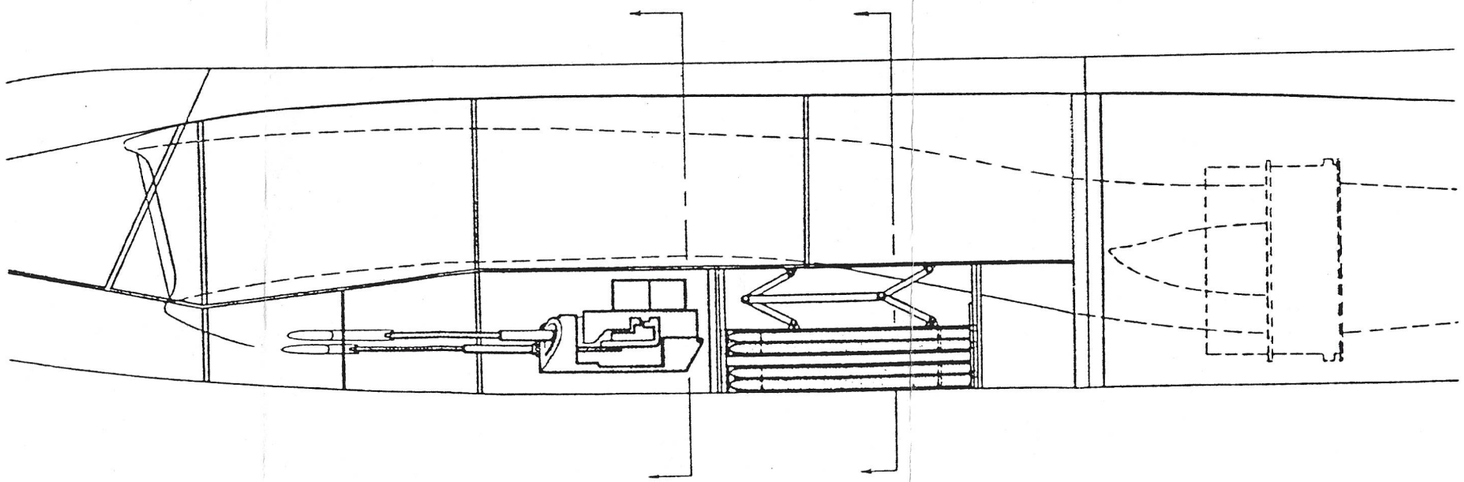


CARDE MISSILE INSTALLATION. C/104/2A

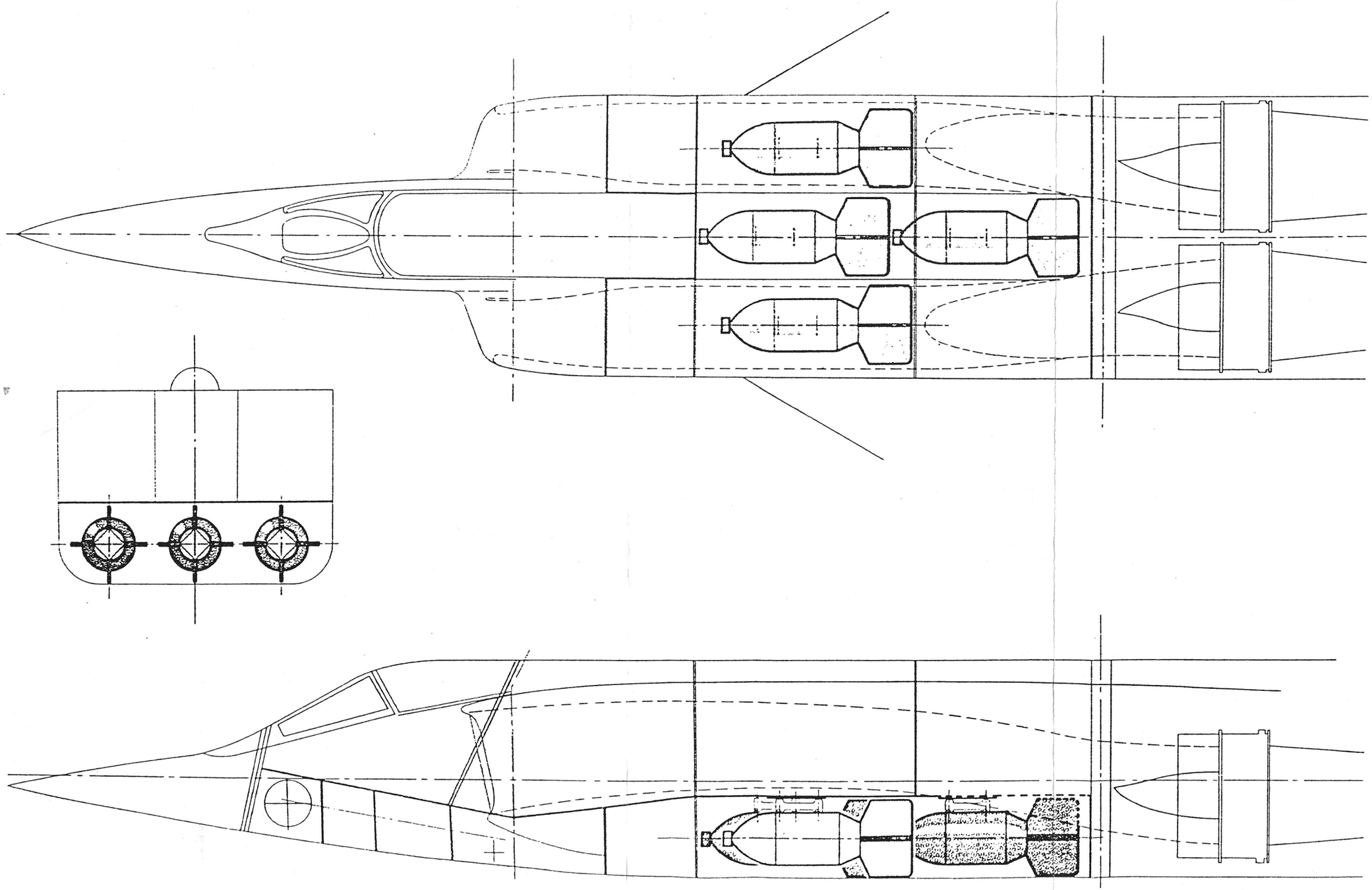




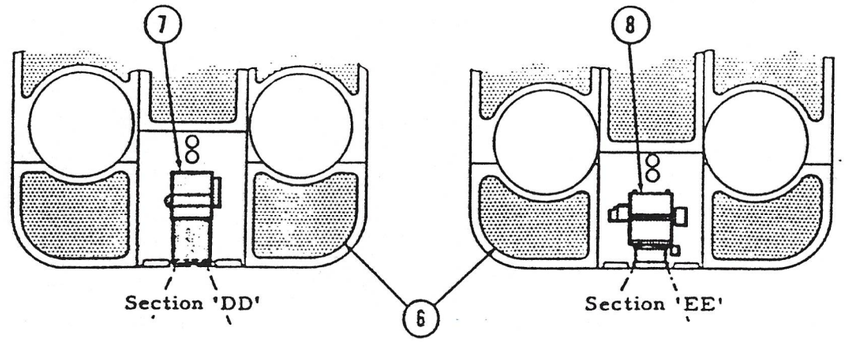


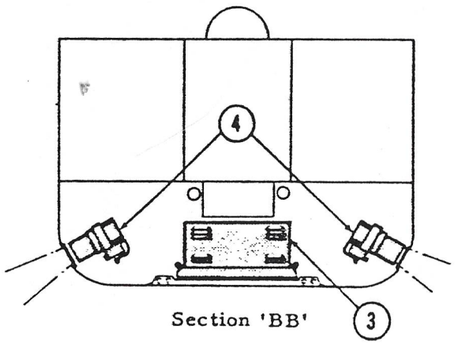


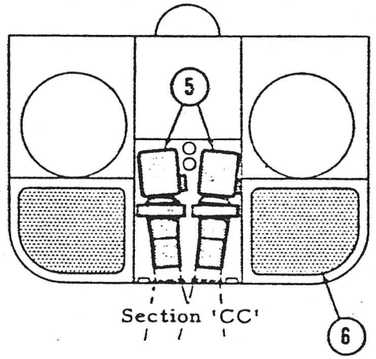
CANNON AND ROCKETS INSTALLATION. C/104/2B

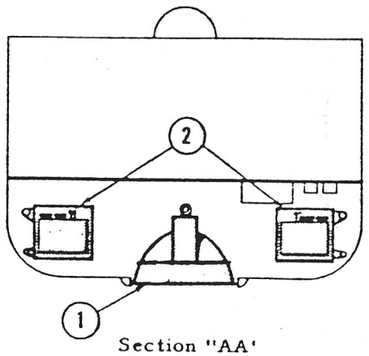


INSTALLATION OF 4-1000 LB GP BOMBS. C/104/2E



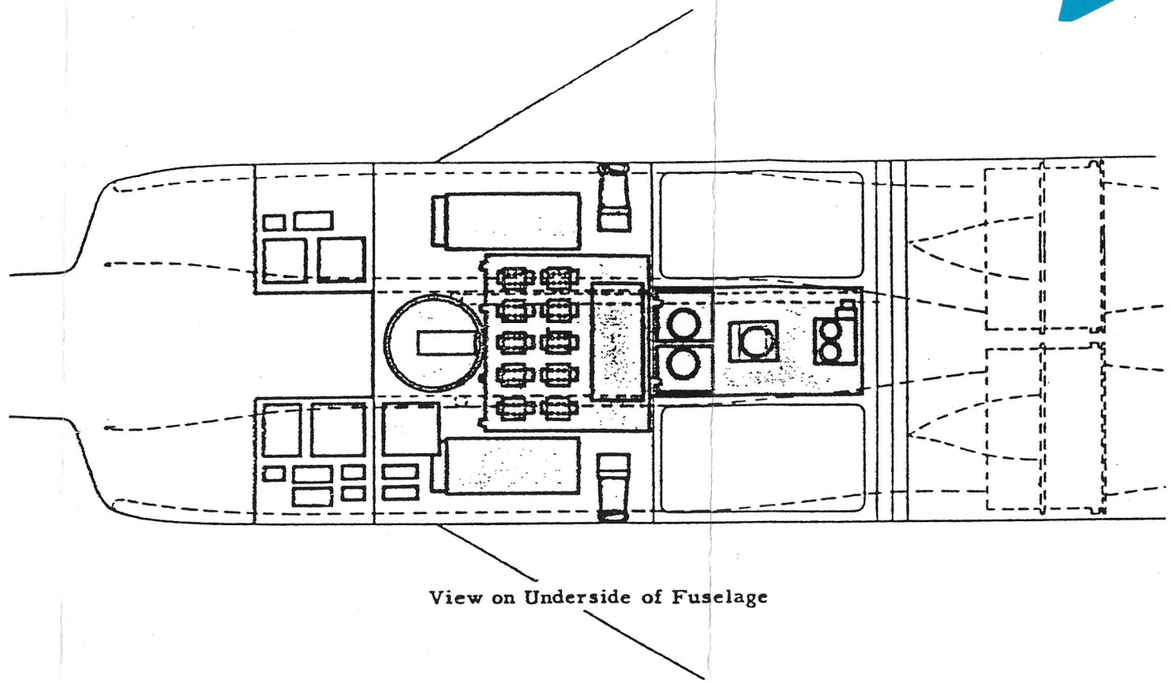


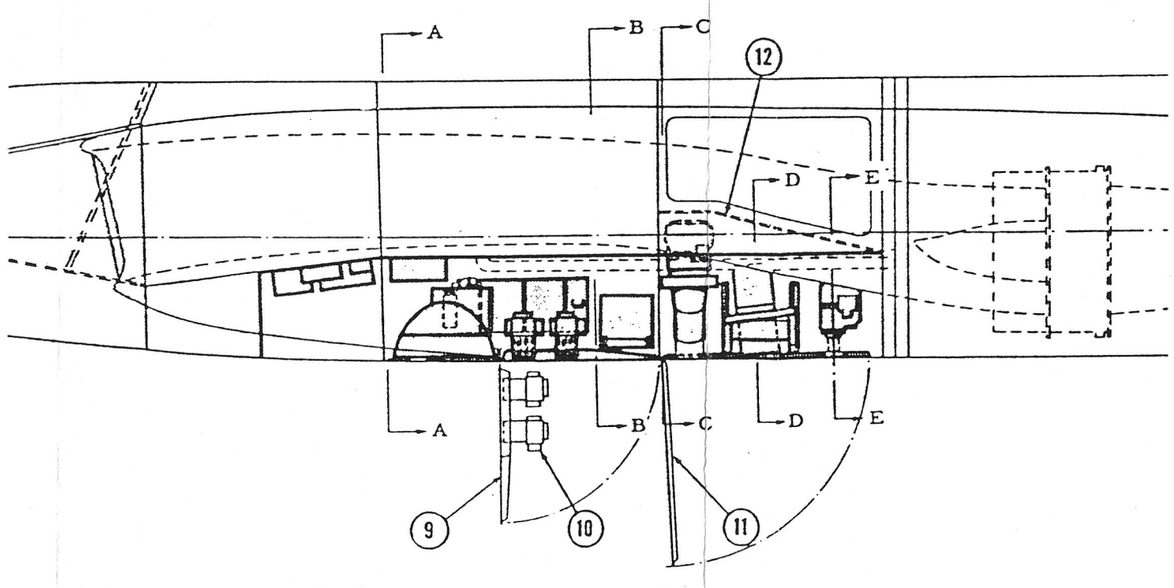




LEGEND

1. Floodlight
2. Condenser Packages
3. Power Unit
4. K/F24 Oblique Camera
5. F. 52 Split Vertical Cameras
6. Fuel Tanks
7. K19B Vertical Night Camera
8. Sonne S7A Vertical Stereo Camera
9. Flash Cartridge Mounting Door
10. Flash Cartridge Containers
11. Access Door
12. Centre Tank Floor





PHOTOGRAPHIC EQUIPMENT INSTALLATION. C/104/2F

C/104/2B.

- 4 - 30mm Aden guns with 200 rds. each plus 56 - 2.75 in. rockets.

C/104/2C

.- As for 2B but with additional fuel for long range fighter role.

C/104/2E.

- 4 - 1,000 lb. bombs. It was assumed that the tactical role for this aircraft would be the destruction of a special target by means of dive bombing attack for which neither an elaborate bombsight, a second crew member, radar search and fire control equipment would be required, which would give a weight saving of 1,000 lb. On the other hand, it would have been necessary to fit a 700 lb. ballast at a point 6.8 ft. from the nose datum in order to keep the C of G of the airplane within allowable limits. The gross weight of the bomber version would have been 54,590 lb. with a range of 420 naut.mi. if flown sub-sonic and the basic airplane's fuel capacity. The guidance system was to have been the Hughes MX 1179 integrated electronic system which provided for:-

(a) Automatic navigation. (c) Fire control.

(b) Interception. (d) Return to base.

The basic feature of this system, was that data from all relevant sources was fed into a single high-speed digital airborne computer which then, successively supplied the information to the airplane controls required for navigation and fire control.

OPTIONAL ARRANGEMENTS.

In addition to the armed versions, there were the following variants:-

C/104/2D.

- Operational trainer with two pilots. Conversion from the basic airplane could have been rapidly accomplished by unbolting the cockpit section of the fuselage forward of the transport joint bulkhead to which the nose gear leg was attached and re- placing it with the longer trainer cockpit section. If it had been desired to carry the same armament and electronic equipment as the fighter version, the resulting increase in gross weight together with the longer fuselage would have, of course de-tracted somewhat from the performance as quoted for the basic fighter airplane.

C/104/2F

.- Photo-reconnaissance. This version was un-armed and was designed to fill the RCAF Operational Requirement OR1/1-31 which had been issued in draft form for the CF-100 conversion on December 20, 1949. The aircraft was designed to carry the following equipment:-

For day operation.

(a) Left and right lateral oblique cameras K/F24 (7/8 in.)

(b) 2 Split vertical F52 cameras. 20 in. lense.

(c) A vertical Sonne 57A stereo camera with 7 in. lense and ground speed synchronizer.

For night operation.

(a) One vertical K19B camera with photo electric pick-up unit and amplifier.

(b) Ten multiple flash cartridge dischargers containing sixty cartridges. (SIS 5343 and AP 1661)

(c) Floodlight (29.75 in. dia.- Raytheon A-123G-X1)

(d) Power unit (Raytheon A-123F-X1)

(e) Two condensers (Raytheon A-123E-X1)

In addition, 1940 lb. of additional fuel was to be carried giving a range of 550 nautical miles. It can be readily appreciated that each of the above versions could be employed with a crew of two, - pilot and navigator. These two reports became the basis for discussion and selection by the RCAF which led to the C-105.

ALIGHTING GEAR.

This was of a conventional nature, with the nose wheel retracting forwards and the main wheels (in tandem configuration), folded forwards and sideways between the spars, into the underside of the wing. A retractable tail skid was provided to cater for the high angle of incidence of the airplane when landing.

CONTROL SURFACES.

Conventional elevators and ailerons were to be fitted, and as for the C-104/1, no horizontal stabilizer was provided.

CONSTRUCTION.

This was of a similar nature to that of the C-104/1, except that the trailing edge castings were projected to be of Magnesium alloy. Subsequent experience has of course shown that this would not have sufficed the loads induced.

SPEED BRAKES.

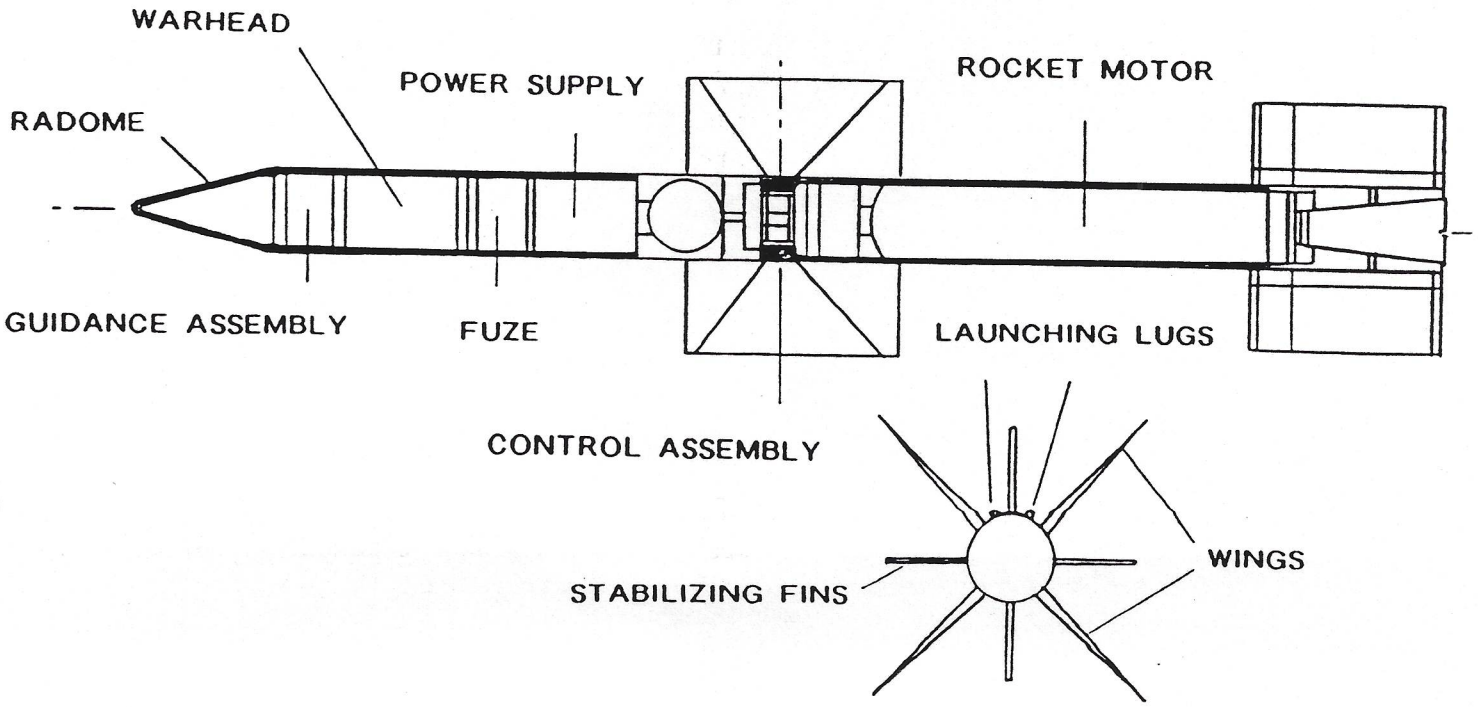
Four speed-brakes flaps were fitted. Two each on the upper and lower surfaces of the rear fuselage. They were of conventional construction.

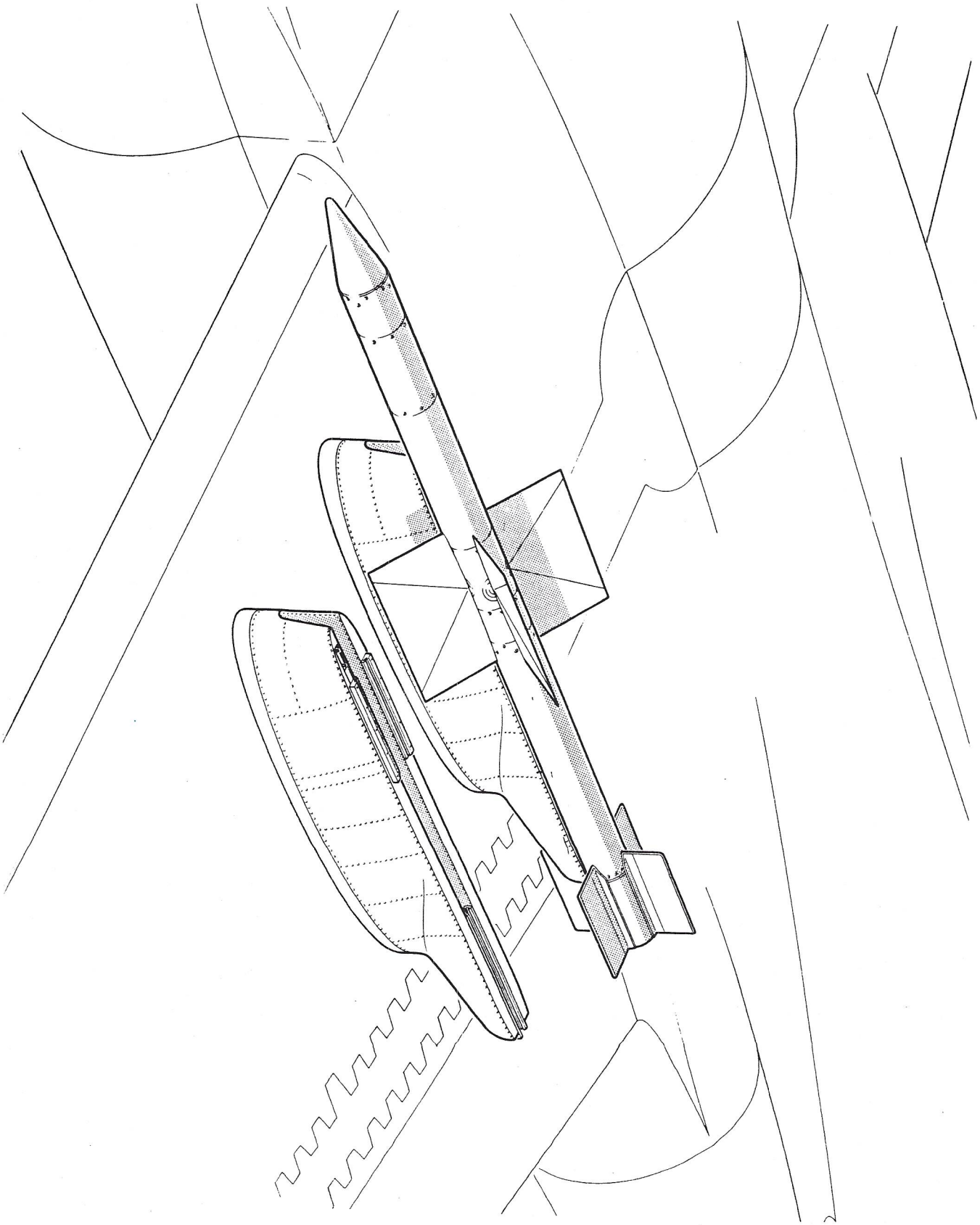
THE CARDE "VELVET GLOVE" MISSILE.

The Velvet Glove missile was designed by the Canadian Armament Research Development Establishment, and one notable figure in its development was the late Dr. Gerald Bull, of the IRAQ gun fame. On September 18, 1950, The Minister of National Defence recommended to Cabinet that an air-to-air missile be developed in Canada. This led to the "Velvet Glove". On April 1, 1951 the CARDE formally began work on the missile, and between December 1951 and December 1953, 28 missiles were ground fired at Point Petre in Ontario. On August 27, 1953, the first air launch of the "Velvet Glove" was made from a Sabre; trials were then carried out using the CF-100. Over 300 missiles were manufactured at a cost to the taxpayer of $24.000.000, and it was canceled in 1955 in favor of the "Sparrow 2".

Description

Length.....128 inches.
Span.....38 inches.
Diameter.....8 inches.
Weight.....318 lbs.
Speed.....Mach 2.3.
Range.....2500 - 4500 yds.
Propulsion.....Aerojet solid fuel 7600 lbs. thrust.





TEST INSTALLATION OF THE VELVET GLOVE ON A CF-100

Forthcoming titles and contents of the Chapters of the book on "THE AVRO ARROW", by Thomas B Dugelby.

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A Chapter on the Arrow Story will be published about the middle of each month. The price for Chapters 1, 3, 5 and 8 will be $25. Chapters 2, 4, 6 and 7 will be $ 40.

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