THE AVRO ARROW

TO MY FRIENDS DOUG & DONETTE
WITH MY COMPLIMENTS.

A BOOK BY

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QUEST FOR SIZE. 2

PROJECT DESIGN STAGE. May/53 - Aug./53.

May/53
- Avro submit to RCAF results of minimum weight study and general design studies of C-105 in Report P/C-105/1 including appendices for version with podded engines at the wing tips and a 900 sq.ft. wing area version. Studies with Rolls-Royce RB-106 engines with afterburners, all based on AIR 7-3 with single crew.

June/53
- Avro submit proposal P/C-105/2 to RCAF covering design, development and manufacture of two prototype aircraft. Total financial forecast to flight of second prototype (estimated Aug/57) is $22,925,000.

July/53
- RCAF and Avro discuss 2 x 30" diameter engine C-105 version. RCAF agrees it is impracticable. Final discussions for Cabinet Defence Committee 2 x 30" diameter engine version: All up weight 41,000 lb., wing area 1,000 sq.ft., t/c 3%, combat ceiling 61,700 ft., 'g' at 50,000 ft. and 1.5 M.N. = 1.85, 6 - Falcons. Fuel capacity 11,400 lb.

- RCAF decides to abandon CF-100 Mk6. Performance and delivery incompatible with threat.

- Two man crew proposal for C-105 due to uncertainties in development of fire control system suitable for single crew operation.

- Avro meeting with RCAF. Agree Company proceed with two man crew airplane with E9 electronic fire control system capable of being retrofitted with MX 1179 and changed to single crew version.

- Preliminary outline of proposal to fire rocket propelled models of the C-105 in co-operation with CARDE.

- Ministerial Direction ACDA-4 received, authorizing design study of C-105 to meet specification AIR 7-3. Financial authorization $200,000 to cover phase until Sept 30/53.

- Avro conclude work on supersonic fighter with 2 x 30" diameter engines. Risk too great to design airframe around hypothetical engines which may never be designed.

Aug/53

- J.A.Chamberlin quells internal criticism of basic wing structure. Agreed that layout of wing structure was basically right, that no advantage gained by changing over undercarriage attachment or retracting space, or by reverting to low wing to ease undercarriage elastic problems.

- The date of commencement of detailed work on the C-105 to Specification AIR 7-3 Iss.1 was set at Sept 1/53 with an objective for first prototype flight 34 months from this date (July 1956).

- The Rolls-Royce RB.106 was selected for installation in the C-105. C-105 design in progress on 1225 sq.ft. version with a crew of 2.

RCAF SPECIFICATION AIR 7-3 April 1953.

In April of 1953, the RCAF issued Spec. AIR 7-3, "Design Studies of Prototype All-Weather Aircraft" to A.V.Roe Canada for the purpose of selecting the optimum aircraft capable of meeting the RCAF Operational Requirement OR1/1-63, "Supersonic All-Weather Interceptor Aircraft". However, following the conveyance by the RCAF of the recommendations contained in the "Final Report of the All-Weather Interceptor Requirements Team" of March 1952, Avro submitted two brochures to the RCAF in June of 1952. These described in very considerable detail two separate proposals; one for a single engined aircraft, the C/104/1 and the other for a twin engined aircraft, the C/104/2. Both of these were intended to meet the conditions laid down by the requirements team. The advantages and disadvantages of these proposals were discussed in the brochures and at several meetings with the RCAF. The general consensus among the RCAF seemed to be in favor of the twin engined proposal. Accordingly, Avro continued its studies of this proposal and investigated general refinements in all aspects which made it possible to offer a performance that could easily exceed the original requirements in all respects; whereas the aircraft as described in the C/104/2 brochure was deficient in some respects. When, in AIR 7-3, the RCAF confirmed their preference for a twin engined proposal, it became evident that the experience gained by Avro in studying this type of configuration for the past year would be applicable, and could be drawn on to produce most of the data required by the design study called for in AIR 7-3 almost immediately. Accordingly an RCAF team visited Avro from April 27 to April 30, 1953, to elucidate the requirements underlying AIR 7-3 and to discuss the results of the Avro studies which had a bearing on this specification. Since the new requirements were really only an elaboration of the draft requirements to which Avro had been working for more than a year, it was found possible to answer most of the questions raised by the RCAF on the spot and to produce a preliminary draft which was to become Avro Report P/105/1 which was submitted in compliance with AIR 7-3.

OBJECT OF THE DESIGN STUDY.

The RCAF team made it clear that they wanted to determine the absolute minimum size of airplane that would just meet their specification. If there were any penalties or risks involved in doing this, they wanted to evaluate these against the gains to be achieved by more generous configurations. The RCAF studies had indicated that performance in excess of their requirements was of very little use, so that every effort should be directed to getting the lightest and hence, cheapest aircraft that would do the job. Since the Avro proposals exceeded the requirements in everything except altitude performance, it was assumed that a considerable weight saving could be achieved by just meeting the requirements. This view was set forth in RCAF report DDA 12. The projected aircraft from these studies was designated the C-105.

AVRO REPORT P/105/1, 1953.- BASIC CONFIGURATION - WING.

To achieve supersonic speeds in level flight by means of turbo-jet engines with after-burning, it is essential that the supersonic drag be reduced to the absolute minimum possible. This required the use of the lowest t/c ratio wing that is technically possible. Convair had made several design studies which showed that the weight per sq.ft. of a delta wing is practically independent of the t/c ratio down to a t/c of 3%. Weights estimated at Avro from scantlings obtained by using methods involving an elaboration of NACA TN2232 and which required the solution of 30 simultaneous equations on IBM machines resulted in similar conclusions. The comparison of conventional swept wings with delta wings shows that there is no doubt that the delta configuration was by far the lightest for low t/c ratios. Due to the large root chord of a very thin delta, the absolute thickness was still adequate to provide room for the stowage of the necessary fuel and undercarriage. It can be readily appreciated that the drag of the fuselage is such that any unnecessary increase in its size to provide stowage of these items would have increased the total drag very materially and hence have added to the fuel load.

The reason for resorting to a tailless configuration was that for a highly swept low aspect ratio layout there was really no place where a tail could have been advantageously located. If the tail was directly behind the wing, it would have either restricted the high ground angle required with a low aspect ratio delta wing or have resulted in an excessively long and heavy undercarriage. If the tail had been moved up higher, it would have been very difficult, if not impossible to support it on a very thin fin. Also the large increase in down-wash at the stall would have rendered it strongly destabilizing so that the stalling characteristics would have been objectionable. The Gloster Javelin being subsonic, had a thick enough fin to support a tail, but did not avoid the considerable limitations imposed by a poor performance at stall.

In order to increase the moment arm of the control surfaces and hence reduce the drag of the elevators, some studies of canard configurations were made, both by Avro and the NAE. These did not prove very fruitful in showing any advantage sufficient to warrant further investigation. A prohibitive reduction in low speed CLmax with only moderate static margins was only one of the many difficulties with this configuration.

Having decided that a tailless design was the lightest and most efficient, it was necessary to choose an apex angle sufficiently high enough to give adequate damping in the transonic region. This required that an apex be about 60 degrees. The difficulties that had been encountered by tailless airplanes employing less than this amount of sweep were too well known to have required discussion. It was sufficient to say that the damping of very large rocket propelled 60 degree delta models had been measured in free flight and had exhibited satisfactory characteristics over the whole Mach range. Having established that the optimum configuration would be a tailless delta with a t/c as close to 3% as was possible with due regard for the room required for stowage, it remained to examine the effect of the various installations on the design.

UNDERCARRIAGE.

Both theory and tests on the Avro 707 indicated that the static ground angle for a 60 degree delta should be about 17 degrees. This required a relatively long undercarriage. In order to secure a reasonable width of track, the upper pivot points of the legs must be outboard on the wings. Folding backwards was impossible in a thin wing, since it would cut through most of the wing bending structure. Therefore inward retraction was necessary. If the wheels were to be housed in the fuselage a low wing arrangement was necessary. If the wheels were to be housed in the wing a high wing arrangement was possible. This had the advantage that when the main undercarriage was clear of the fuselage, the accessability and flexibility of installation of both engines and armament was greatly improved. Since the engine accessories are normally on the bottom, it was possible to carry the main wing box through the fuselage with the high wing arrangement and still have virtually perfect access for servicing the engines from underneath. On the other hand, with a low wing, either very poor engine accessability is achieved or the main box is reduced to a multiple spar construction underneath the engine. This lowers the efficiency of the wing structure so that its extra weight is greater than that saved by the simpler undercarriage. Using data representative of the Convair F-102 multi-spar low wing construction and the Avro C/104/2 high wing construction, the saving in wing weight was 3,500 lb. for the high wing version as against a loss on the undercarriage of 350 lb. giving a net saving of 3,150 lb. for an aircraft similar to the C/104/2. Although somewhat more complicated, the undercarriage installation for the high wing airplane results in a lower gross weight, and gives considerably better access and flexibility to the engine and armament bays.

ENGINE INSTALLATION.

The high wing layout with the engines slung from the wing and covered by large non-structural doors is ideal for service and maintenance. It also permits the installation of different makes of engines with a minimum of rework to the basic airframe. In this case, and accessories that come in awkward places can be accommodated by small bulges in non-structural fairings. This feature was also especially important when it is considered that none of the engines under consideration had even been run at this date. There were bound to be modifications during the course of development, some of which would undoubtably have been embarrassing to a tight situation, and would have caused excessive delay in adapting the airframe, or might even have resulted in a non-standard engine detail becoming necessary.

With a low wing installation, it is virtually essential to have the fuselage surrounding the engines to be stress carrying, in order to provide torsional stiffness for the wing and to support the fin. Engine removal must then be through stress carrying doors or out the rear end of the fuselage. Of these two methods, the latter is probably preferable. It has the disadvantage however that any part or accessory that falls outside the basic envelope must be made clear at all points on the with-drawl path. It should be regarded as purely fortuitous, if an installation of this kind involving engines still in the design stage, escaped without major structural fouls during the course of development. Hence there is no reason to dispute the advantage of the high wing arrangement as far as the engine installation is concerned.

ARMAMENT.

The most promising fire control and armament configuration for the proposed fighter appeared to have been the Hughes MX 1179 system together with 6 Falcon guided missiles and 50 - 2" dia. folding fin rockets. It was envisioned that it might have become necessary to substitute other equipment if this did not work out as planned. (This subsequently proved to be the case.) The major design studies however were based on the assumption that this system would be fitted. In order to give some appreciation of the effect of external missiles on the performance, some data was worked out and showed that at 50,000 ft. in the transonic range and beyond, with the high drag of the externally stowed missiles, it would have been impossible to maintain level flight. A great amount of research and testing was required by literally breaking into new ground in order to provide a solution to this problem, therefore there was a great incentive to use internally stowed missiles only and to consider externally stowed ones as a means of last resort.

The method of installation of the electronic equipment, that is easiest to design and maintain in service was believed to be where all this equipment is mounted in a crate. In the larger versions of the aircraft studied in this chapter, it would have been possible to adopt this configuration with the fuselage envelope required for balance.

On some of the smaller versions it would have become necessary to compress the fuselage to such an extent that the electronic equipment would have had to have been spread out along the lower corners of the fuselage. This would have given a much more complicated wiring and air conditioning problem, and have added about 150 lb. to the weight.

The internally stowed guided missiles were lowered on swinging arms. Light doors were arranged to open by means of a linkage while the missiles were being extended and closed when they were fully extended. This would have given considerably less interference to the airflow during firing than if the doors remained open.

For the larger versions, the missiles were arranged in two rows with two abreast in front and four abreast behind. This would have given greater freedom for sequencing the firing ripple, than the arrangement of two rows of three missiles as is required to compress the fuselage for the smaller versions.

The 2" dia. rockets would have been housed in an extensible elevator similar to that which was (at the time) being designed for the CF-100 Mk4, if possible.

RADOME AND COCKPIT.

The MX 1179 or any other equivalent system required the introduction of accurate air data in several computations. It had been concluded by Hughes that the only place to sense these data to the required degree of accuracy on an aircraft of this type was at the end of a nose mounted boom. Experience on the CF-100 with the air data problem led the design team to concur with this viewpoint. They also concluded that, for supersonic speeds, the radome would have to be moderately pointed. Accordingly Hughes laid down a contour that was a compromise between the aerodynamic and radiation requirements and was suitable for the mounting of a nose boom. A relatively long term development program was laid down for the particular contours decided upon for the Convair F-102 and other aircraft. These contours were used in all the studies. Having, of necessity, put the radome in front to give it an adequate field of view, the pilot could be most readily located in a conventional cockpit behind the radome with a canopy which gave him a view over the radome. In order to simplify the problem of glazing this canopy, the optical surfaces were constructed of two flats to form a wedge. This made it possible to use flat glass panels which were best suited to resisting the higher temperatures and pressures encountered on these designs.

CAMBER.

Camber was proposed as a means of reducing the elevator drag at high altitudes. A saving of 1,000 lb. of fuel to complete the specified missions and an increase in the ceiling of about 5,000 ft. were in order of the gains hoped for.

It was found that with no camber, the elevator angles to trim were always up. If the wing was cambered, a couple was produced which caused the elevator angle to trim to be zero under any selected condition depending upon the amount of camber.

The difficulty with camber was in the predicting and controlling the conditions occurring in the transonic region at low altitudes. Here relatively high down elevator angles are associated with a high dynamic pressure to give excessively high down hinge moments required to trim.

It was seen that a limitation of the airplane to Mach numbers below about .95 at low altitudes was exceedingly likely. The higher the peak hinge moment, the higher the altitude at which the limitation is removed.

The incorporation of camber into the design requires a nice compromise between the gains at high altitude and the limitations at low altitude, based on an accurate knowledge of the aerodynamic properties of camber in the transonic region. Since data on this point were virtually non-existent, wind tunnel tests were scheduled in the 4 ft. x 5 ft. transonic throat of the wing tunnel at the Cornell Aeronautical Laboratories Inc. It was felt that the size and freedom from shock reflection problems made this throat the best facility for this work.

Continued testing and investigation up till August 1953, showed that a negative camber of 0.75% was calculated to give the best results, in spite of the fact that NACA seemed to prefer a positive camber.

FUEL STOWAGE.

The internal fuel capacity of the various aircraft considered was determined by considerations of practical installation and balance about the desired centre of gravity of the airplane. Integral wing tanks were resorted to on all aircraft in the family, in order to make full use of the limited amount of space in the very thin wings. Due to the fact that the wing fuel is situated aft of the C of G it was necessary to balance this by fuel contained in the centre fuselage forward of the engines. No fuel was to be carried in the leading edges of the wing because this space was reserved for hot air anti-icing. When looking at the general arrangements of the aircraft, the question might be asked why fuel was not carried in the outer wings or the fin. The answer is that more fuel would have to be carried within the forward fuselage which in turn would have to be increased in length which would result in the C of G being too far forward in the fuel empty condition, and moving the wings forward to try to compensate would alter the ground angle which would necessitate further lengthening of the undercarriage, which was impossible.

Here then follows a table of internal fuel capacities of the aircraft in the family, all with a 3% thick wing.

C-105/1000........12.900 lb.
C-105/1100........14,200 lb.
C-105/1200........16,500 lb.
C-105/1300........17,600 lb.
C-105/1400........20,400 lb.

It appeared possible to increase the t/c ratio of the smaller wings with the same size fuselage without exceeding the permissible C of G range and the internal fuel capacities would then have been;

for C-105/1000 with t/c of 4%.......16,600 lb.
for C-105/1100 with t/c of 3.5%.....15,900 lb.

EXTERNAL FUEL.

External fuel capacity was required to permit a minimum overload range of 1,500 naut. mi. with combat armament installed, in accordance with AIR 7-3 para 3.07.01. The tanks were to be jettison-able in flight and to be able to be installed and removed rapidly whilst on the ground. For reasons of the C of G limits, there were only two points at which these tanks could be fitted, namely either suspended from the wing outboard of the undercarriage or suspended from the fuselage belly. Due to aero-elastic problems, height above the ground and structural problems due to the weight involved, the former was ruled out which left the only place for such a tank was to suspend it from the centre beam of the rear fuselage. The C-105/1200 is shown fitted with such a tank being of 500 Imp. Gals. capacity or 3,750 lb. in weight.

LANDING GEAR INSTALLATION.

As will be seen from the general arrangement drawings of the various aircraft, the landing gear consists of an orthodox tricycle arrangement. The nose gear retracts forward into a space below the cockpit and is of simple design for all the aircraft in the family. The solution of the main gear retraction and stowage problem required a great deal of ingenuity but was solved satisfactorily for the larger aircraft but for the smaller ones, it was far more difficult. Such an undercarriage could just be installed in the C-105/1000 wing and then only by means of an excessively complicated mechanism and relatively large bulges on the airfoil of the wing next to the fuselage which would give greater drag.

MAIN UNDERCARRIAGE FOR C-105/1200.

This undercarriage was designed so as to obviate the undesirable slamming down of the front wheel of the bogie when the rear wheel contacts the ground in the normal tail-down landing attitude. The bogie chassis is linked at the front wheel axle to the main leg by means of a member which is free to shorten but cannot extend.

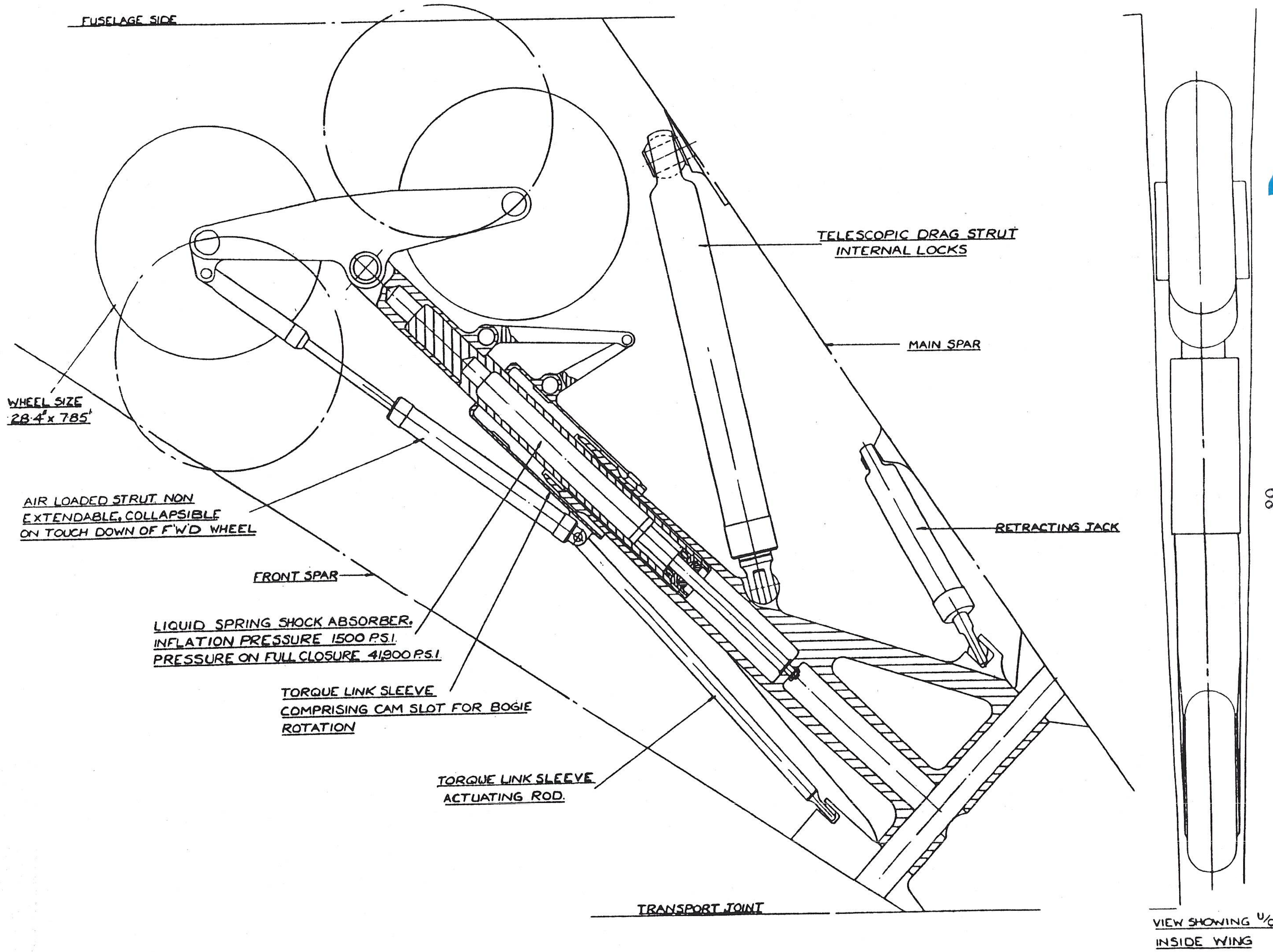
This is done by means of an air loaded telescopic strut which is fully extended for landing. On touch down of the rear wheels, the bogie chassis rotates about the front axle attachment and closes the main shock absorber at half velocity and prevents the front wheel acquiring an additional downward velocity. As soon as both wheels are in contact with the ground, this strut telescopes along with the main shock absorber which is a liquid spring housed inside the leg. Due to the inclined pivot axle of the gear where it attaches to the wing, it was necessary to twist the bogie chassis about the main leg during retraction and also it had to be tilted about its attachment axle to the main leg. These motions were obtained mechanically as the undercarriage was retracted by and actuating rod attached at one end to a point on the wing structure offset from the main pivot axle and at its other end to a torque sleeve situated around the lower portion of the main leg. This torque sleeve was provided with a profiled cam slot which engaged with a roller fixed to the main leg. The torque sleeve was also provided with splines which engaged with splines on the main leg when the sleeve was in its "up" position, (gear extended), and which were disengaged when the torque sleeve was slid down (retracted). To the torque sleeve were attached the conventional torque scissor links which also attach to the bogie chassis. When the undercarriage starts being retracted, the sleeve starts moving down the leg and disengages the splines, further retraction forces the sleeve to rotate around the leg by virtue of the profiled cam slot and roller and this rotation is communicated to the bogie chassis via the scissor links. Tilting of the bogie chassis is automatically done during the downward movement of the torque sleeve by virtue of the telescopic air loaded strut which also attaches to this sleeve and which pushes the front of the bogie chassis down relative to its attachment to the main leg. The side stay of the undercarriage is telescopic and incorporates internal locks. The retraction jack operates directly onto the main pivot, and it can be seen that the main gear can just be stowed within the airfoil contour of the wing and required no bulges.

MAIN UNDERCARRIAGE FOR THE AIRCRAFT C-105/1000.

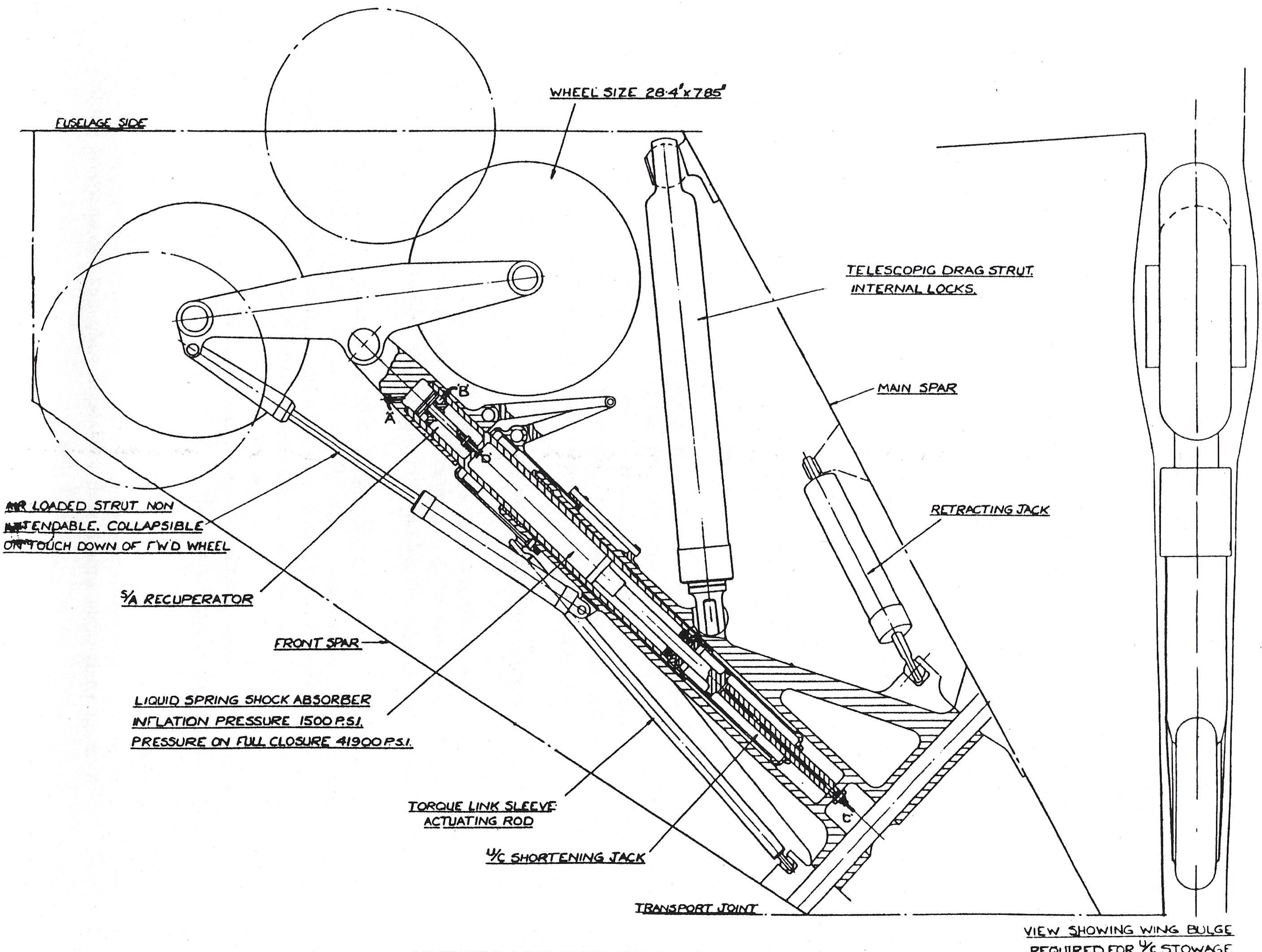
This undercarriage must be shortened 12 inches during retraction in addition to the motions described under the heading Main Undercarriage for the Aircraft C-105/1200. The shortening was to be accomplished hydraulically and presented great difficulties of seal servicing which could only be done by dismantling of the leg and also a high pressure in the order of 41,900 psi had to be maintained at the valve "D" without leakage. The gear when retracted could not be stowed within the airfoil and bulges of about 2 inches would have had to have been provided. This also applies to the C-105/1100 aircraft except that a mechanical means of shortening was apparent with the distance to be shortened about half that of the C-105/1000.

COMPARISON OF AIRCRAFT.

Having previously established that the high wing delta layout was the preferable configuration, a comparison in detail of a family of aircraft of varying sizes was



UNDERCARRAIGE INSTALLATION - 1200 sq.ft. WING.



UNDERCARRAIGE INSTALLATION - 1000 sq.ft. WING.

conducted. Size was varied by using wings of different areas, but keeping the aspect ratio and sweep back constant. Smaller wings required shorter fuselages for reasons of weight and balance. The fin and rudder area was largely determined by the one engine-inoperative condition and, for similar thrust engines, could be kept the same for all aircraft considered if the family. The possible effect of fitting engines made by three different manufacturers on the size of the fuselage was investigated. The size of the fuselage and wing would of course influence the space available for internal fuel and also the installation of armament, avionics and fixed equipment. The length of the undercarriage was determined by the ground angles for landing and takeoff, which are the same for all aircraft considered in the family, and the effect on the stowage problem of the retracted undercarriage in the wing must therefore be investigated. The size of the aircraft which fall in this family will therefore effect;

Weights
Performance
Installation features.

Each of these criteria are analyzed and tabulated in subsequent paragraphs of this chapter. The aircraft considered in this family were:

Model	Code
High wing delta with 1000 sq.ft. wing area	C-105/1000
High wing delta with 1100 sq.ft. wing area	C-105/1100
High wing delta with 1200 sq.ft. wing area	C-105/1200
High wing delta with 1300 sq.ft. wing area	C-105/1300
High wing delta with 1400 sq.ft. wing area	C-105/1400

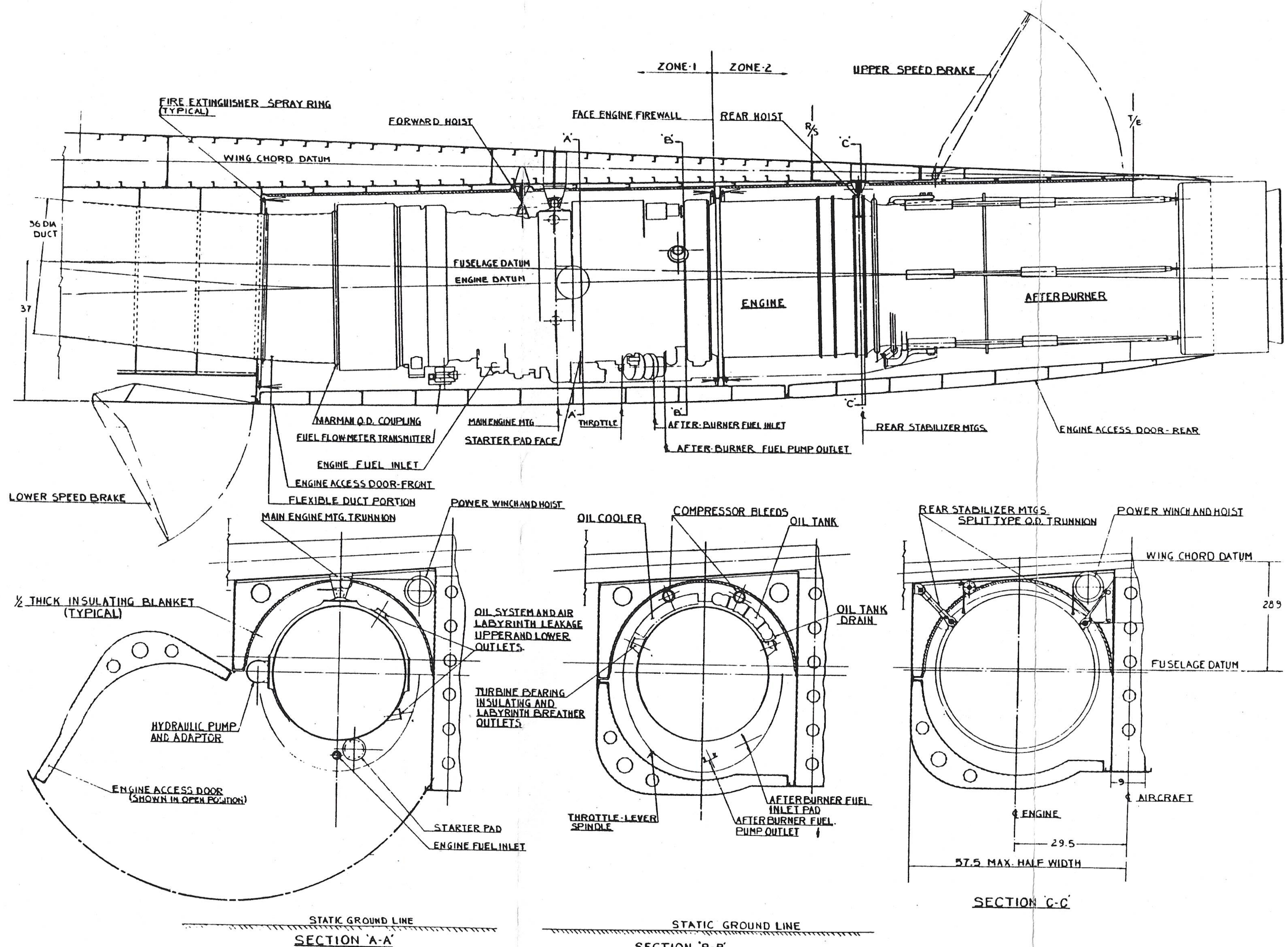
The power plants considered were:

1. Two Rolls-Royce turbo-jet engines RB 106 plus afterburners.
2. Two Bristol turbo-jet engines - B.OL.4 plus afterburners.
3. Two Curtiss-Wright turbo-jet engines - J67 plus afterburners.

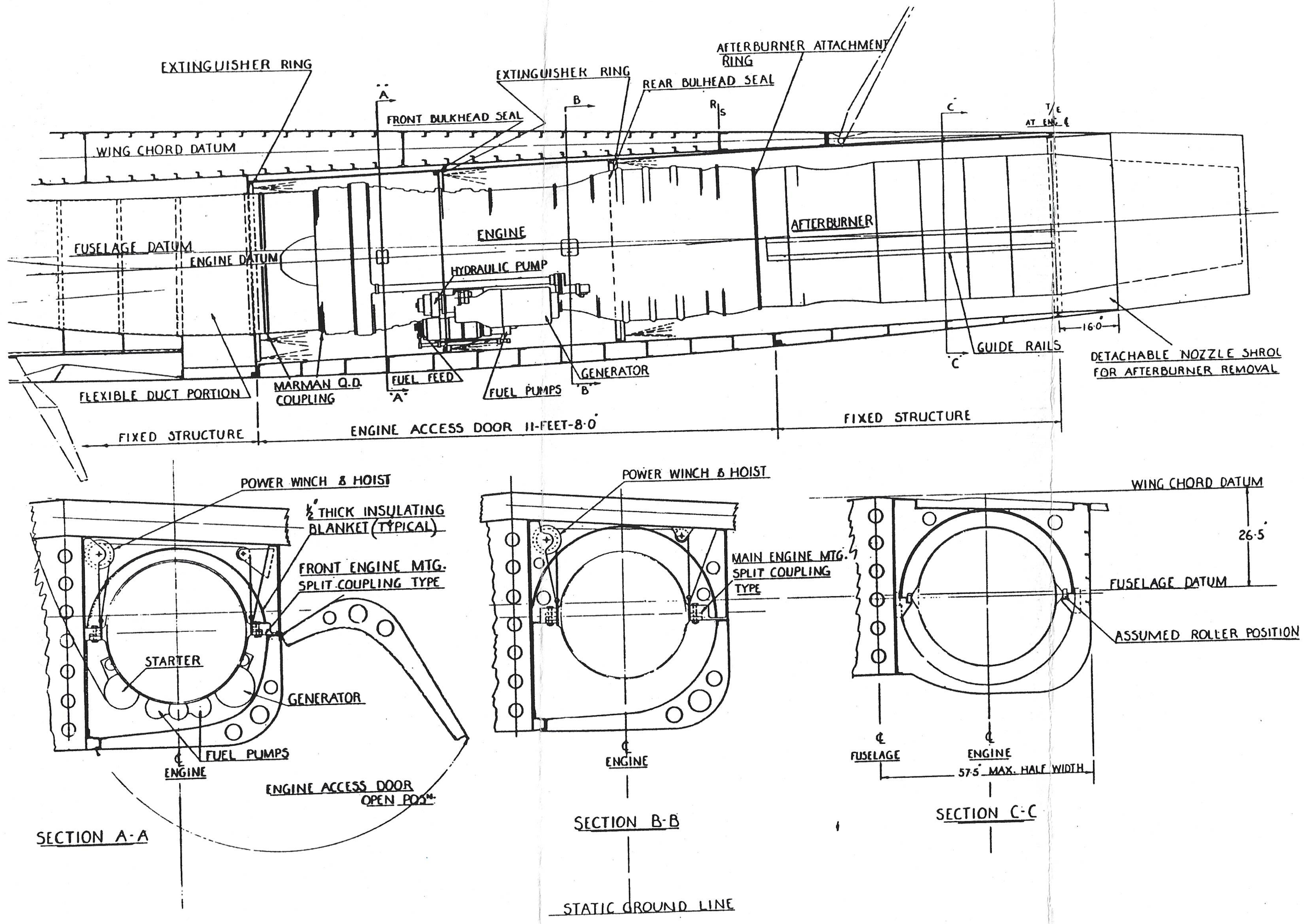
In accordance with AIR 7-3 paragraph 4.01.02 one aircraft in this family is shown converted to accommodate a crew of two, the 1200 sq.ft. version, (Code no. C-105/1200/T). The effects of such a version are discussed in subsequent paragraphs. Briefly it can be stated that any of the aircraft in the family could be converted by means of fitting a longer front fuselage and the fitting of ballast as required; however, the relative effect on gross weight and performance is obviously more pronounced on the smaller aircraft.

C-105/900.

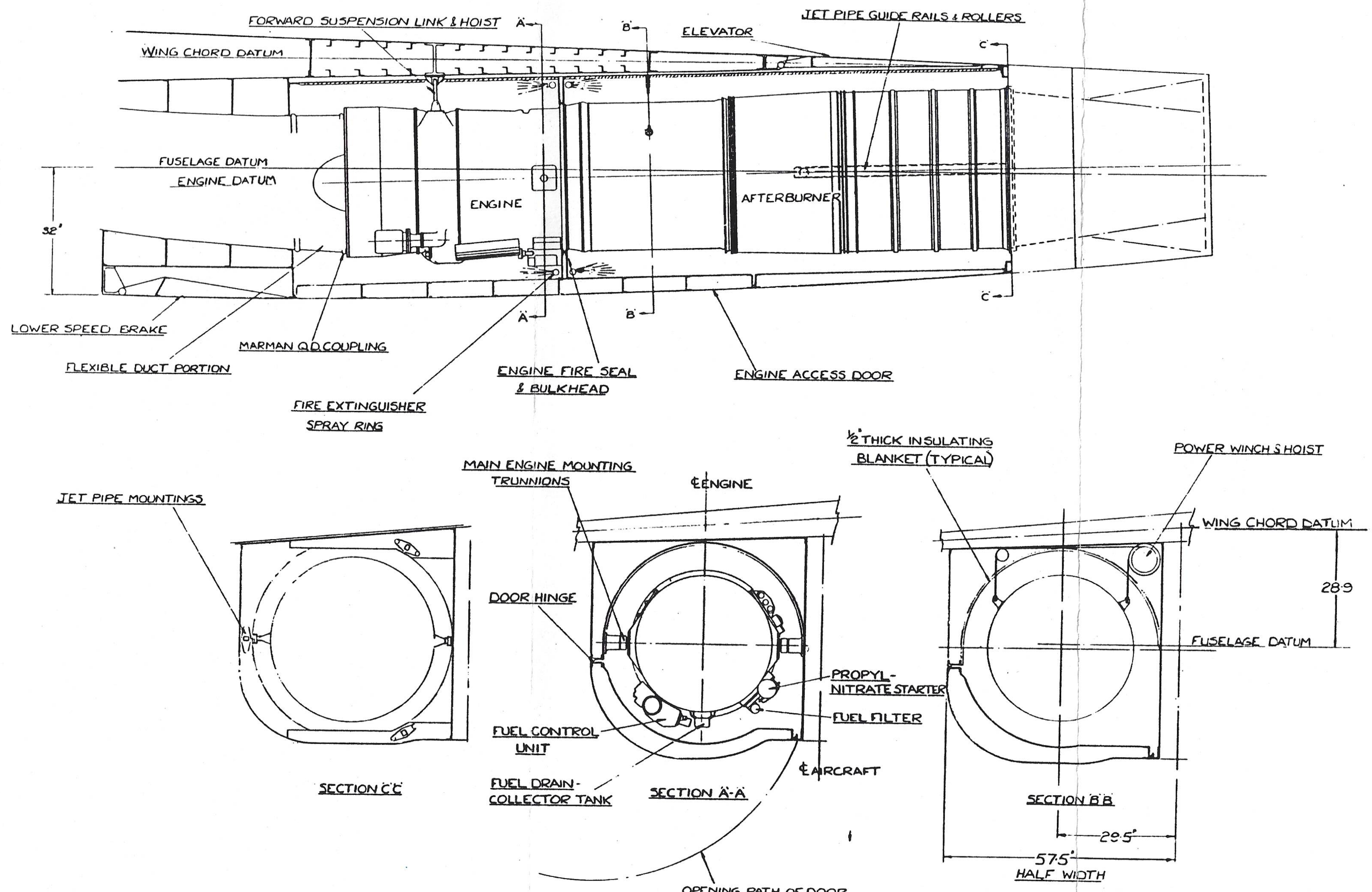
A design study of an aircraft with a 900 sq.ft. wing area was analyzed, but this



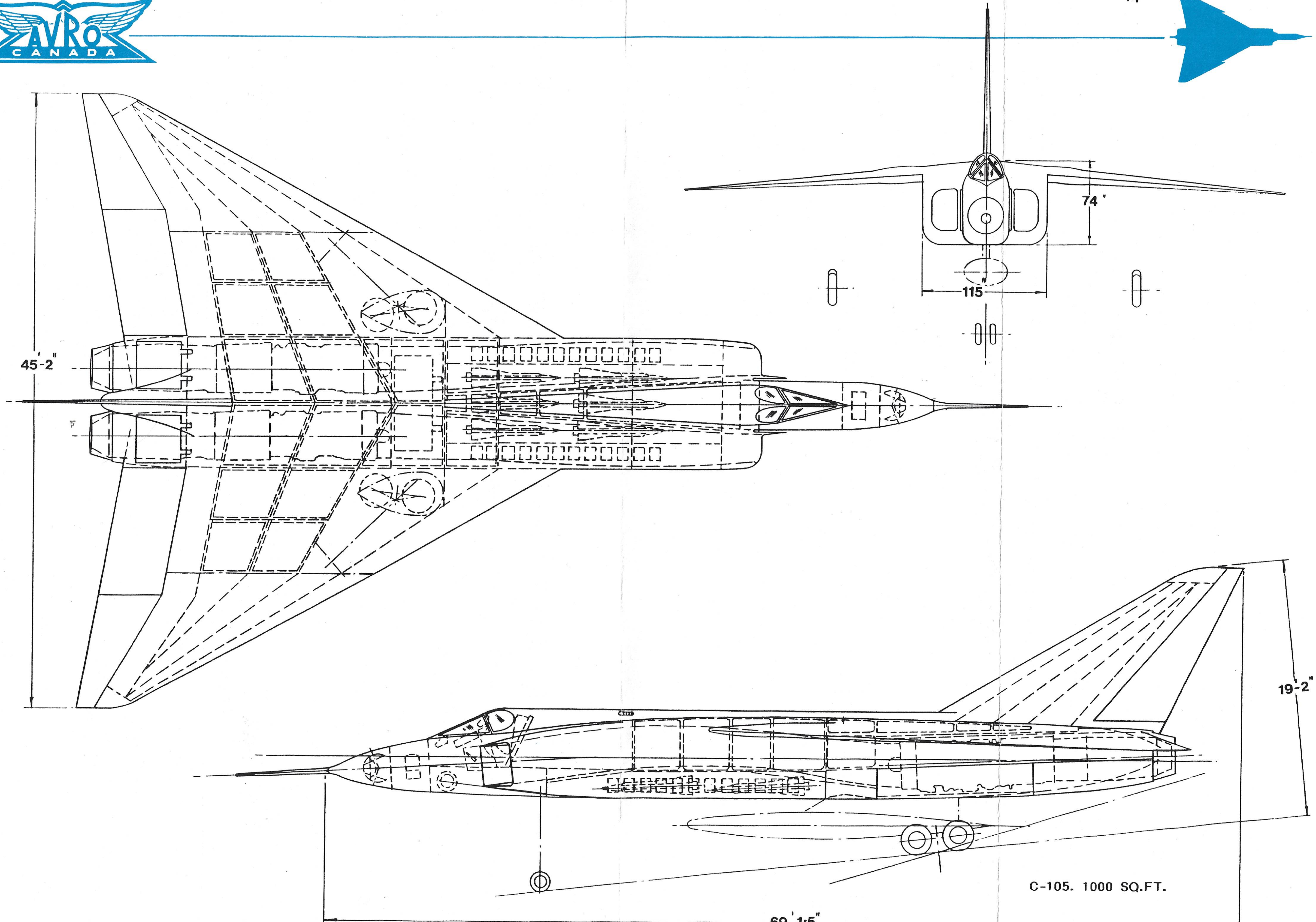
CURTISS-WRIGHT J-67 INSTALLATION



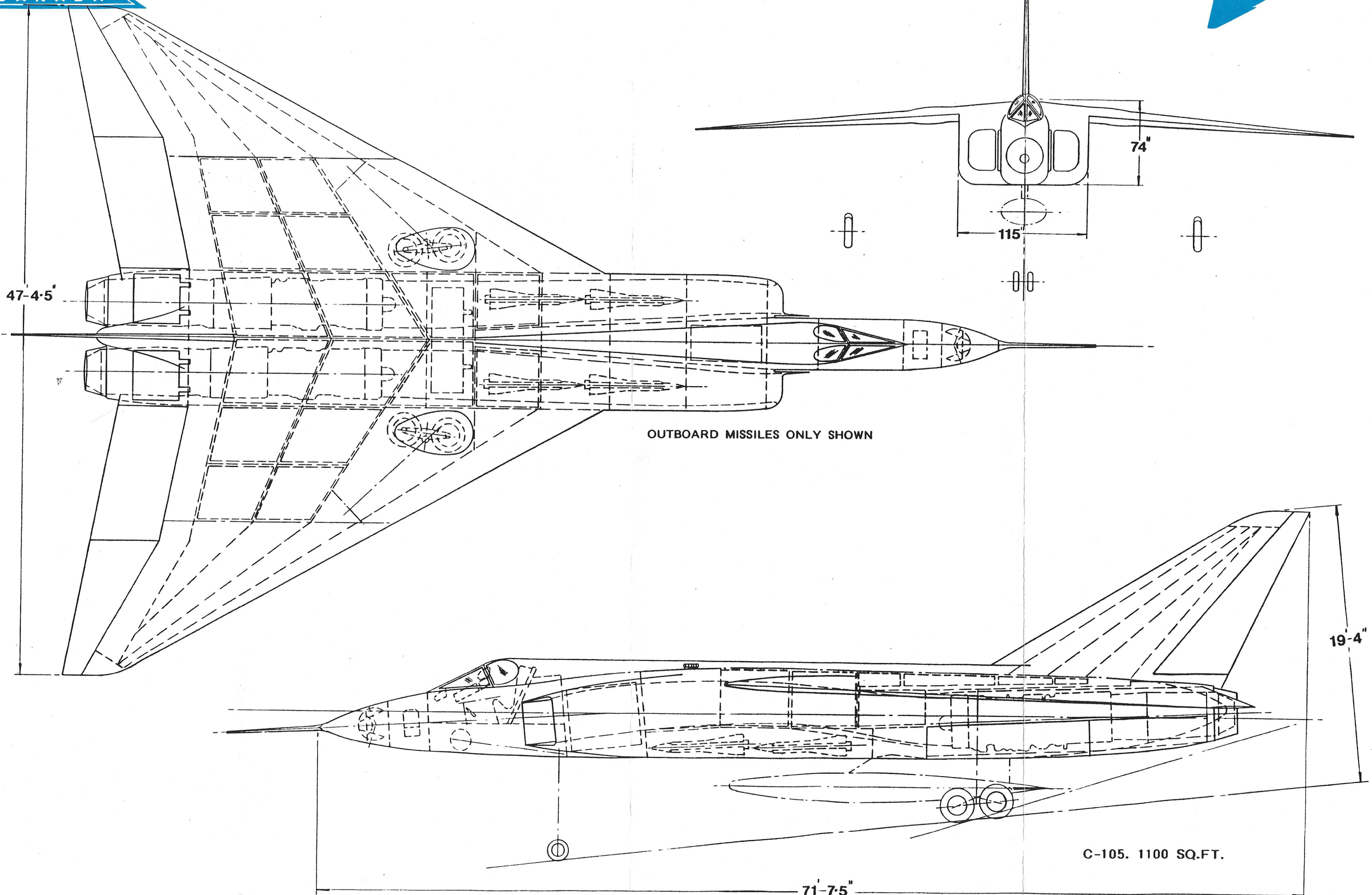
BRISTOL OLYMPUS B-OL4 INSTALLATION.



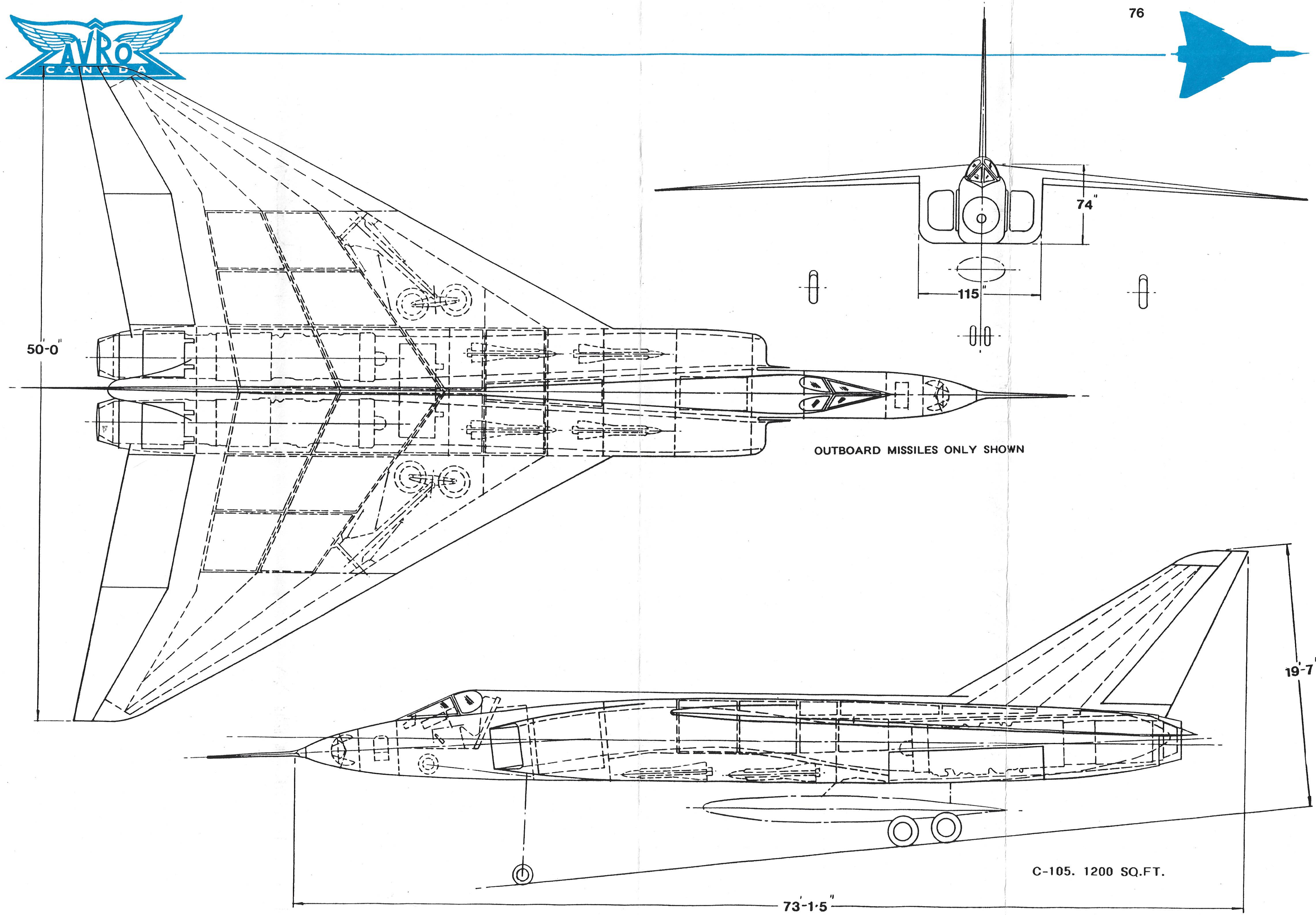
ROLLS-ROYCE RB-106 INSTALLATION.



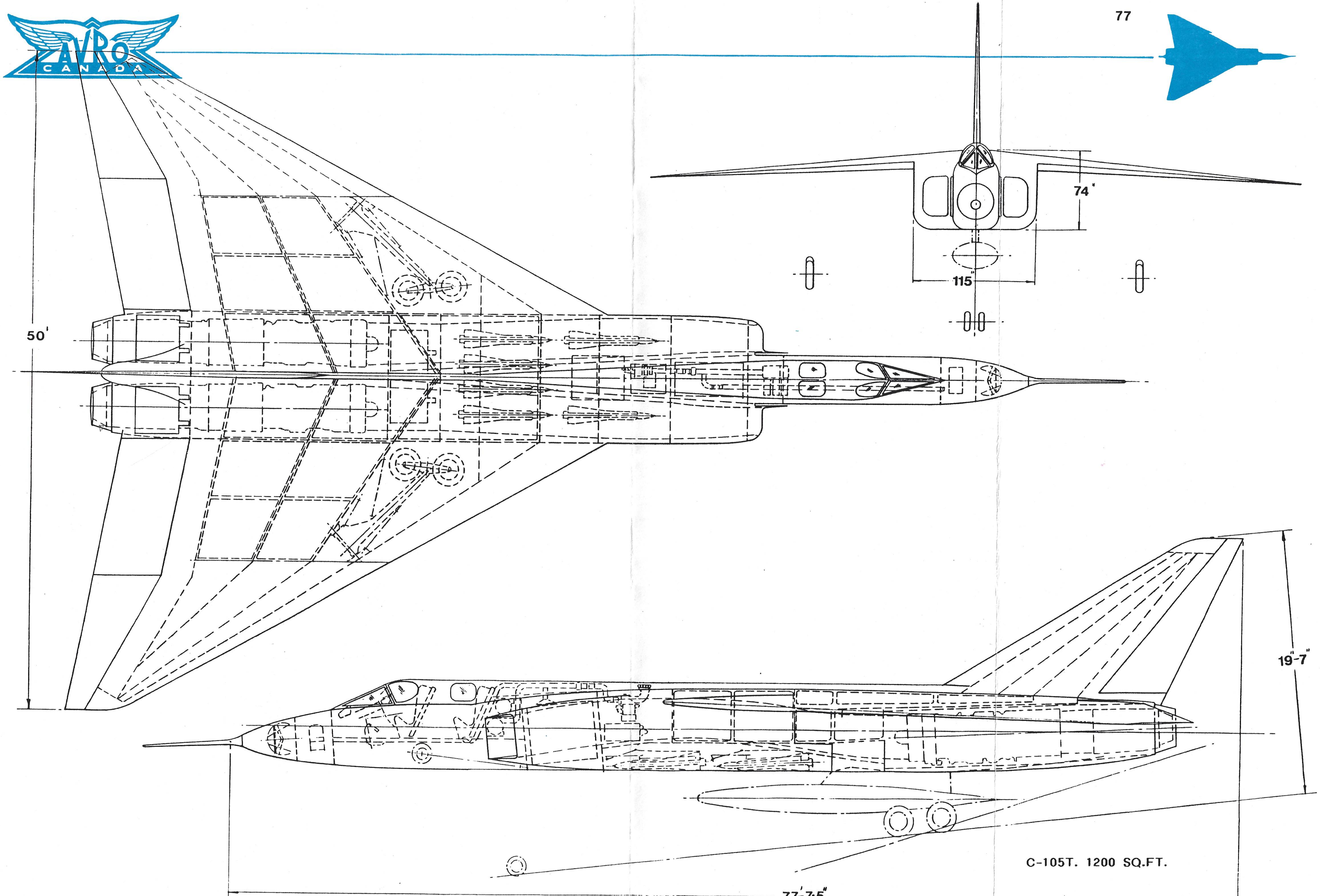
C-105. 1000 SQ.FT.



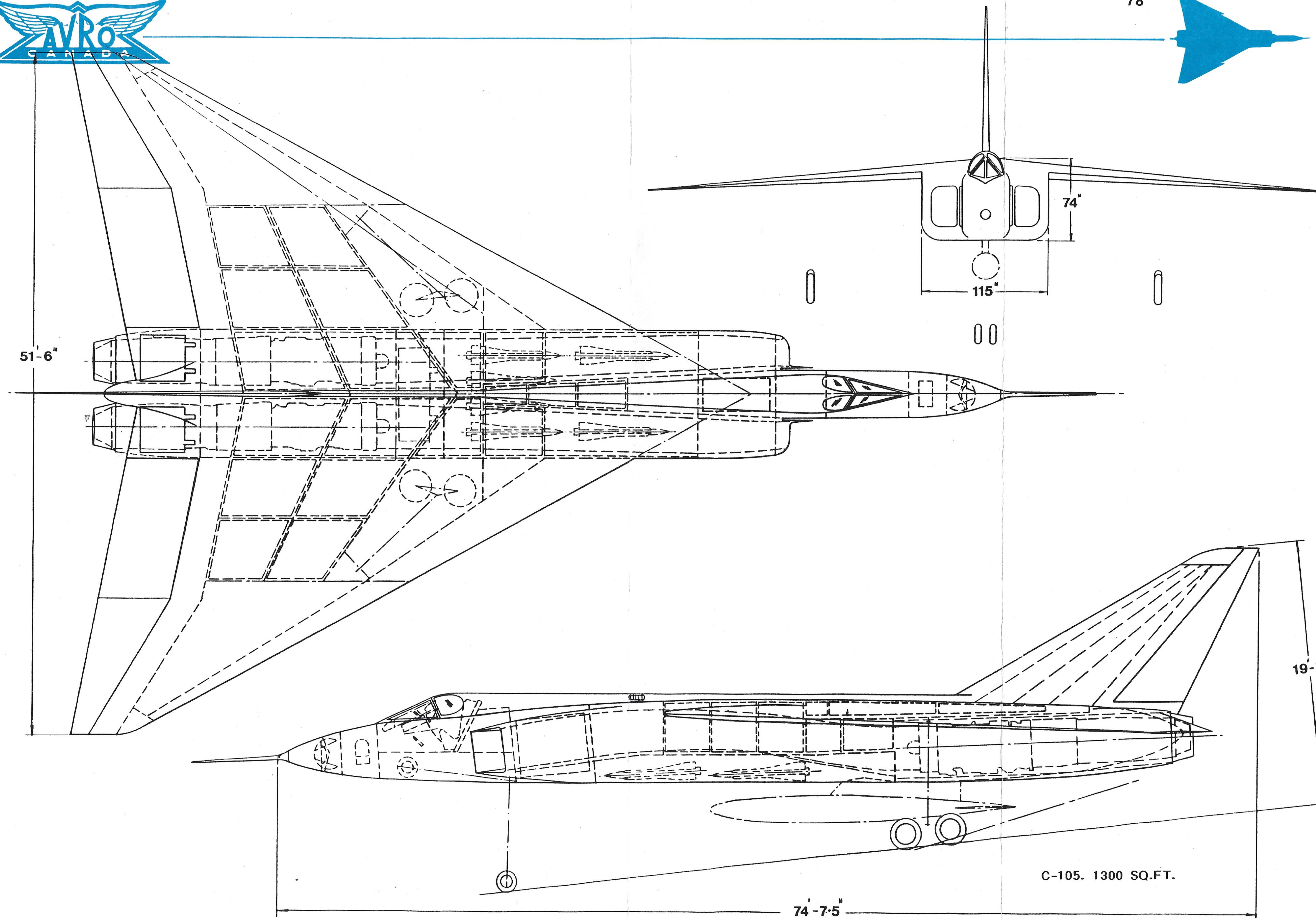
47'-4·5"
74"
115"
OUTBOARD MISSILES ONLY SHOWN
19'-4"
C-105. 1100 SQ.FT.
71'-7·5"



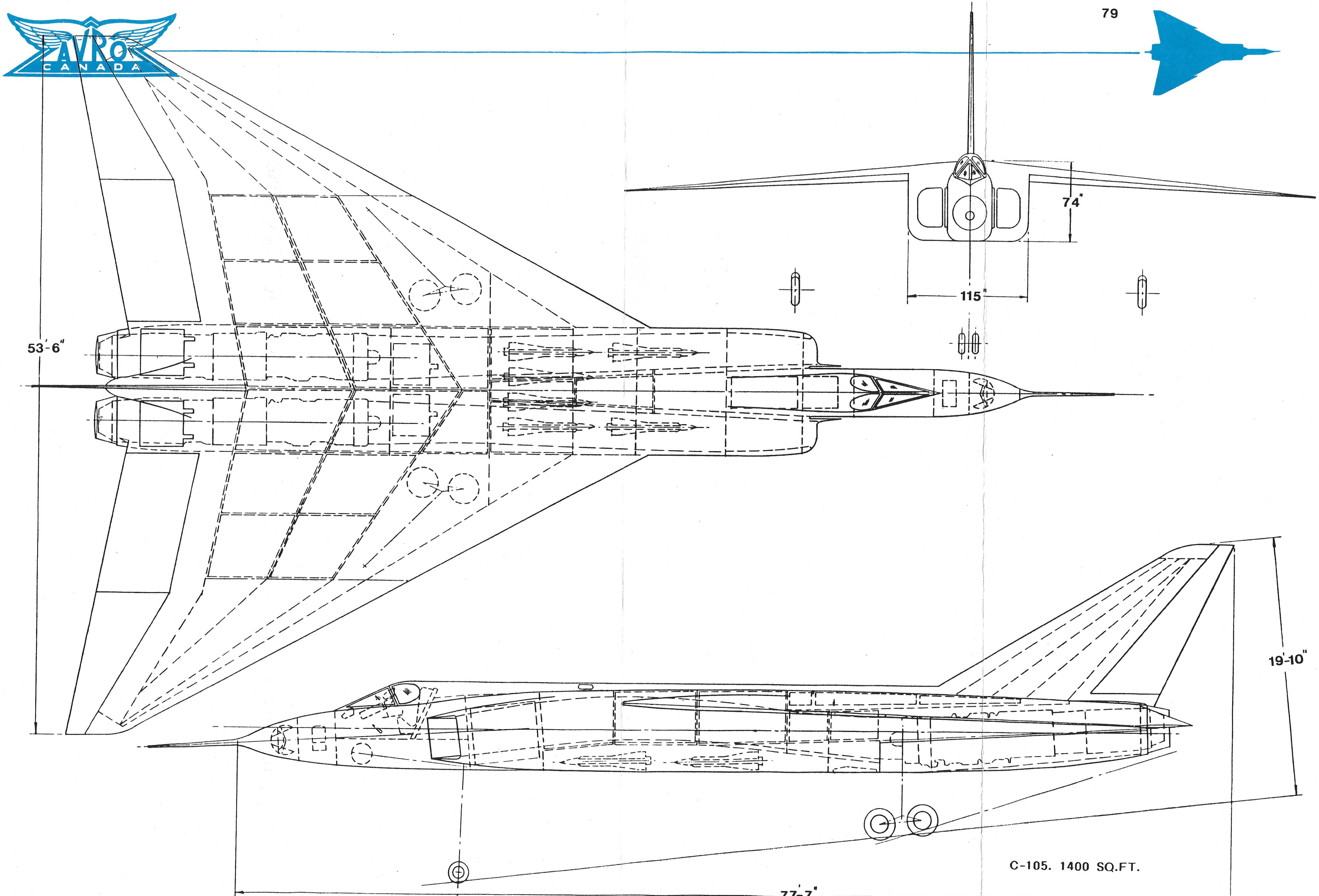
C-105. 1200 SQ.FT.



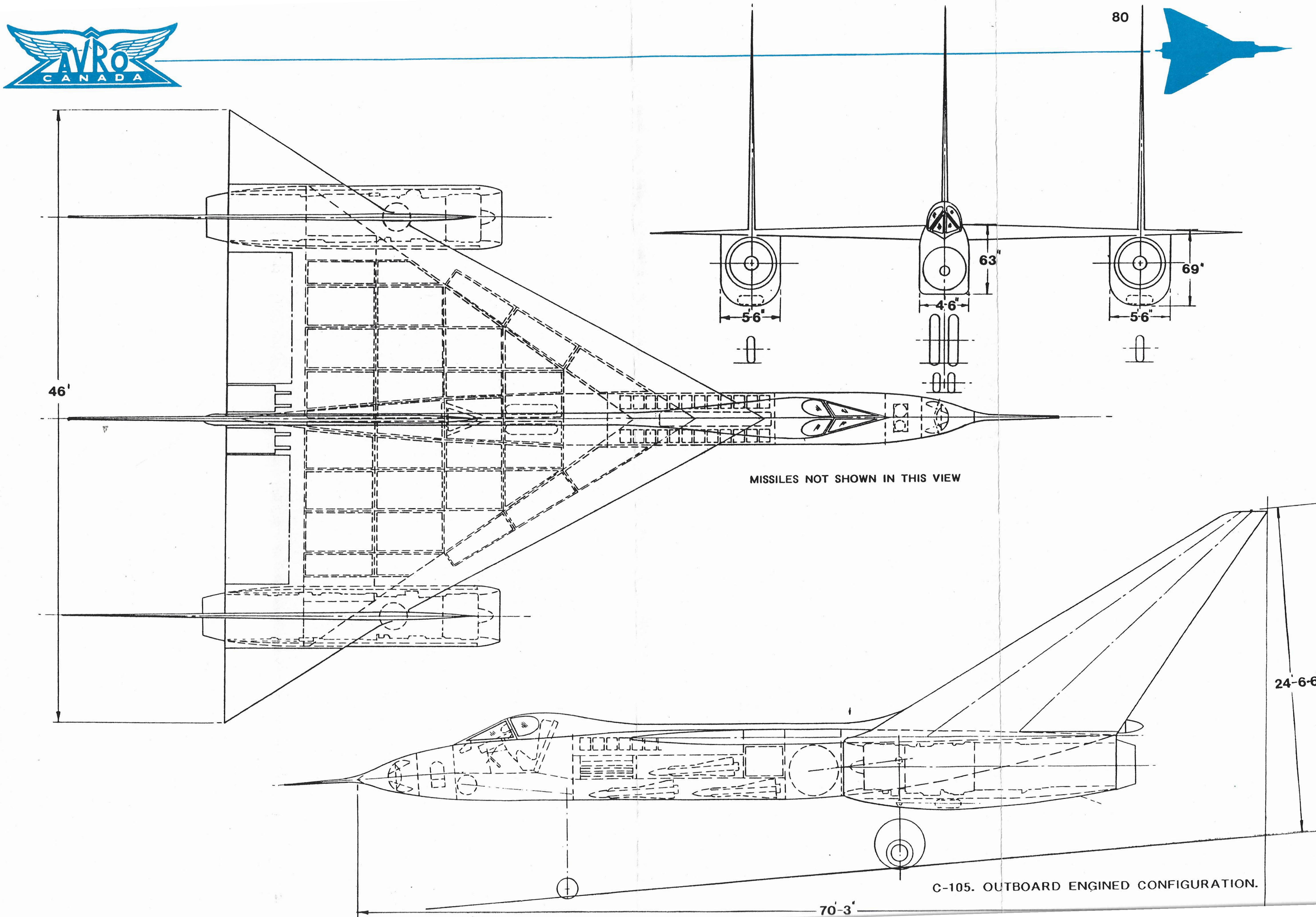
C-105T. 1200 SQ.FT.



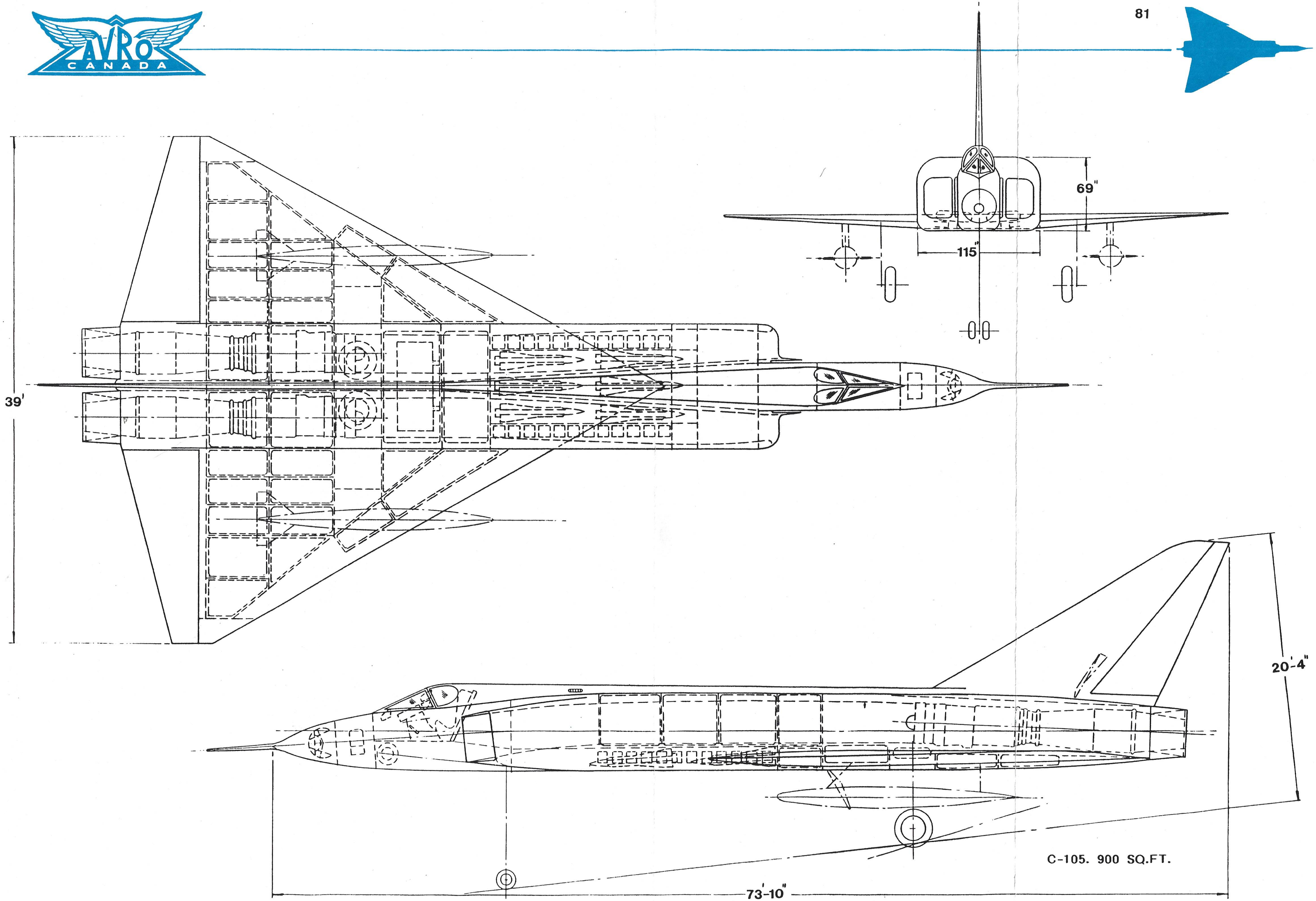
C-105. 1300 SQ.FT.



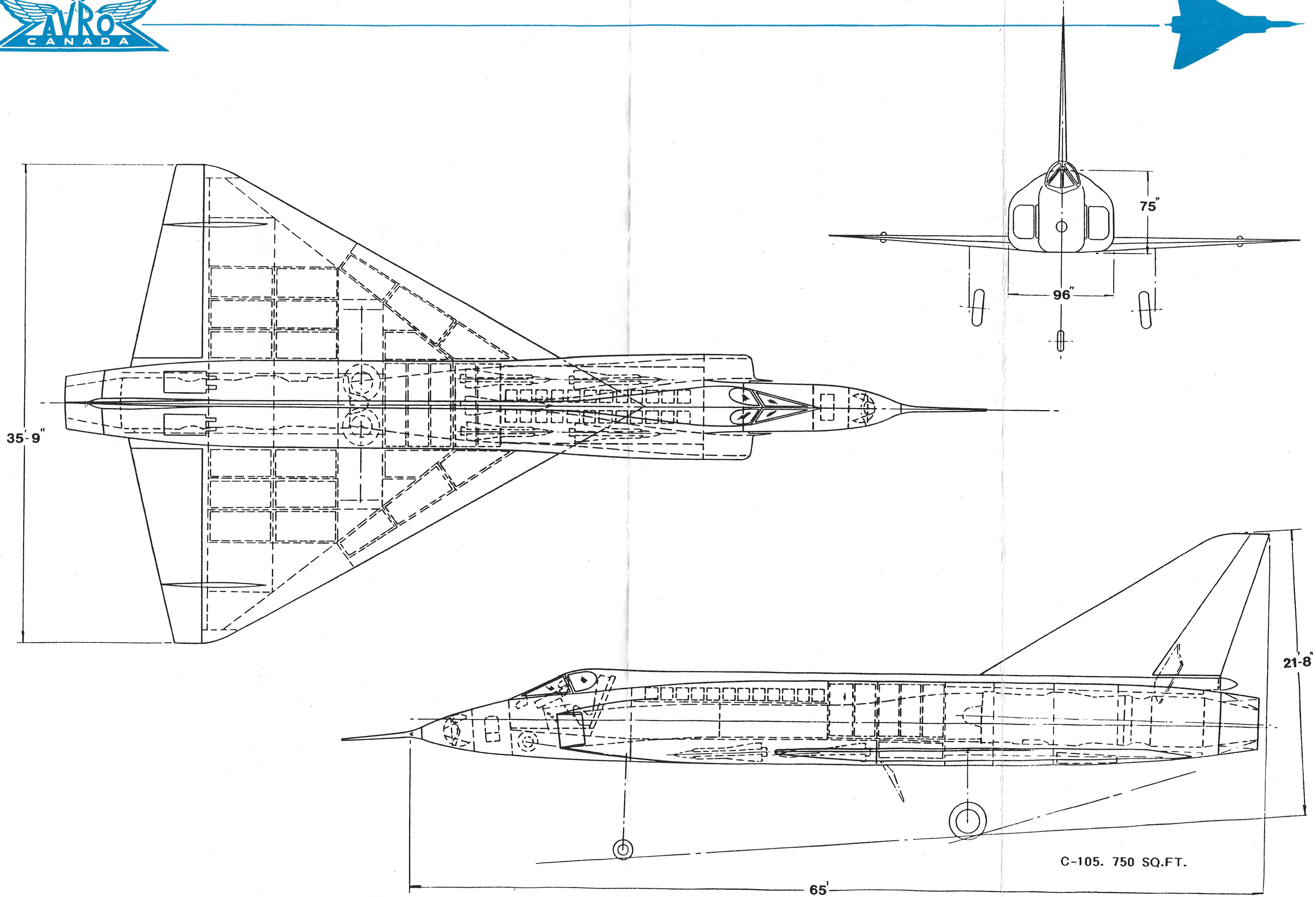
C-105. 1400 SQ.FT.



C-105. OUTBOARD ENGINED CONFIGURATION.



C-105. 900 SQ.FT.



C-105. 750 SQ.FT.

wing was too small for housing the undercarriage in a high wing configuration and therefore it was necessary to adopt the low-wing layout, with the undercarriage retracting sideways into the fuselage.

Also shown, a design study of a delta aircraft of entirely different configuration is discussed together with reasons why such a layout was unsatisfactory. The main result of this study showed that the gross weight of an aircraft with the specified military load and engines could only be varied within very narrow limits, even with fairly large changes in the aircraft size. Increased aircraft size results in improved performance with increased margins for contingencies. The installations were not so tight and hence could be engineered in less time and would result in a more serviceable aircraft. On this score, there is reason to doubt that there is nearly as great a saving on cost by going to the smaller versions as figures based on weight alone would indicate. Hence it was evident that it was appropriate to strike a compromise. With a wing area of 1,100 sq.ft. or less, the undercarriage becomes more difficult, and the wing must be thickened to accomodate extra fuel. The tighter installations and the extra aerodynamic risks involved in the thicker wings make these versions undesirable, when one considers the very small weight saving involved balanced against the penalties. On the other hand the larger versions, that is, 1,300 and 1,400 sq.ft., appear to have more than the necessary amount of room required to make simple installation of such things as the landing gear and the various items of equipment. It was accordingly felt that the 1,200 sq.ft. version represented the most satisfactory compromise between minimum weight and the maximum performance and flexibility.

It has been shown that the smaller the wing area, the lighter the aircraft. Although it appeared that a point of diminishing returns had been reached with the 1,000 sq.ft. version, it cannot be said that this gave the absolute minimum weight theoretically possible and regardless of all penalties involved. Accordingly, a study was made of a still smaller aircraft with only 900 sq.ft. of wing area. A general arrangement of this aircraft is shown.

As previously stated, it was found impossible to stow the main undercarriage in a high wing with a wing area less than 1,000 sq.ft. It was therefore necessary to adopt the low wing configuration with the undercarriage retracting sideways into the fuselage belly. The main problem centred around the fitting of external fuel tanks such as are required for ferry missions. The difficulty was due to the virtual impossibility of dealing with the aero-elastic problem on such a thin, highly swept wing. Even with external wing tanks fitted, of 150 gallons capacity each, as shown, it be would necessary to increase the t/c ratio of the wing to 4% and to fill the complete wing from centre line to the tips with fuel in order to just meet the ferry range requirement without any margin for contingencies. It will be seen from the drawing that the fuselage length of this aircraft requires to be longer than the length of the 1,200 sq.ft. version in order to fit fuselage tanks so as to balance the fuel in the wing. The extra weight incurred in this manner can only be taken off again by the deletion of all transport joints, that is, making the fuselage and wing as one component each.

It has also been shown that unless the wing main spar box is carried through the fuselage, the weight of a low wing would be greater than for a high wing. In view of this and the fact that this main spar box also contained fuel where it would pass underneath the engine, the engine accessability in the lower region is virtually non-existent. Since large access doors in the stressed monocoque fuselage are not permissible for a minimum aircraft weight, the engines would have to be removed through the rear end for servicing, with all its attendant disadvantages.

It would have also been necessary to crowd the armament and avionics in a similar manner to that of the 1,000 sq.ft. high wing version with its attendant disadvantages although it was found possible to install the rockets in front of the missiles, due to the longer fuselage required to balance the airplane.

It may be concluded therefore that the penalties involved in carrying weight reduction to this extreme was out of all proportion to any gains that could have been achieved, and so it was felt that an aircraft of this configuration could not really be considered in anything but a study of this nature, where it was desired to find the theoretical minimum weight.

C-105 OUTBOARD ENGINED CONFIGURATION.

During the meetings with the RCAF, a configuration was discussed which attempted to get around some of the snags inherent in the 900 sq.ft. low wing configuration. The argument was that by positioning the engines outboard on the wings, weight could be saved because of the bending moment relief and also solve the undercarriage stowage problem by retracting the single main gear into the fuselage with outriggers in the nacelles; at the same time engine accessability would be good. A drawing of this aircraft is shown.

The main disadvantages of this design are compared with the orthodox configuration are as follows:

1. A tremendously large fin area is required to cater to the one engine-inoperative condition. This adds weight and drag.

2. There is some possibility of choking of the airflow between the three fins at high speeds.

3. The interference drag is bound to be higher in this condition.

4. Installing the engines in separate bodies require 58% more wetted area and 23% more frontal area.

5. The adequacy of lateral control is very much open to question.

6. The small fuselage cross section will jeopardize the installation of armament, avionics and equipment.

7. It was found impossible to balance this configuration without excessive lengthening of the front fuselage.

8. Even if none of the above disadvantages were present aero-elastic conditions ruled out the feasibility of attaching a heavy pod to an extremely thin wing in the speed bracket considered.

C-105/750. SINGLE ENGINED VERSION WITH A BRISTOL BE.23 ENGINE.

After the issue of the C-104/1 brochure, Bristols had started the design of an engine with a breathing capacity 50% in excess of the B.OL.4. It was accordingly thought that, with this new engine, the BE.23, a single engine aircraft could be designed that would not be as marginal in some respects as the C-104/1. A proposed layout for this airplane is shown. The configuration is in general very similar to the C-104/1. Due to the extra breathing capacity of the engine, the ducts had to be considerably enlarged. Because the engine was somewhat heavier, and required a longer and heavier fuselage to balance it, the wing area was increased from 600 to 750 sq.ft. It is evident that the good features of the engine and electronic installations of the twin engined version could not be retained for a single engine low wing layout. Although there was no doubt that going to a single engine layout was the only way to reduce the gross weight of the aircraft below 45,000 lb., there were several very serious drawbacks, which may be enumerated as follows.

1. PERFORMANCE.

As can be understood, the performance was very much inferior to that of the twin engined versions. There was no margin for fuel capacity available for contingencies for the short range missions, even with a 4 1/2% t/c wing. Hence the chances of getting good results with camber as for the 3% wings on the twin engine version were very much reduced.

2. EXTERNAL TANKS.

As previously discussed, the fitment of external tanks on a low wing aircraft with such a thin highly swept wing may well have been impossible for aeroelastic reasons. Accordingly this airplane could not be counted on for long range missions.

3. INSTALLATIONS.

The installations of the engine and electronics equipment might be classed as reasonably satisfactory but servicing would have been much more difficult than with the twin engined version.

4. EXTERNAL MISSILES.

The penalties due to fitting external missiles would be more severe than for large aircraft inasmuch as the armament is a larger portion of the total drag. There follows a set of tables of pertinent facts on each of the aircraft discussed.

1. Aircraft type..................C-105/1000.

Fuel for combat mission.................12,900 lb.
Operational weight empty..............34,340 lb.
Gross weight...............................47,200 lb.
T/C ratio..4%
Supersonic radius..........................200 naut.mi.
Overload range..............................1,180 naut.mi.
Ceiling...64,300 ft.
Installation.
a. Undercarriage............................Very complicated.
b. Electronics.................................Dispersed - tailored.
c. Armament and equipment...........Poor.

2. Aircraft type.................C-105/1100.

Fuel for combat mission................12,800 lb.
Operational weight empty.............34,900 lb.
Gross weight...............................47,700 lb.
T/C ratio.......................................3.5%
Supersonic radius.........................195 naut.mi.
Overload range.............................1,170 naut.mi.
Ceiling..64,900 ft.
Installation.
a. Undercarriage............................Complicated.
b. Electronics...............................Crated.
c. Armament and equipment..........Crowded.

3. Aircraft type..................C-105/1200.

Fuel for combat mission..................12,900 lb.
Operational weight empty................35,475 lb.
Gross weight.................................48,375 lb.
T/C ratio...3%
Supersonic radius............................200 naut.mi.
Overload range...............................1,280 naut.mi.
Ceiling..65,100 ft.
Installation.
a. Undercarriage.............................Good.
b. Electronics.................................Crated.
c. Armament and equipment............Good.

4. Aircraft type....................C-105/1300.
Fuel for combat mission....................13,000 lb.
Operational weight empty................36,075 lb.
Gross weight....................................40,075 lb.
T/C ratio..3%
Supersonic radius.............................200 naut.mi.
Overload range.................................1,350 naut.mi.
Ceiling...65,300 ft.
Installation.
a. Undercarriage...............................Good.
b. Electronics.....................................Crated.
c. Armament and equipment.............Good.

5. Aircraft type.....................C-105/1400.
Fuel for combat mission.....................13,100 lb.
Operational weight empty.................36,685 lb.
Gross weight....................................49,785 lb.
T/C ratio..3%
Supersonic radius.............................200 naut.mi.
Overload range.................................1,500 naut.mi.
Ceiling...66,000 ft.
Installation.
a. Undercarriage...............................Good.
b. Electronics.....................................Good.

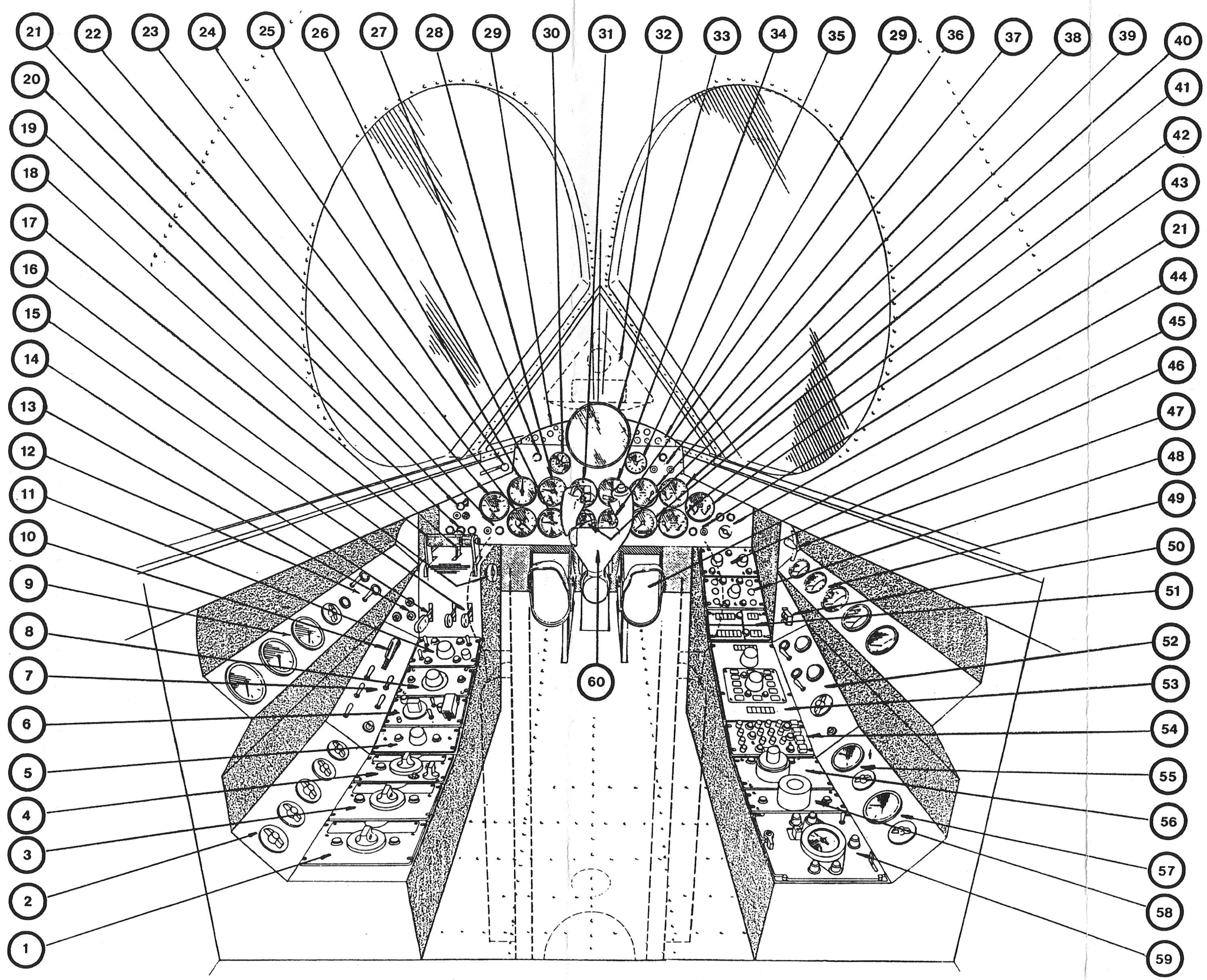
6. Aircraft type.........................C-105/900.
Fuel for combat mission,
13,300 lb Operational weight empty.........32,330 lb.
Gross weight...45,630 lb.
T/C ratio..4%
Supersonic radius.................................200 naut.mi.
Overload range.....................................1,600 naut.mi.
Ceiling...66,200 ft.
Installation.
a. Undercarriage...................................Satisfactory.
b. Electronics...Satisfactory.
c. Armament and equipment....................Poor.

7. Aircraft type..........................C-105/750.
Fuel for combat mission..........................11,100 lb.
Operational weight empty........................26,180 lb.
Gross weight..37,280 lb.
T/C ratio..4.5%
Supersonic radius....................................200 naut.mi.
Overload range..1,500 naut.mi.
Ceiling...53,000 ft.
Installation.
a. Undercarriage..Satisfactory.
b. Electronics...Satisfactory.
c. Armament and equipment.....................Poor.

LEGEND

1. Data receiver (sub-channel) control panel.
2. Cockpit lighting control panel.
3. Data receiver (R.F. Channel) control panel.
4. A.R.C. communications control panel.
5. Headphone control panel.
6. Ground -to- air I.F.F. control panel.
7. Exterior lighting control panel.
8. Air-to-air I.F.F. control panel.
9. Hydraulic and pneumatic pressure indicators.
10. Brake lever.
11. Armament selection control panel.
12. Anti-icing control panel.
13. Starting and re-light control panel.
14. Braking chute and control lever.
15. H.P. fuel controls.
16. Throttle levers friction control.
17. Throttle levers.
18. Speed brake control lever.
19. Undercarriage position indicators.
20. Undercarriage controls.
21. Fire warning indicators and extinguisher button.
22. Trim indicator.
23. Altimeter.
24. Canopy control handle.
25. Air speed indicator.
26. Rate of climb indicator.
27. Canopy lock indicator.
28. Machmeter.
29. Radar indicator control panels.
30. Accelerometer.
31. Cross-point indicator.
32. Optical sight.
33. Radar indicator.
34. Turn and bank indicator.
35. Clock.
36. Tachometer.
37. Optical sight controls and indicator.
38. Oil temperatures indicator.
39. Radio and magnetic compass.
40. Oil pressures indicator.
41. Flow meter and fuel contents indicator.
42. Exhaust temperatures indicator.
43. Fuel pressures indicator.
44. Fuel booster pumps control switch and indicators.
45. Rudder pedals.
46. Radar and power control panel.
47. Emergency brake.
48. Flight sequence control panel.
49. Electrical power indicators.
50. Emergency flying instruments switch.
51. Computer counter panel.
52. Electrical power control panel.
53. Computer control panel.
54. Computer control panel.
55. Cockpit heating control and indicator.
56. Glide slope control panel.
57. DME-OMNI control panel.
58. Cockpit pressure control panel and indicator.
59. Oxygen regulator.
60. Flight and antenna hand control incorporating:

    - Trim control switch.
    - Auto pilot over-ride switch.
    - Nose wheel steering switch.
    - I.F.F. interrogate switch.
    - Range gate switch.
    - Lock and action switch.



PROPOSED PILOT'S COCKPIT FOR THE C-105

THE CF-105 EMERGES.

RCAF SELECTION-MAY 1953 CF-105 DESIGNATION-JULY 1954.

After a complete review and consultation with Avro, the RCAF in May of 1953, selected the C-105/1200 in the C-105/1200/T configuration, as a basis for the design of their new fighter. It was to have a crew of two. Between May 1953 and July 1954, Avro devoted their attention to the design of the CF-105, and in July, issued a report

"CF-105 Twin Engine Supersonic Fighter."

The details of the CF-105, from this brochure are as follows:-
Service model designation..........Supersonic all-weather fighter
Designer's name and Model no..A.V.Roe Canada Ltd, CF-105
Number of crew.........................Two (Pilot and navigator)
Number and kind of engines.......Prototypes - two Curtiss-Wright turbo-jets engines - YJ.67-W-fitted with afterburners.

Design information.

Length-max...........73 ft. 1.65 in.
Height-max...........20 ft. 9.5 in.
Wing span.............50 ft. 0 in.
Aerofoil section.....NACA-0003.5-63.7 (modified)
.0075 camber (modified)
Root chord.............45 ft. 0 in.
Tip chord (basic)....4 ft. 0 in.
Total wing area......1225 sq.ft.
Elevator area..........53.39 sq.ft. (each)
Aileron area...........33.25 sq.ft. (each)
Vertical tail area....138 sq.ft.
Rudder area............38.6 sq.ft.
Main wheel size.....29 x 7.7
Nose wheel size.....18 x 5.5
Anhedral.................4 degrees
Performance...........1240 kts at 50,00 ft.-780 kts. at sea level.
Max. ceiling...........62,500 ft.
Combat radius........436 naut.mi.
Max. range.............1869 naut.mi.

ROLE OF THE AIRCRAFT.

The main role of the aircraft was high altitude, all-weather, night and day interception and destruction of enemy bomber aircraft.

The secondary role of the aircraft was low altitude, all-weather, night and day interception and destruction of enemy bomber aircraft. However, the aircraft was to be designed to fulfil its primary role and limitations would be accepted in the fulfilment of its secondary role.

From the outset, the CF-105 was designed to be a completely automatic aircraft as all navigation and fire control were to be performed by onboard computers and even landing was automatic. Under normal circumstances , the only flight functions expected from the pilot were:-

(a) Taxying.

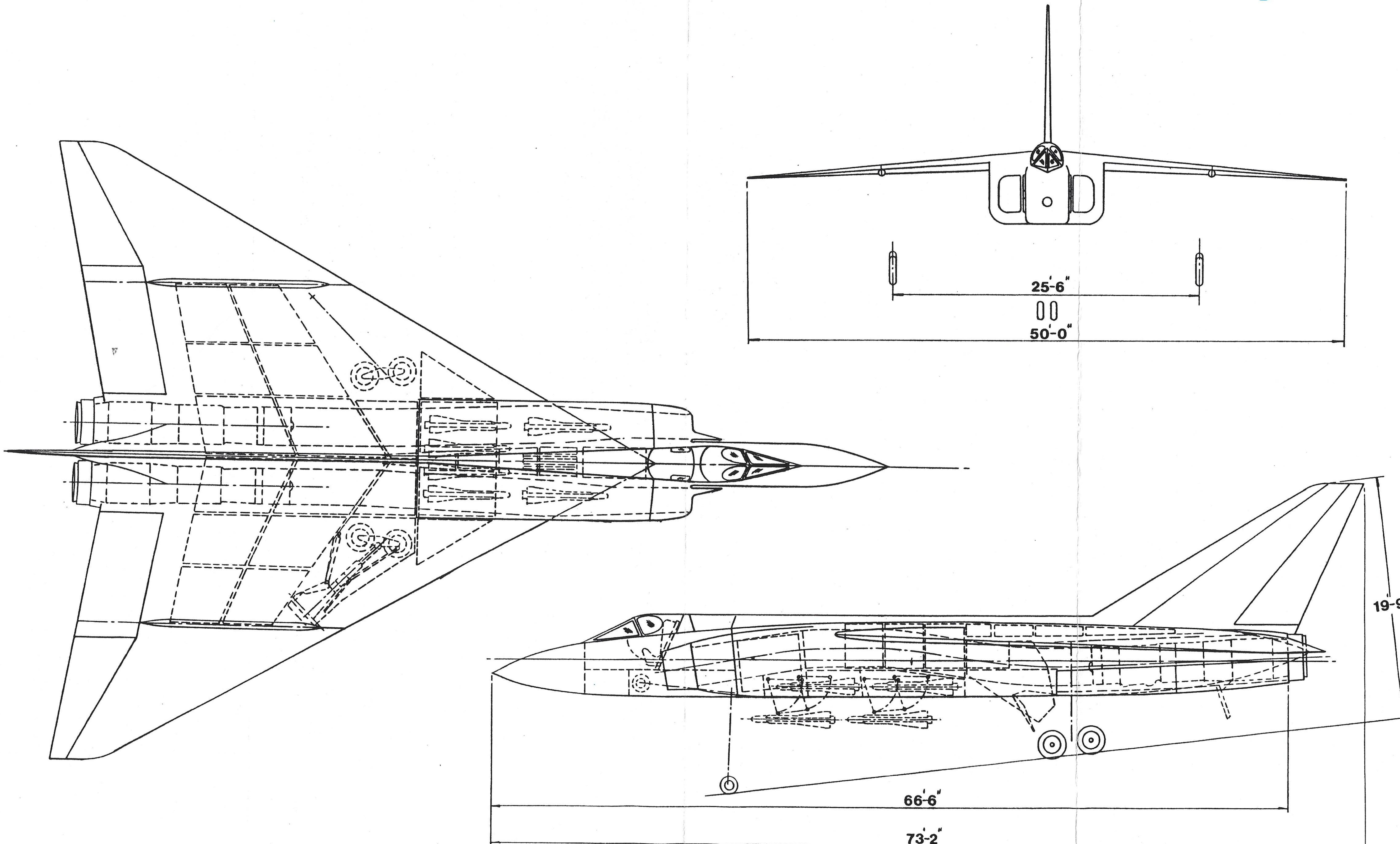
(b) Take-off until terrain clearance had been secured.

(c) Stopping the engines after taxying to the ramp after landing.

It is of interest to record here that a French News Agency in Istres, France on March 10, 1978, issued a statement to the fact that the (then) new Dassault Mirage 2000, was the first French aircraft to equipped with "fly-by-wire" electronic controls. The "Arrow" as the CF-105 was to become, was already doing this in 1957.

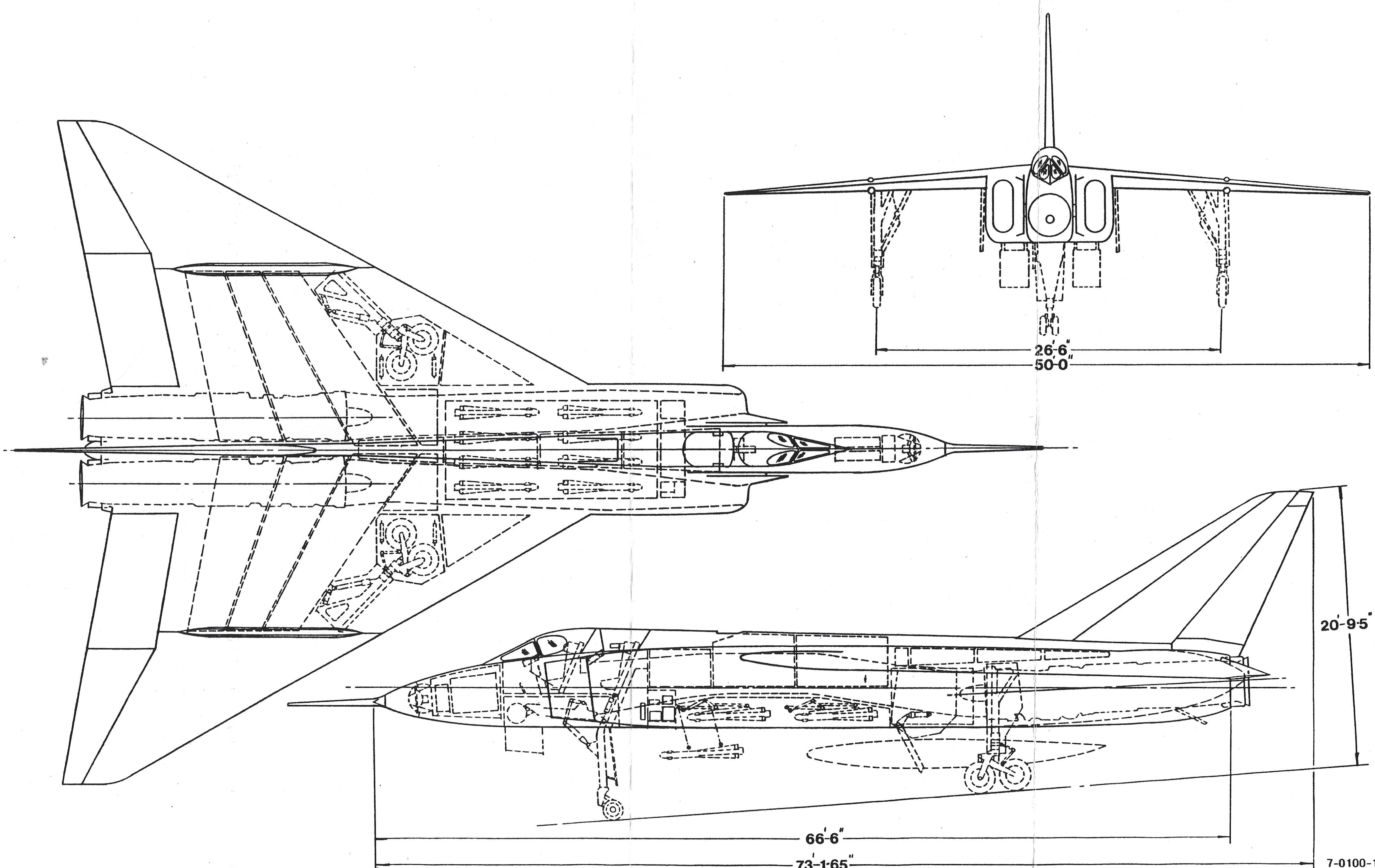
CREW STATION.

The crew consists of pilot and navigator/radar- operator, both seated in automatic type ejection seats. The pilot is provided with normal flying and engine controls, a radar scope, flight instruments, switches, etc. to enable the aircraft to be flown at all times, if necessary, by the pilot alone. The navigator/radar-operator, is provided with a radar scope, the essential flight instruments and the main radar controls to monitor the attack, including lock-on. It was intended to fit the MX.1179 single man fire control system when available, at which time the navigator/radar-operator station will become redundant. However, this was being delayed due to pressure from the USAF on Hughes for the Air Force work already in being, which left Hughes no choice. Also there were security problems resulting in delays again between Avro/Douglas and Hughes/Douglas. These problems resulted in falling back on the E9/MG-3 system until these problems were solved. The cockpit is pressurized to a pressure differential of 4.5 lb./sq.in. and is fully temperature controlled. Special attention has been given to the pilot's view, both forward over the nose for landing, and to achieve the best presentation of instrument and equipment panels. Escape is achieved automatically by simple selection which opens the canopy and fires the automatic ejection seat.



SK 20785

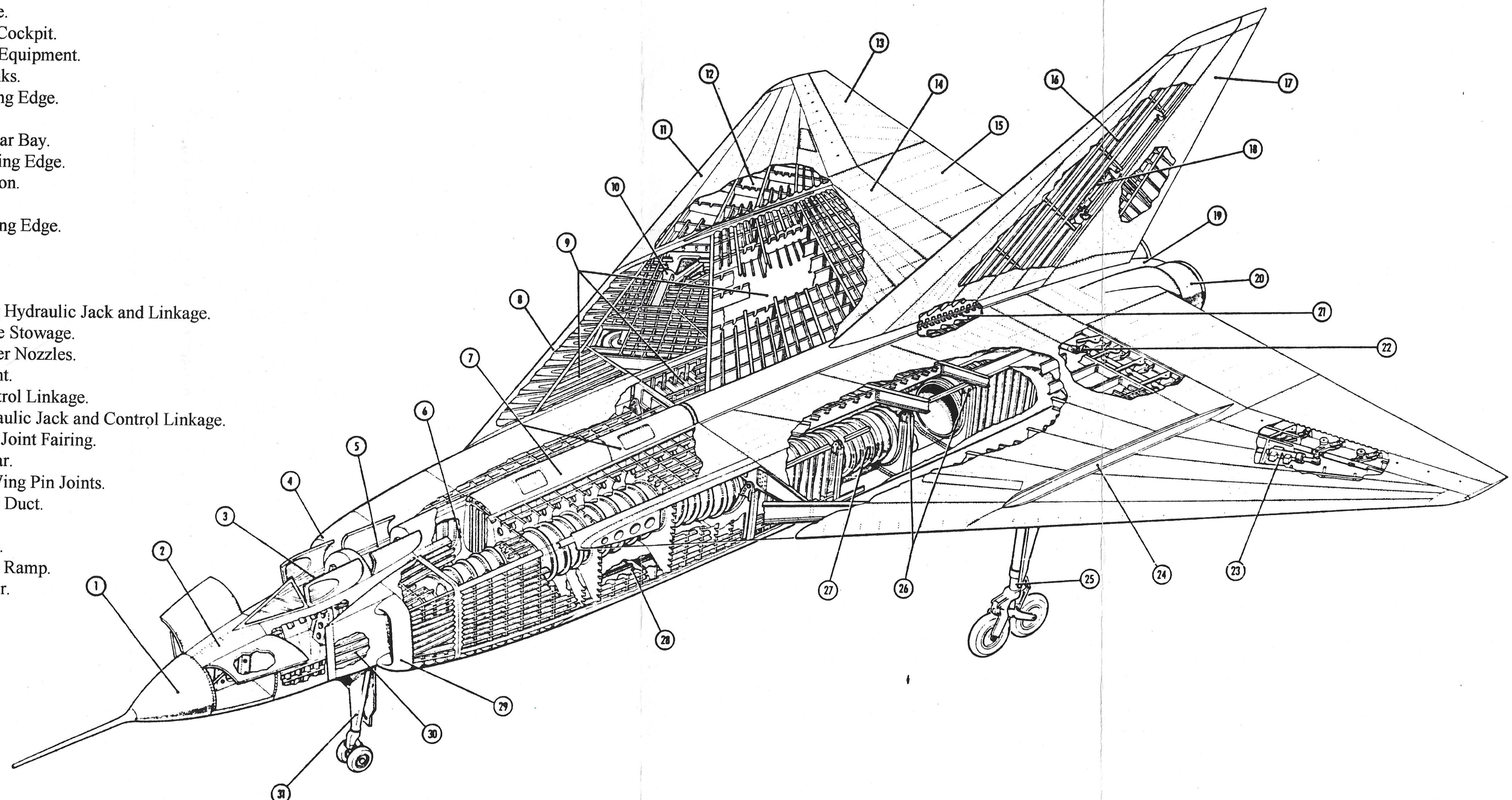
CF-105. RB/106. AUGUST 1953.

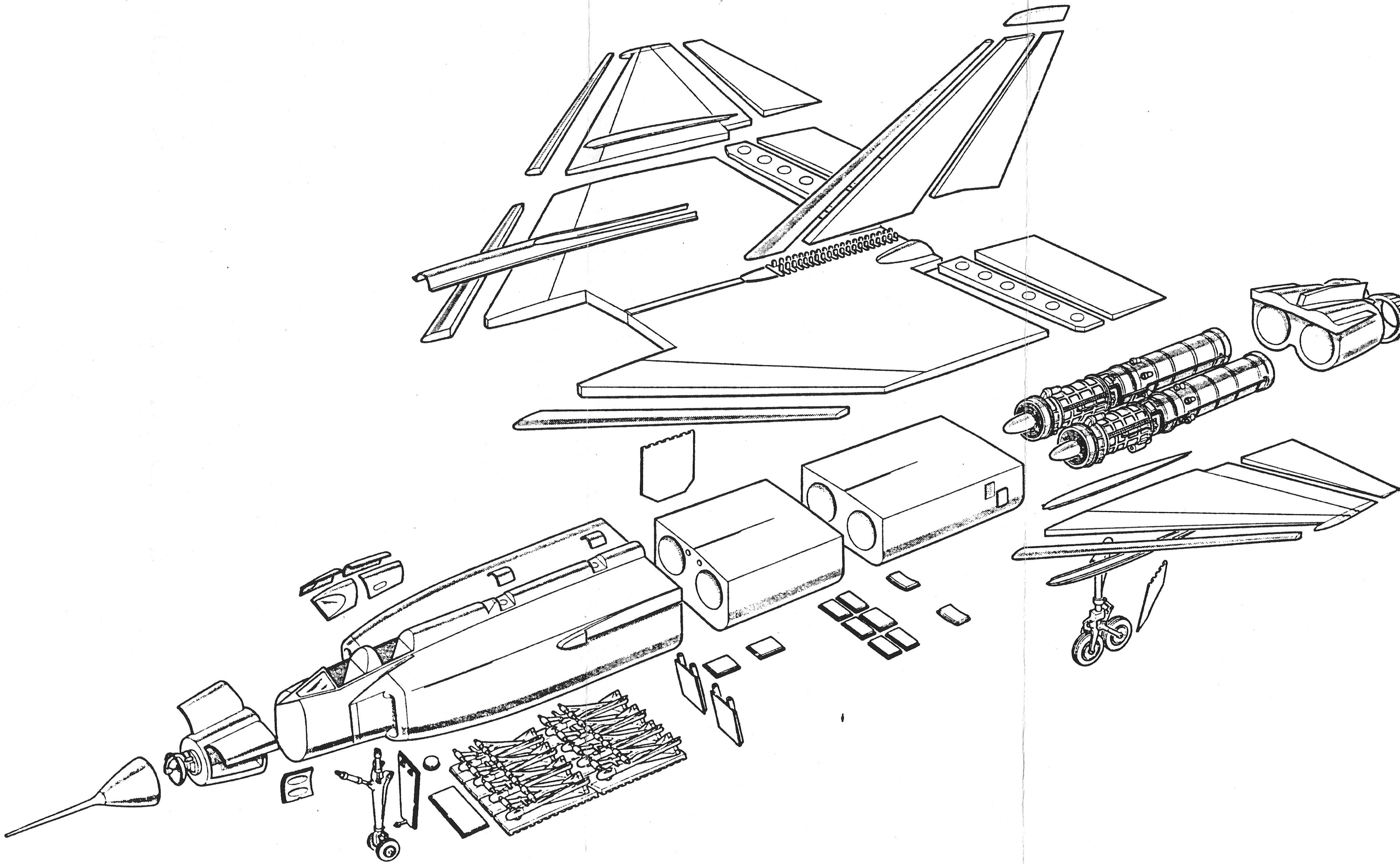


CF-105. J.67. MAY 1954.

LEGEND

1. Radome and Probe.
2. Nose Electronic Compartment.
3. Pilot's Cockpit.
4. R.H.Engine Intake.
5. Radar Operator's Cockpit.
6. Air Conditioning Equipment.
7. Fuselage Fuel Tanks.
8. Inner Wing Leading Edge.
9. Wing Fuel Tanks.
10. Main Landing Gear Bay.
11. Outer Wing Leading Edge.
12. Outer Wing Section.
13. R.H.Aileron.
14. Inner Wing Trailing Edge.
15. R.H.Elevator.
16. Fin.
17. Rudder.
18. Rudder Operating Hydraulic Jack and Linkage.
19. Landing Parachute Stowage.
20. Engine Afterburner Nozzles.
21. Fin/Wing Lap Joint.
22. L.H.Elevator Control Linkage.
23. L.H.Aileron Hydraulic Jack and Control Linkage.
24. Inner/Outer Wing Joint Fairing.
25. Main Landing Gear.
26. Fuselage Frame/Wing Pin Joints.
27. L.H.Engine Intake Duct.
28. Armament Bay.
29. L.H.Engine Intake.
30. L.H.Engine Intake Ramp.
31. Nose Landing Gear.





CF-105 COMPONENT BREAKDOWN

ARMAMENT OPTIONS.

The CF-105 armament will consist of the following options:

HUGHES "FALCON" MISSILES.

8 - Falcon air-to-air guided missiles, carried in two rows of four each in the armament bay. The rear four will be infra-red and the forward four will be radar seeker missiles. Missile lowering is by means of a hydraulically operated parallel link
mechanism. Doors underneath each missile are mechanically linked to the lowering mechanism and will open to permit extension and will close again as the missile approaches the fully extended position. In order to avoid homing and aerodynamic interference between missiles, inboard missiles will be angled out 1 deg. 40 min. from the airplane centre line and outboard missiles 5 deg. from the airplane centre line at the time of firing.

Also, missiles are angled 4 deg. down from the airplane datum to ensure clean separation from the fuselage. The missiles are stowed 3 deg. nose down relative to the fuselage datum and parallel to the aircraft centre line. Rotation to 4 deg. nose down will take place gradually during lowering. Transition to 1 deg.40 min. or 5 deg. in azimuth will take place as soon as the missile fins are clear of the doors.

To permit servicing of the missiles and missile auxiliaries, provisions are included for partial lowering of the launchers, the doors being retained fully open.

Missiles may be fired in a salvo of eight, a salvo of either four radar seekers or four infra-red seekers or a mixed salvo of two radar seekers and two infra-red seekers. In launching mixed salvos the rear missiles will be fired first, their launchers being left extended while the front missiles are lowered and fired. All empty launchers will then be retracted immediately. In the case of an attack with either four radar seekers or four infra-red missiles the appropriate row will be lowered and fired and the empty launchers retracted immediately.

DOUGLAS "SPARROW" MISSILES.

As an alternative, three Douglas "Sparrow 2" fully active missiles could be carried in the armament bay.

AIR-TO-AIR ROCKETS.

A further alternative installation could have been arranged along either of the following lines for conditions which might have been unsuitable for missiles, such as low altitude attacks:

(a). An expendable rocket package containing fifteen 2-inch diameter rockets to be fitted in place of each Falcon missile giving a total of 120 rockets.

(b). With the launching gear strengthened to allow increased loads, there is sufficient space to accommodate 8 launchers each containing 25 rockets, or a total of two-hundred 2 inch diameter rockets.

WING GROUP.

The wing is of a Delta plan form, that is, triangular in shape, and the structure is continuous over the top of the fuselage. The main reason for adopting the high wing configuration is to get better flexibility in the armament bay so that the introduction of larger weapons will not compromise the wing structure and, similarly, with the engines to allow for larger engines to be fitted without basic changes to the structure. The high wing also makes re-arming and engine servicing and changing easier. While the high wing arrangement makes for a longer undercarriage, the employment of 4 degrees anhedral to the wing, which is acceptable from aerodynamic considerations, materially assists in getting a shorter and simpler undercarriage geometry. The wing thickness was increased from 3% t/c in May of 1954 to 3.5% of the chord at the root tapering to 3.8% of the chord at the wing tip. The wing is manufactured in a number of sub-assemblies which are bolted together at the transport joint.

These assemblies are:

(a) Left and right inner wing joined at the fuselage centre line.

(b) Left and right inner wing trailing edges.

(c) Left and right inner wing leading edges.

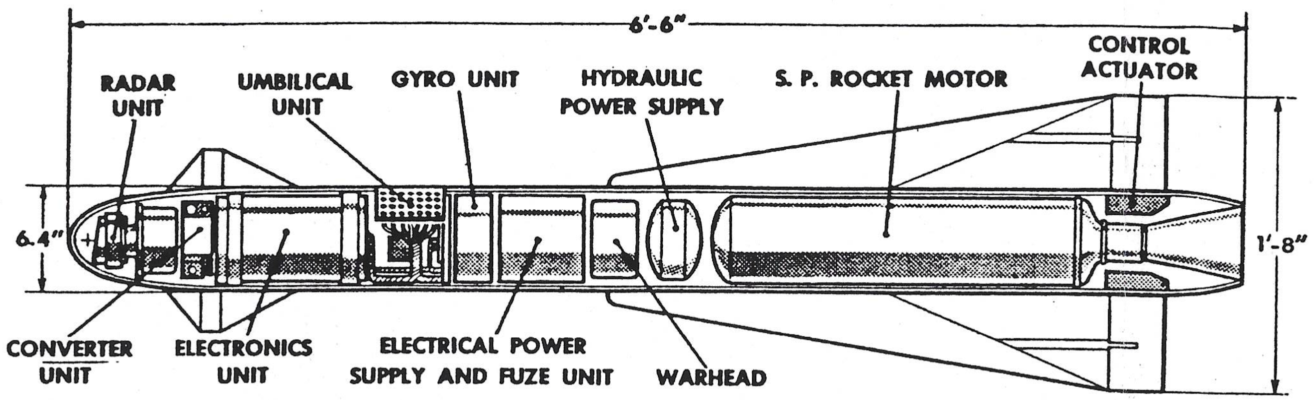
(d) Left and right outer wings.

(e) Left and right outer wing leading edges.

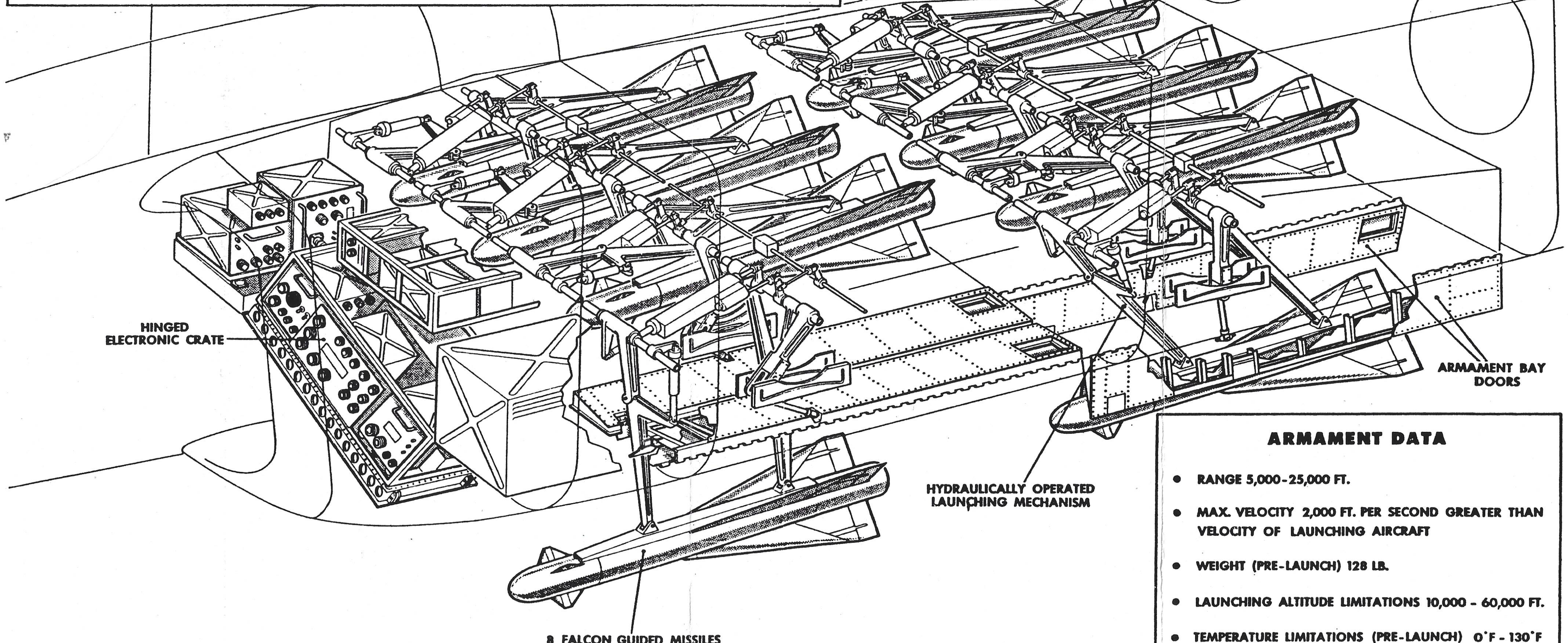
Left and right ailerons and separate elevators are then fitted to the main wing assembly.

WING CONSTRUCTION - INNER WING ASSEMBLY.

This component consists of a main spar box and separate leading and trailing edges. The main spar box has four span-wise spars. The outer skin panels are of integral structure, having stringers and rib caps machined from a solid billet. The skins and spars form the integral fuel tanks. The main wing transport



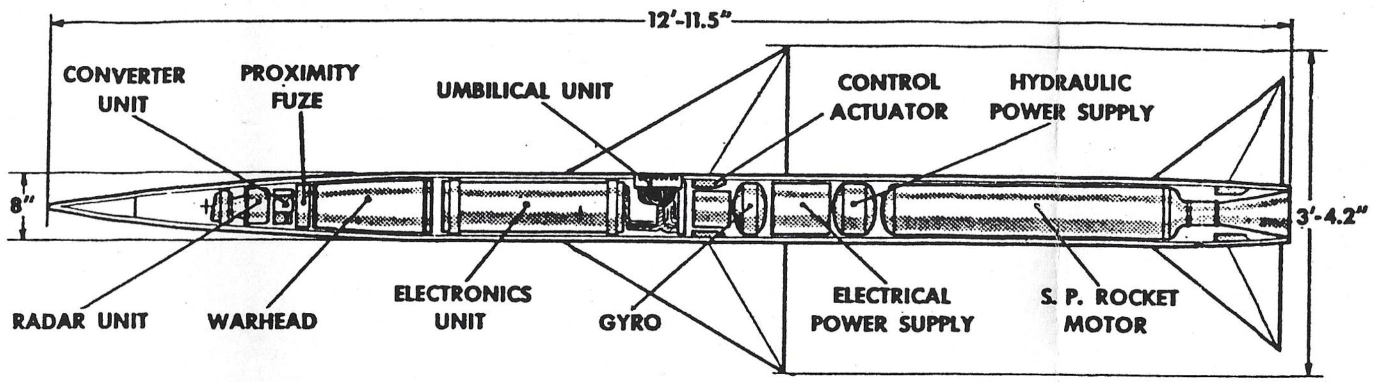
SECTION THROUGH "FALCON GAR 1"



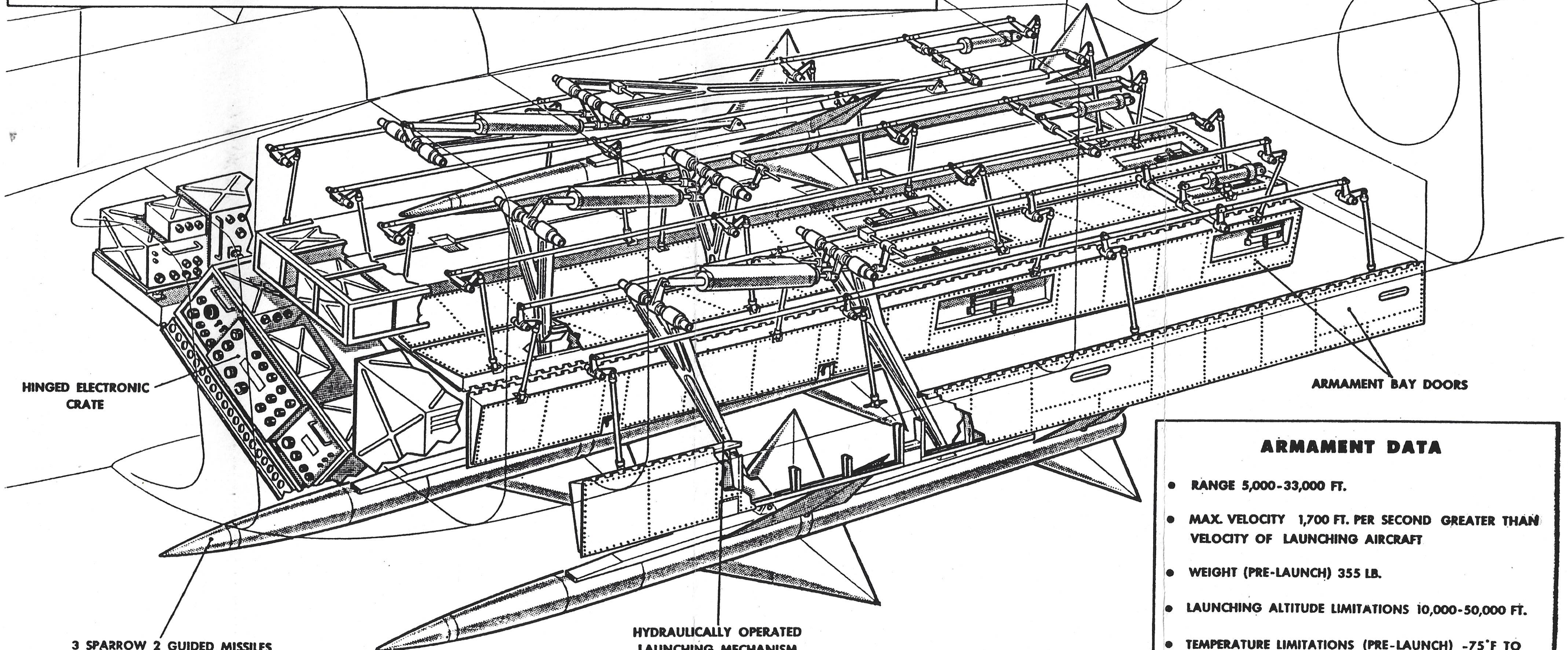
ARMAMENT DATA

- RANGE 5,000-25,000 FT.
- MAX. VELOCITY 2,000 FT. PER SECOND GREATER THAN VELOCITY OF LAUNCHING AIRCRAFT
- WEIGHT (PRE-LAUNCH) 128 LB.
- LAUNCHING ALTITUDE LIMITATIONS 10,000 - 60,000 FT.
- TEMPERATURE LIMITATIONS (PRE-LAUNCH) 0°F - 130°F

ARMAMENT AND ELECTRONIC INSTALLATIONS. FALCON.



SECTION THROUGH "SPARROW 2" MISSILE



ARMAMENT DATA

- RANGE 5,000-33,000 FT.
- MAX. VELOCITY 1,700 FT. PER SECOND GREATER THAN VELOCITY OF LAUNCHING AIRCRAFT
- WEIGHT (PRE-LAUNCH) 355 LB.
- LAUNCHING ALTITUDE LIMITATIONS 10,000-50,000 FT.
- TEMPERATURE LIMITATIONS (PRE-LAUNCH) -75°F TO +150°F (FOR ROCKET MOTOR)

ARMAMENT AND ELECTRONIC INSTALLATIONS. SPARROW.

joints are covered by a streamlined fairing. The main spar box takes the greater part of the landing gear loads which are transmitted into the box by stout end ribs located at the inner to outer wing transport joint. The fin structure is attached to the main wing by a simple multi-plate joint.

INNER WING - TRAILING EDGE ASSEMBLY.

This assembly is made up of sheet metal skins and forged aluminum alloy ribs. The assembly houses the elevator controlling mechanism which consists of a long push-rod operating six elevator bell cranks.

OUTER WING ASSEMBLY.

This component consists of a multi-cell arrangement of spars and ribs bounded by a leading edge spar and a rear spar, the whole assembly being covered with relatively thick aluminum alloy skin. The spars are of formed channel sections. The ribs are intercostal with shear attachments through the spars.

OUTER WING TRAILING EDGE ASSEMBLY.

This component is made up in a similar manner to the inner wing trailing edge assembly with sheet metal skins and forged ribs and houses the aileron controlling mechanism which consists of a long push rod operating seven aileron bell cranks.

MATERIAL.

In stressing the wing structure, account was taken of the effect of elevated temperature due to air friction at the design speeds of this aircraft. The effect of this temperature which may reach a value of 250 degrees F at a Mach number of 2, is to decrease somewhat the strength and stiffness of the light alloy material. The skin panels, ribs and spars are of 75ST high strength aluminum alloy.

ELEVATOR.

This component is hinged to the trailing edge assembly of the inner wing by means of a special extruded piano hinge. The elevator is actuated by six push-pull rods equally spaced along the span. Special self-aligning roller bearings are used. The structure of the elevator consists of a leading edge spar and closely spaced ribs covered with thick aluminum alloy skins. A blunt trailing edge is used which consists of a light alloy extrusion; the reason for this is that this type of trailing edge improves the torsional stiffness considerably and yet causes no additional drag at supersonic design speed. Mass balance or aerodynamic balance devices are not incorporated in the design of the elevator and no tabs are fitted.

AILERON.

This component is similar in design and construction to the elevator and is hinged to the outer wing assembly by means of a special extruded piano hinge. The ailerons, which are fully power operated are actuated by seven push-pull rods equally spaced span-wise. As on the elevator, special self-aligning bearings are used, No mass balance or aerodynamic balance is incorporated and no tabs are fitted.

FIN.

The fin mounts directly on to the top surface of the wing and its root-shear, bending moment and torque are distributed directly into the wing structure. The structure of the fin consists of a multi-cell arrangement of spars integrated with span-wise rows of vertical members. There are four main ribs attached at 90 degrees to the rear spar, the whole assembly being covered with taper rolled skins of aluminum alloy. The attachment of the fin to the wing is achieved by means of a multi-plate arrangement of aluminum alloy strips forming a series of lap joints to carry the end loads from the main members into the torsion box formed by the wing-to-fin attachment. The trailing edge of the fin aft of the rear spar contains the rudder operating linkage and hinges. This structure is removable as a complete structural unit for servicing and access to the rudder control actuating mechanism. The hydraulic rudder actuating jack and control valves are located in the fin forward of the actuating mechanism. Access to this is provided through a large access door on the left-hand side of the fin.

RUDDER.

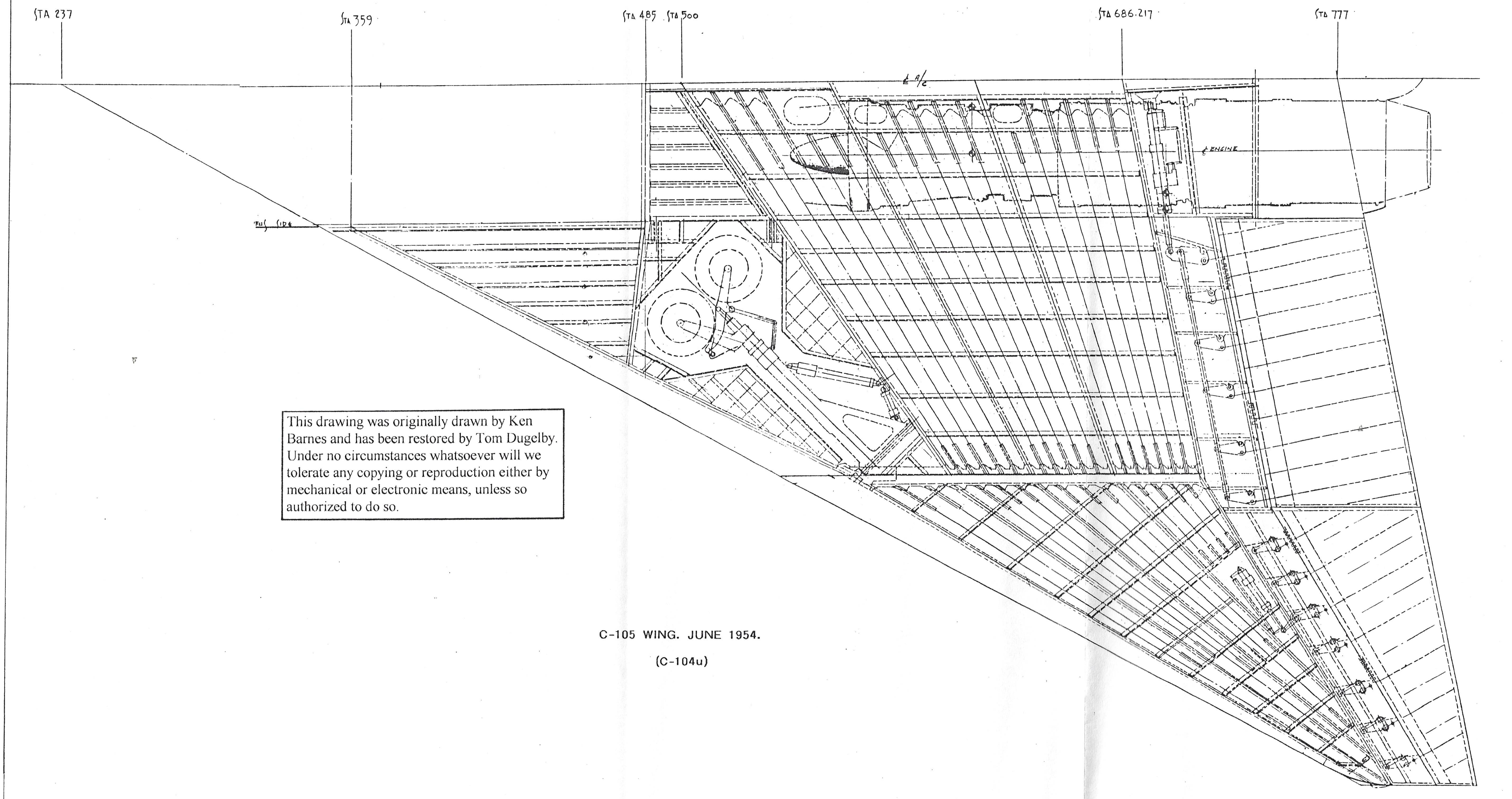
This component is hinged to the trailing edge of the fin by five roller bearing hinges on the actuating levers and two plain hinges bolted to the right-hand skin surface.

BODY GROUP - FUSELAGE.

The fuselage is slung underneath the wing. The cross section over a good portion of the length is almost rectangular with rounded corners. The fuselage accommodates the pilot and radar operator, nose landing gear, the armament and equipment bays, engine intake ducts, speed brakes, engines and afterburners, flying and power plant controls, fuselage fuel tanks and brake parachute. The fuselage is manufactured in six sections, made up as separate units and bolted together at transport joints. From front to rear, these consist of:

(a) The radome and probe section.

(b) The nose electronics section.



C-105 WING. JUNE 1954.

(C-104u)

K. Barnes

(c) The front fuselage section containing the cockpit, intakes fuselage fuel tanks, armament and equipment.

(d) The fuselage centre section containing the speed brakes and equipment.

(e) The rear fuselage section containing the engines and afterburner.

(f) The tail cone section.

CONSTRUCTION - RADOME SECTION.

The radome houses the nose probe which in turn contains the pitot-static head, the relative wind sensors for the air data computer and the radome de-icing fluid dispenser. The radome is made of suitable dielectric material of sandwich construction.

NOSE ELECTRONICS SECTION.

The main bulk of the radar equipment is housed in this section which is made up as a separate component with large side access doors for ease of servicing.

FRONT FUSELAGE SECTION.

This is the largest fuselage component. It houses the pilot's and radar operator's compartments, the fuselage fuel tanks, the equipment installation section (including air conditioning equipment), and the armament bay. The general structure follows conventional practice, using formers, stringers, and skin construction, mostly of 75ST high strength aluminum alloy. The crew compartment is pressurized and has clamshell type canopies which may be operated from the outside or inside the aircraft. A "V" type windscreen is fitted for aerodynamic reasons. This type of windscreen improves the airflow over the canopy and cuts down the drag to a minimum, and is so arranged that the optical properties are adequate. Provision is made for anti-icing and de-misting. The front fuselage also houses the nose landing gear. Engine side intakes are used with supersonic intake ramps on the inboard portion of the intake lips. The engine ducts run from an almost rectangular section at the intake to a circular section just aft of mid-length. The engine intake ramps are wedge-shaped and are fitted to get good pressure recovery characteristics in the intakes at supersonic speeds. These ramps are integral with the intake lips and also form the boundary layer bleed, which is approximately of triangular shape with the centre portion feeding the air-cooling turbine for the air conditioning system. Bag type fuel tanks are carried in this portion of the fuselage. Special attention has been given to housing equipment to achieve ease of servicing and maintenance, and the wide fuselage required by the twin engine installation has been utilized to the fullest extent to provide a very large armament bay of approximately 19 ft. long x 7 ft.8 in. wide x 2 ft.1 in. high and accommodates eight Hughes "Falcon" missiles or weapons of equivalent size.

FUSELAGE CENTRE SECTION.

The centre section of the fuselage houses the speed brakes and a proportion of aircraft equipment.

REAR FUSELAGE SECTION.

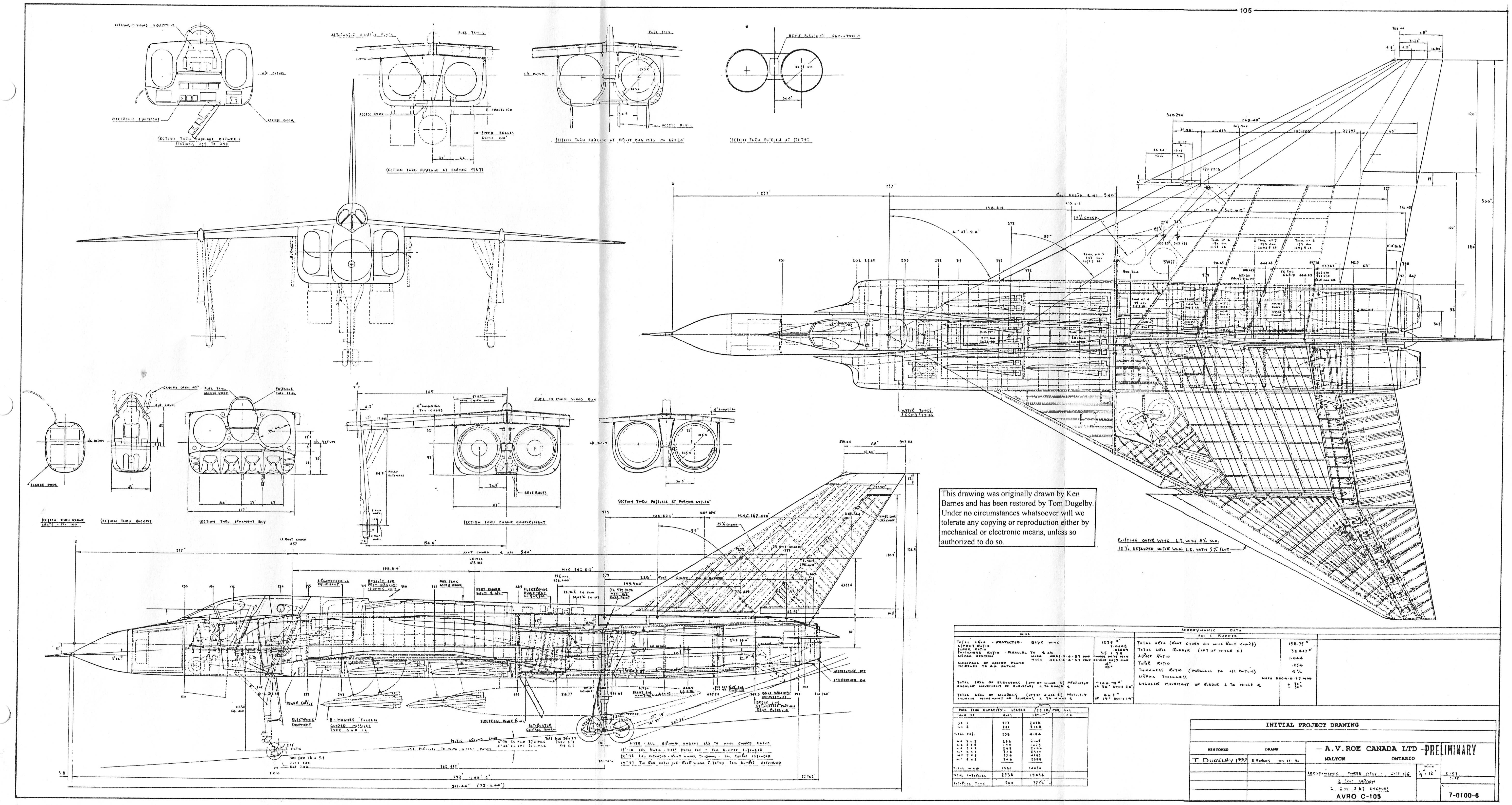
This assembly is a continuation of the front and centre fuselage structure. The primary structural elements consist of a series of transverse frames pin-jointed at their outboard flanges to the underside of the wing and carry two circular tunnels side-by-side which house the engines and afterburners. The centre structure consists of the lower inboard quadrants of the two tunnels, and a horizontal "cat walk" between them, which is supported through pairs of struts pin-jointed to the centre of the wing.

No stringers are used, but a longeron is used at the lower outboard portion of the structure. The two engine tunnels of titanium material for fire resistance, are pressure vessels attached to all frames around the lower halves with independent support for the top halves. Direct attachment of the tunnels at the forward end to the rear of the air intake is achieved through a semi-flexible joint. This structure takes aerodynamic loads only, since all engine and afterburner loads are taken directly through the main wing structure.

The initial design studies provided for large side swinging doors in the engine bay for the removal and servicing of the engines, however with the decision to cool the engines with air from the intakes, the engine tunnels, being extensions of the intake ducts, were pressurized and therefore stress bearing. The engines then could be removed only from the rear after two relatively small doors at the bottom rear of the engine bay were hinged down.

TAIL CONE SECTION.

This assembly forms a completely detachable fairing of monocoque construction containing the continuation from the rear fuselage section of the two engine tunnels, a landing parachute with operating mechanism and a rudder fairing. The unit is attached to the rear of the main fuselage through eight quick release toggle action fasteners. The main functions of this unit are to transmit parachute landing and tail skid loads to the rear fuselage section, and to provide a fairing around the two afterburner nozzles. Engine removal and installation are accomplished by detaching the whole unit to permit the engine to roll on tracks through the rear of the power plant bays.


105
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INITIAL PROJECT DRAWING
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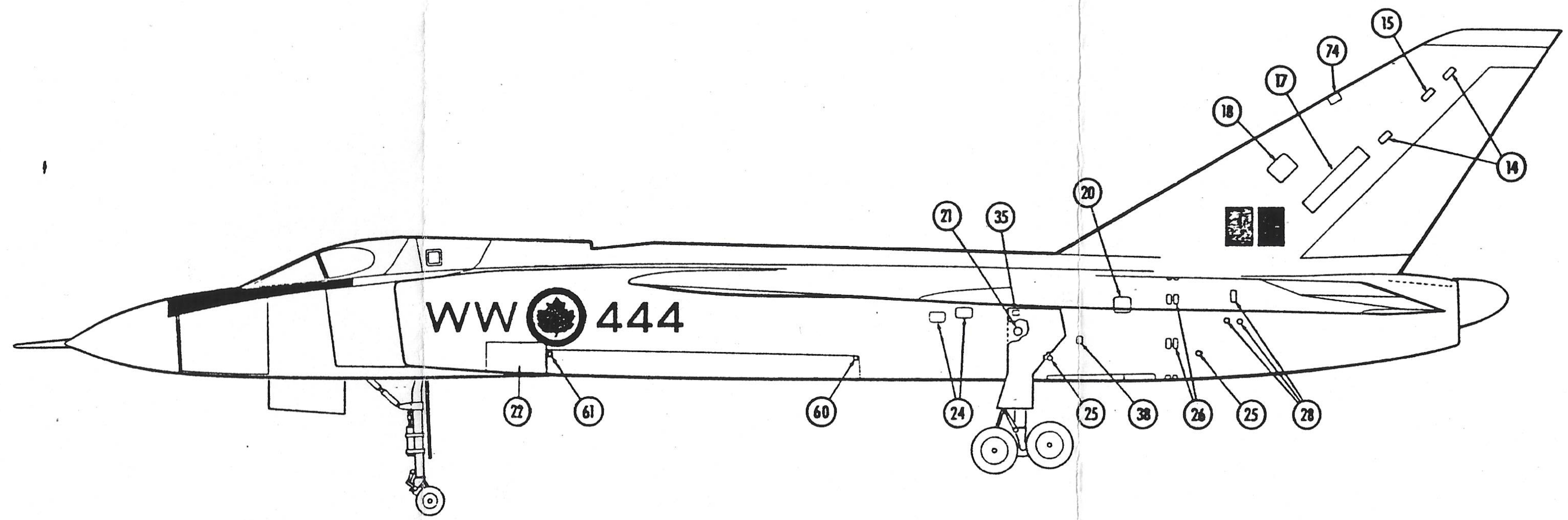
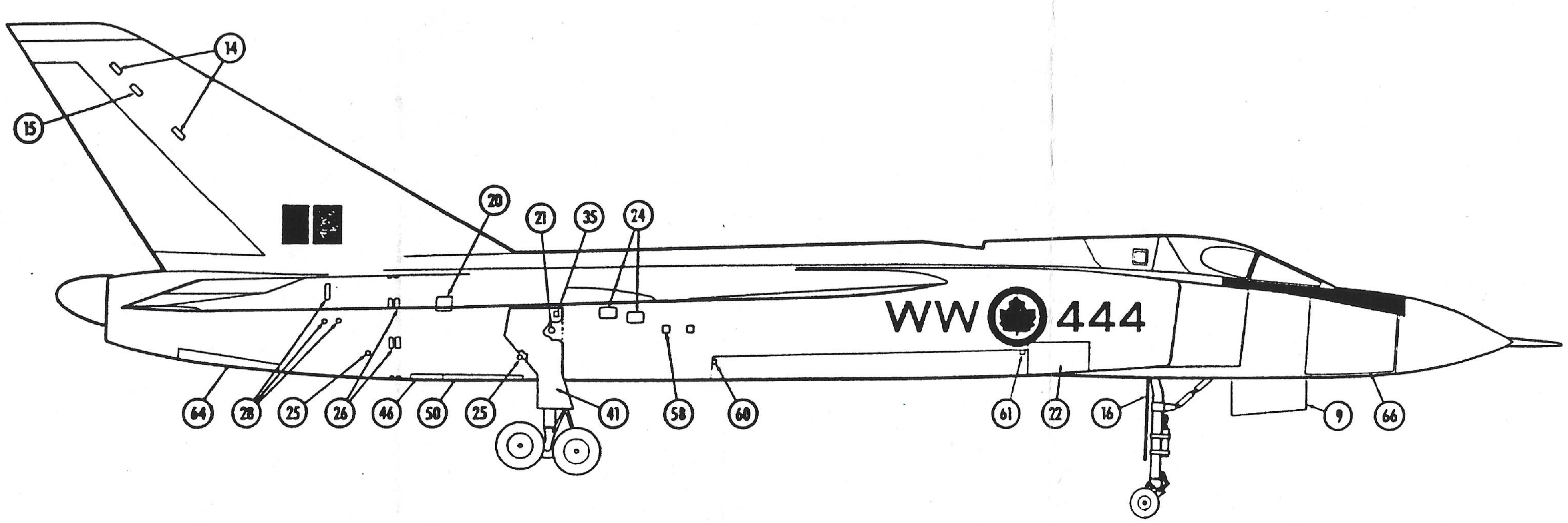
T. DUGELBY
A.V. ROE CANADA LTD
PRELIMINARY
MALTON
ONTARIO
AVRO C-105
7-0100-6

14 ACCESS PANEL - WAVE GUIDE ANTENNA
15 ACCESS PANEL - ATTACHMENT OF TRAIL EDGE TO FIN
17 ACCESS PANEL - RUDDER JACK
18 ACCESS PANEL - HINGE MOMENT LIMITER
20 ACCESS PANEL - AIR CONDITIONING MANIFOLD
21 ACCESS PANEL - OUTBOARD ENGINE MOUNT
22 SIDE ACCESS DOOR - ELECTRONIC BAY
24 ACCESS AFT DUCT ATTACHMENT
25 HOLE - FIRE EXTINGUISHER
26 PRESSURE VENT DOORS
28 VENT HOLE - REAR ENGINE MOUNT
33 COMPRESS BLEED ACCESS
35 OUTBOARD ENGINE MOUNTING ACCESS
60 PICK-UP LATCH ACCESS - INSTRUMENT PANEL - AFT
61 ACCESS - INSTRUMENT PACK - FORWARD
74 WAVE GUIDE JOINT ACCESS PANEL



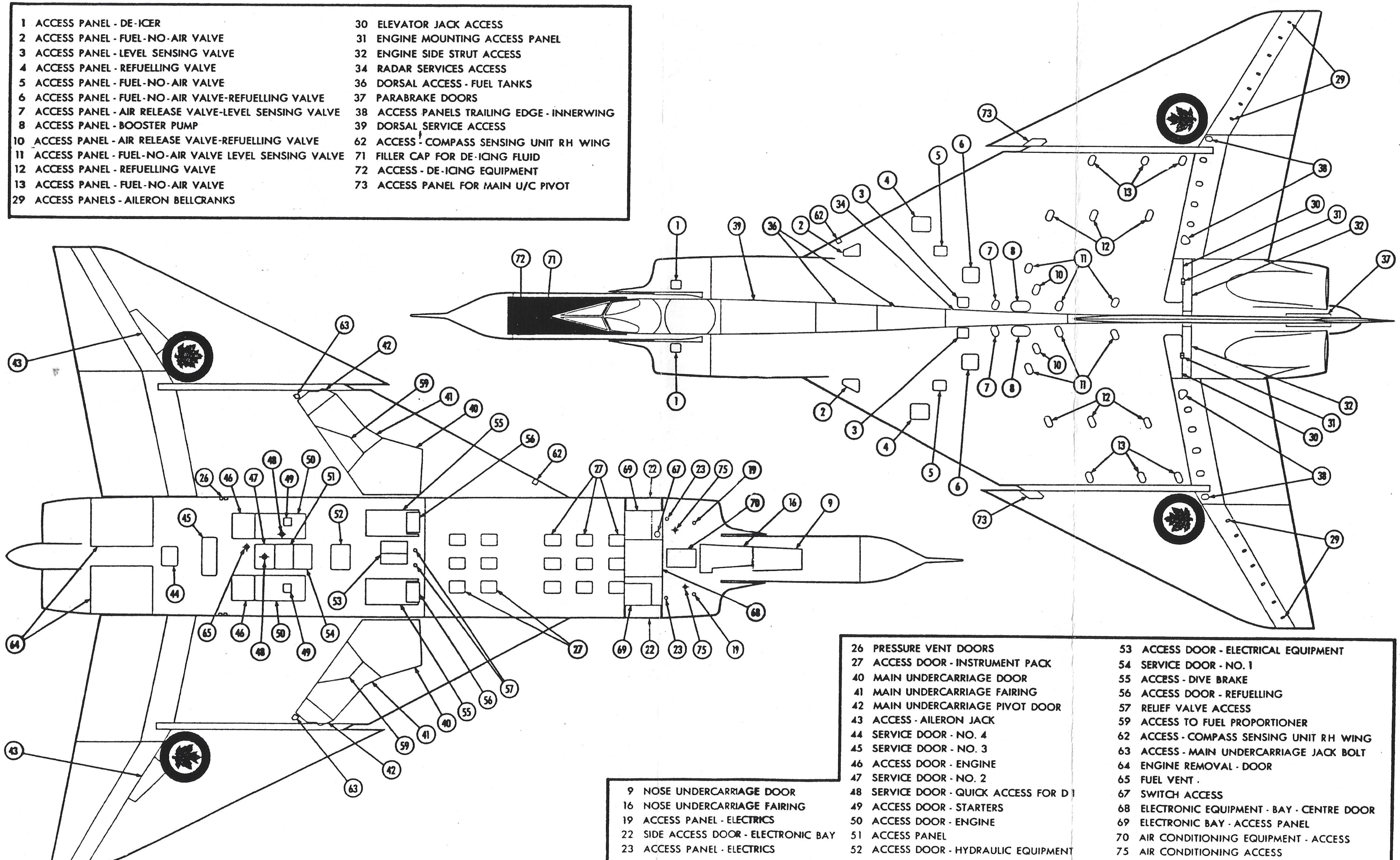


MAIN U/C DOOR OMITTED FOR CLARITY

9 NOSE UNDERCARRIAGE DOOR
14 ACCESS PANEL - WAVE GUIDE ANTENNA
15 ACCESS PANEL - ATTACHMENT OF TRAIL EDGE TO FIN
16 NOSE UNDERCARRIAGE FAIRING
20 ACCESS PANEL - AIR CONDITIONING MANIFOLD
21 ACCESS PANEL - OUTBOARD ENGINE MOUNT
22 SIDE ACCESS DOOR - ELECTRONIC BAY
24 ACCESS AFT DUCT ATTACHMENT
25 HOLE - FIRE EXTINGUISHER
26 PRESSURE VENT DOORS
28 VENT HOLE - REAR ENGINE MOUNT
35 OUTBOARD ENGINE MOUNTING ACCESS
41 MAIN UNDERCARRIAGE FAIRING
46 ACCESS DOOR - ENGINE
50 ACCESS DOOR - ENGINE
58 ACCESS PANEL - HYDRAULICS
60 PICK-UP LATCH ACCESS - INSTRUMENT PANEL - AFT
61 ACCESS - INSTRUMENT PACK - FORWARD
64 ENGINE REMOVAL - DOOR
66 RADAR ACCESS DOOR

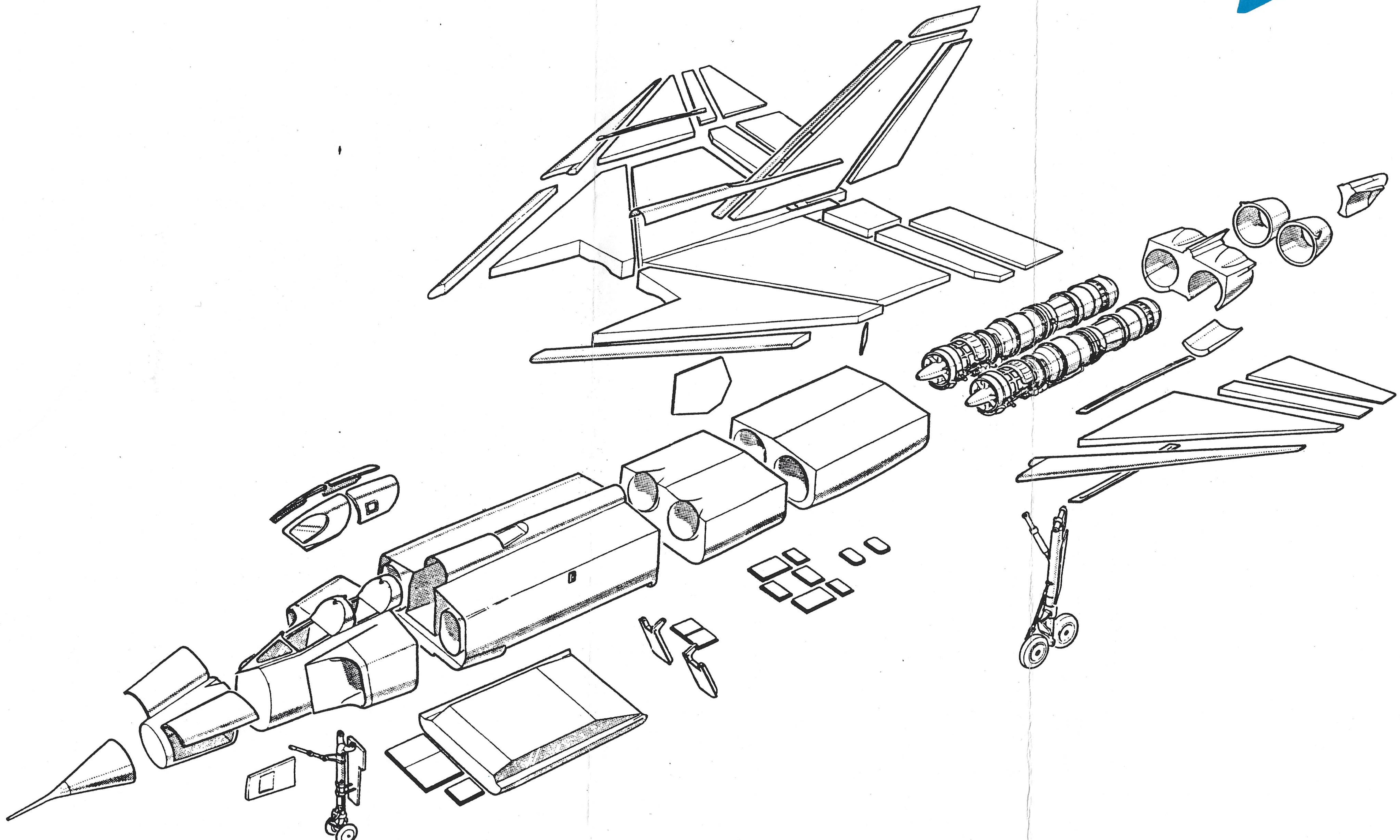
CF-105 WOODEN MOCK-UP. LH AND RH SIDES

1 ACCESS PANEL - DE-ICER
2 ACCESS PANEL - FUEL-NO-AIR VALVE
3 ACCESS PANEL - LEVEL SENSING VALVE
4 ACCESS PANEL - REFUELLING VALVE
5 ACCESS PANEL - FUEL-NO-AIR VALVE
6 ACCESS PANEL - FUEL-NO-AIR VALVE-REFUELLING VALVE
7 ACCESS PANEL - AIR RELEASE VALVE-LEVEL SENSING VALVE
8 ACCESS PANEL - BOOSTER PUMP
10 ACCESS PANEL - AIR RELEASE VALVE-REFUELLING VALVE
11 ACCESS PANEL - FUEL-NO-AIR VALVE LEVEL SENSING VALVE
12 ACCESS PANEL - REFUELLING VALVE
13 ACCESS PANEL - FUEL-NO-AIR VALVE
29 ACCESS PANELS - AILERON BELLCRANKS
30 ELEVATOR JACK ACCESS
31 ENGINE MOUNTING ACCESS PANEL
32 ENGINE SIDE STRUT ACCESS
34 RADAR SERVICES ACCESS
36 DORSAL ACCESS - FUEL TANKS
37 PARABRAKE DOORS
38 ACCESS PANELS TRAILING EDGE - INNERWING
39 DORSAL SERVICE ACCESS
62 ACCESS - COMPASS SENSING UNIT RH WING
71 FILLER CAP FOR DE-ICING FLUID
72 ACCESS - DE-ICING EQUIPMENT
73 ACCESS PANEL FOR MAIN U/C PIVOT

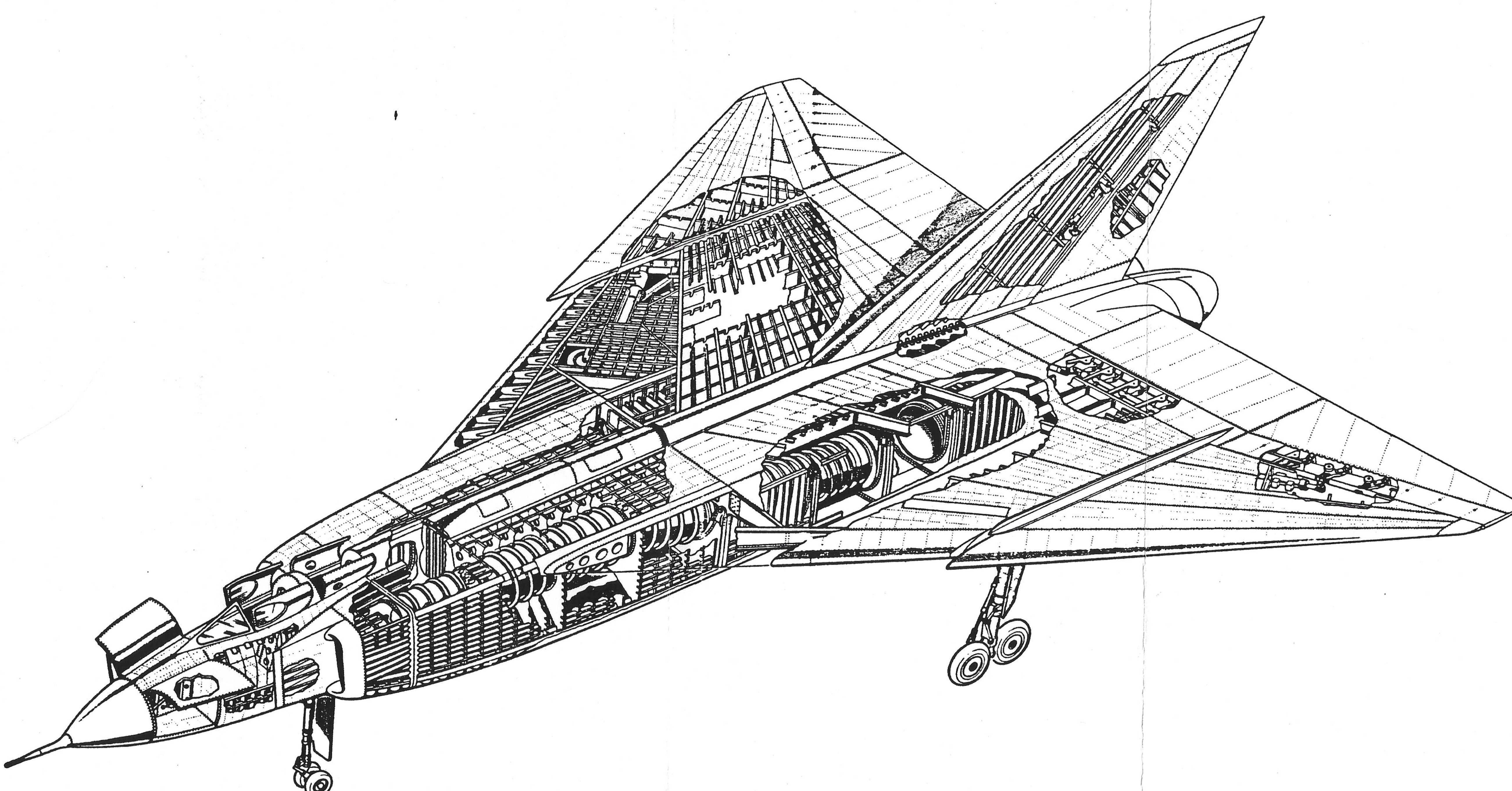


9 NOSE UNDERCARRIAGE DOOR
16 NOSE UNDERCARRIAGE FAIRING
19 ACCESS PANEL - ELECTRICS
22 SIDE ACCESS DOOR - ELECTRONIC BAY
23 ACCESS PANEL - ELECTRICS
26 PRESSURE VENT DOORS
27 ACCESS DOOR - INSTRUMENT PACK
40 MAIN UNDERCARRIAGE DOOR
41 MAIN UNDERCARRIAGE FAIRING
42 MAIN UNDERCARRIAGE PIVOT DOOR
43 ACCESS - AILERON JACK
44 SERVICE DOOR - NO. 4
45 SERVICE DOOR - NO. 3
46 ACCESS DOOR - ENGINE
47 SERVICE DOOR - NO. 2
48 SERVICE DOOR - QUICK ACCESS FOR D 1
49 ACCESS DOOR - STARTERS
50 ACCESS DOOR - ENGINE
51 ACCESS PANEL
52 ACCESS DOOR - HYDRAULIC EQUIPMENT
53 ACCESS DOOR - ELECTRICAL EQUIPMENT
54 SERVICE DOOR - NO. 1
55 ACCESS - DIVE BRAKE
56 ACCESS DOOR - REFUELLING
57 RELIEF VALVE ACCESS
59 ACCESS TO FUEL PROPORTIONER
62 ACCESS - COMPASS SENSING UNIT RH WING
63 ACCESS - MAIN UNDERCARRIAGE JACK BOLT
64 ENGINE REMOVAL - DOOR
65 FUEL VENT
67 SWITCH ACCESS
68 ELECTRONIC EQUIPMENT - BAY - CENTRE DOOR
69 ELECTRONIC BAY - ACCESS PANEL
70 AIR CONDITIONING EQUIPMENT - ACCESS
75 AIR CONDITIONING ACCESS

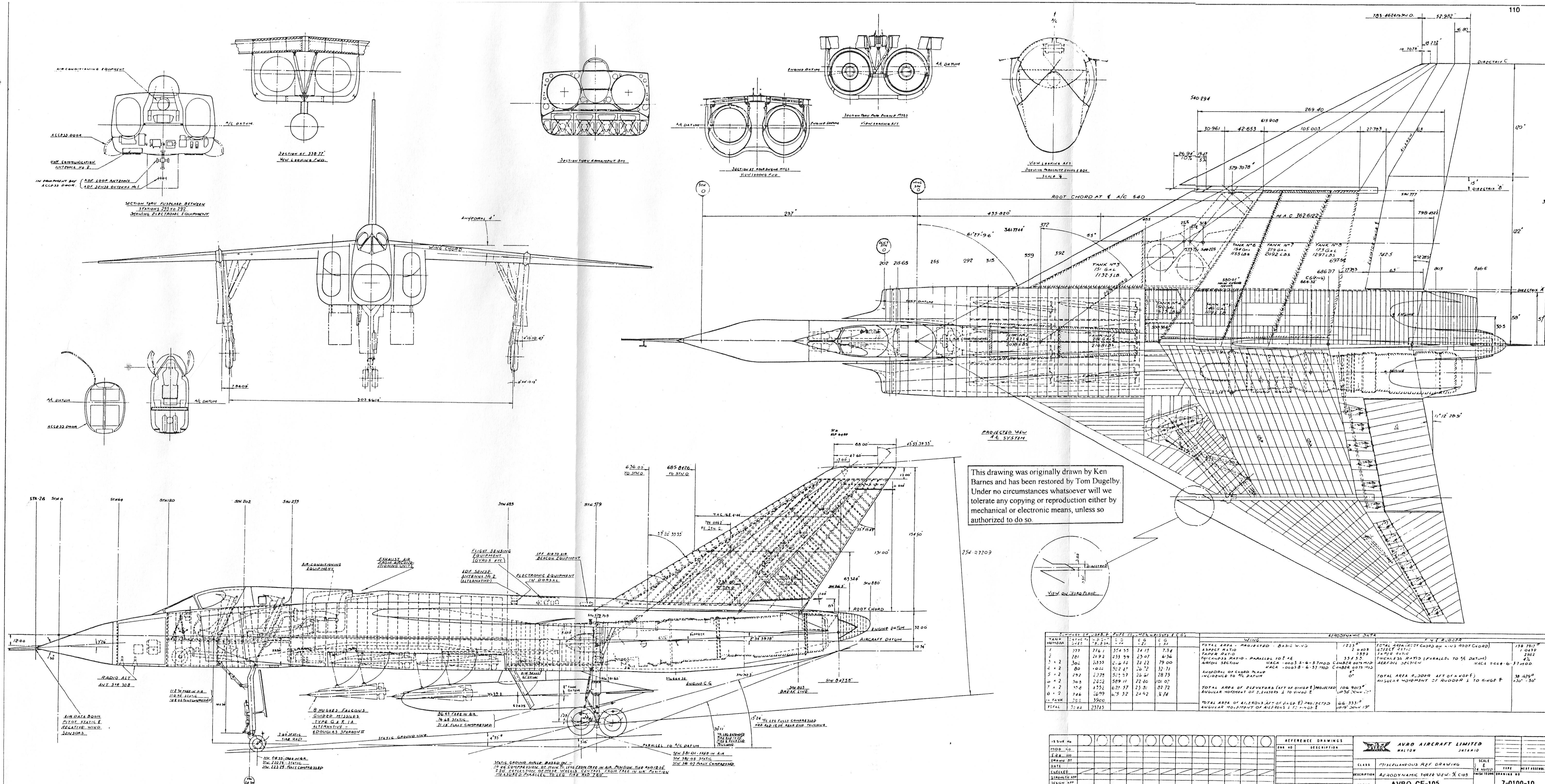
CF-105 WOODEN MOCK-UP. TOP AND BOTTOM SIDES



CF-105 WOODEN MOCK-UP. COMPONENT BREAKDOWN



CF-105 WOODEN MOCK-UP. STRUCTURE



SUMMARY OF USABLE FUEL VOLUMES WEIGHTS & C.G.'S					
TANK NUMBER	CAPACITY GALS	WEIGHT LBS	C.G.	C.G.	C.G.
1	277	2161	354.35	24.13	7.34
2	281	2192	433.99	23.07	6.36
3 × 2	302	2355	2-6.14	24.22	79.00
4 × 2	80	[illegible]	502.47	26.72	32.71
5 × 2	292	2278	525.57	26.61	28.73
6 × 2	303	2452	589.11	22.40	101.07
7 × 2	358	4352	627.57	23.31	82.72
8 × 2	346	2699	675.52	24.92	76.74
[illegible] TANK	500	3900			
TOTAL	3044	23745			

AERODYNAMIC DATA

WING	
TOTAL AREA - PROJECTED - BASIC WING	1225 □'
ASPECT RATIO	2.0409
TAPER RATIO	.0999
THICKNESS RATIO - PARALLEL TO ℄ A/C	3.5 & 3.8
AIRFOIL SECTION NACA -0003.5-6-3.7 MOD CAMBER 0075 MOD	
NACA -0003.8-6-3.7 MOD CAMBER 0075 MOD	
ANHEDRAL OF CHORD PLANE	4°
INCIDENCE TO A/C DATUM	0°
TOTAL AREA OF ELEVATORS (AFT OF HINGE ℄) PROJECTED	106.9013 □'
ANGULAR MOVEMENT OF ELEVATORS ⊥ TO HINGE ℄	UP 30° DOWN 30°
TOTAL AREA OF AILERONS (AFT OF HINGE ℄) PROJECTED	66.5531 □'
ANGULAR MOVEMENT OF AILERONS ⊥ TO HINGE ℄	UP 19° DOWN 19°

FIN & RUDDER	
TOTAL AREA (ROOT CHORD ON WING ROOT CHORD)	158.7917 □'
ASPECT RATIO	1.0439
TAPER RATIO	.2982
THICKNESS RATIO (PARALLEL TO A/C DATUM)	4%
AEROFOIL SECTION NACA 0004-6-3.7 MOD	
TOTAL AREA RUDDER AFT OF HINGE ℄	38.1679 □'
ANGULAR MOVEMENT OF RUDDER ⊥ TO HINGE ℄	+30° -30°

AVRO AIRCRAFT LIMITED
MALTON ONTARIO

CLASS	MISCELLANEOUS REF DRAWING
DESCRIPTION	AERODYNAMIC THREE VIEW - A/C C105
GROUP	AVRO CF-105
SCALE	1/24 NOTED
DRAWING NO	7-0100-10

SPEED BRAKES.

The speed brakes consist of two separate flaps mounted on the underside of the fuselage centre section flush with the outside contour and are actuated by independent hydraulic jacks which rotate the flaps into the air stream.

ALIGHTING GEAR.
GENERAL DESCRIPTION AND COMPONENTS.

The alighting gear is the conventional type of tricycle undercarriage. The nose undercarriage retracts forward into a compartment below the pilot's floor. The main undercarriage folds sideways and forwards into a compartment inboard of its pivot axis inside the wing. The main gear consists of a two-wheel bogie. The main wheels are positioned relative to the centre of gravity of the airplane so that a line drawn from the aft C of G limit of the airplane (31% m.a.c.), and normal to the tail down static ground line, passes through the centre of the bogie chassis pivot axle; this line makes an angle of 15 degrees 20 minutes with a line drawn normal to the wing chord. The angle between the wing chord and the static tail up ground line is 3 degrees 55 minutes.

MAIN LANDING GEAR - DESCRIPTION.

This gear consists essentially of a two-wheel bogie. Retraction is effected about an inclined pivot axle, the motion of the gear being inboard and forward, so that the wheels in their retracted position are considerably ahead of their extended position. Due to the inclination of the pivot axle in plan view, it is necessary to rotate the bogie chassis about the leg centre line during retraction, by about 45 degrees. The whole gear will be made quickly detachable from the airplane. For this reason the main pivot shaft is designed so that it can be extracted through a detachable portion of the wing leading edge. It is proposed to use needle bearings wherever possible; this is in accordance with the best contemporary practice and results in lower friction losses during retraction and hence smaller hydraulic jacks.

SHOCK ABSORBERS.

The main shock absorber, which will be of the liquid spring type, is housed inside the leg casing. Total travel is in the order of 12 inches. In addition to the main shock absorber, there is a small damper strut, which connects the bogie chassis to the main leg and serves the following purposes:-

(a) To damp out oscillations of the bogie due to sudden load transference between the front and rear wheels during spin-up and braking while landing the airplane.

(b) To act as a spring to position the bogie in its correct touch-down attitude prior to landing.

(c) To act as a subsidiary to the main shock absorber during the early part of a touch-down.

NOSE LANDING GEAR.

This is a single leg levered suspension unit with a liquid spring shock absorber. The axle travel for shock absorption is 10 inches. Dual nose wheels are employed. Nose wheel steering is provided by a spring centred steering cylinder attached to the main leg strut and steering is controlled through a mechanical linkage between the rudder pedals and the steering valves and shimmy damping is provided.

CF-105 DEVELOPMENT - AERODYNAMIC PROBLEMS.

It became very apparent during wind tunnel testing, that in order to maintain stability and eliminate pitch-up, the wing would have to be extensively modified. For this reason, in November 1954, the outboard wing leading edge was extended by 10% with a 5% notch, the fin enlarged by 15% from 138 sq,ft. to 158.75 sq.ft. and its t/c increased to 4%. In June of 1955, further tests had indicated more modification to the wing, hence the outboard wing leading edge was drooped at 8 deg. 25 min. and the inboard wing leading edge was drooped at 9 deg. Other refinements included fuselage shaping by employing area rule, the undercarriage being redesigned, a larger nose for a 38 inch diameter scanner and the air intakes being refined.

Also in June, the J-67 engine had been canceled in the US, and the Pratt and Whitney J-75 was selected as a replacement.

During this development period, results of other tests had become known, and the fuselage was further split-up into manufacturing modules. These are as follows:-

a. Radome and probe section.

b. The nose electronics section.

c. The front fuselage section containing the cockpit and intakes.

d. The duct bay section containing ducts, fuselage fuel tanks, armament bay and electronic equipment.

e. The fuselage centre section containing the speed brakes and equipment.

f. The rear fuselage section containing the engines and afterburners.

g. The tail cone section. (The engine nacelles were separate.)

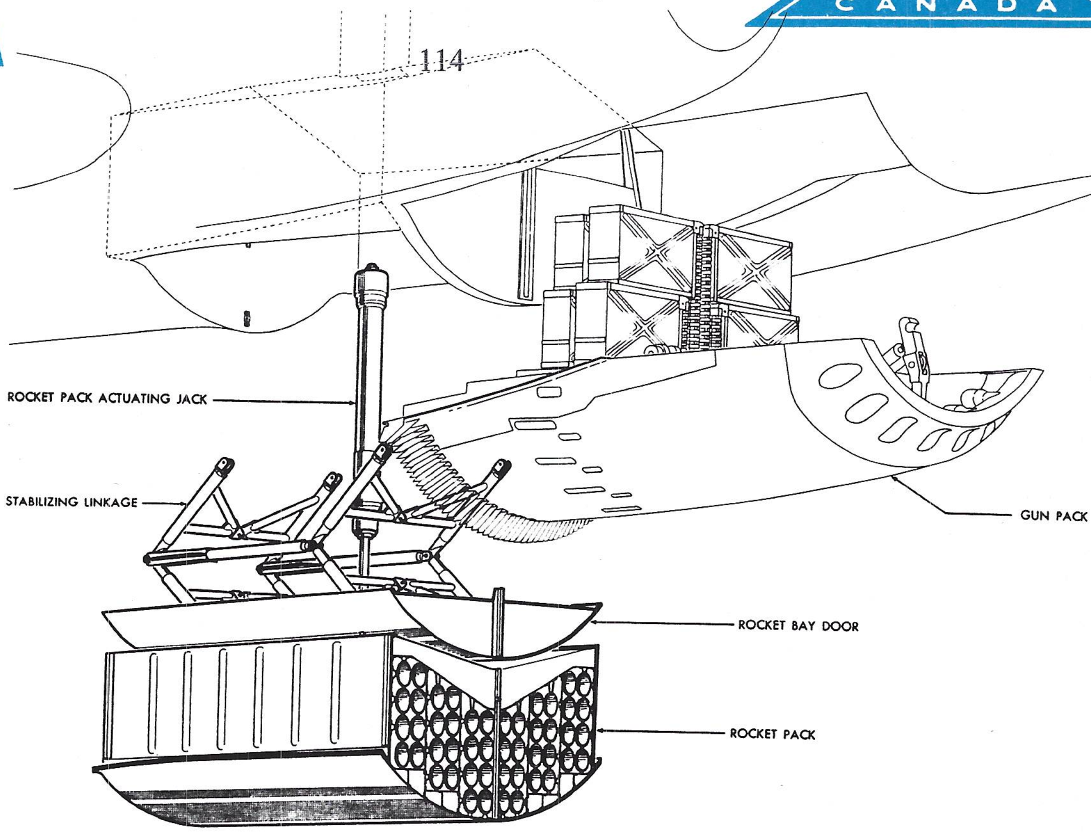
AIR-TO-AIR ROCKETS.

During the course of development of the CF-105, work was also progressing with the CF-100-4B and its extensible rocket pack. Severe buffeting, pitch-up and structural cracking had been experienced during flight test, and on the last flight, conducted by Avro test pilot Jan Zurakowski, internal explosions caused the controls to lock. The pilot ejected and the aircraft, the prototype, was a total loss. This accident of course, heralded the death-knell of this armament feature and thus it was eliminated from the CF-105 program in May of 1954.

INSTALLATION OF EIGHT FALCON MISSILES.

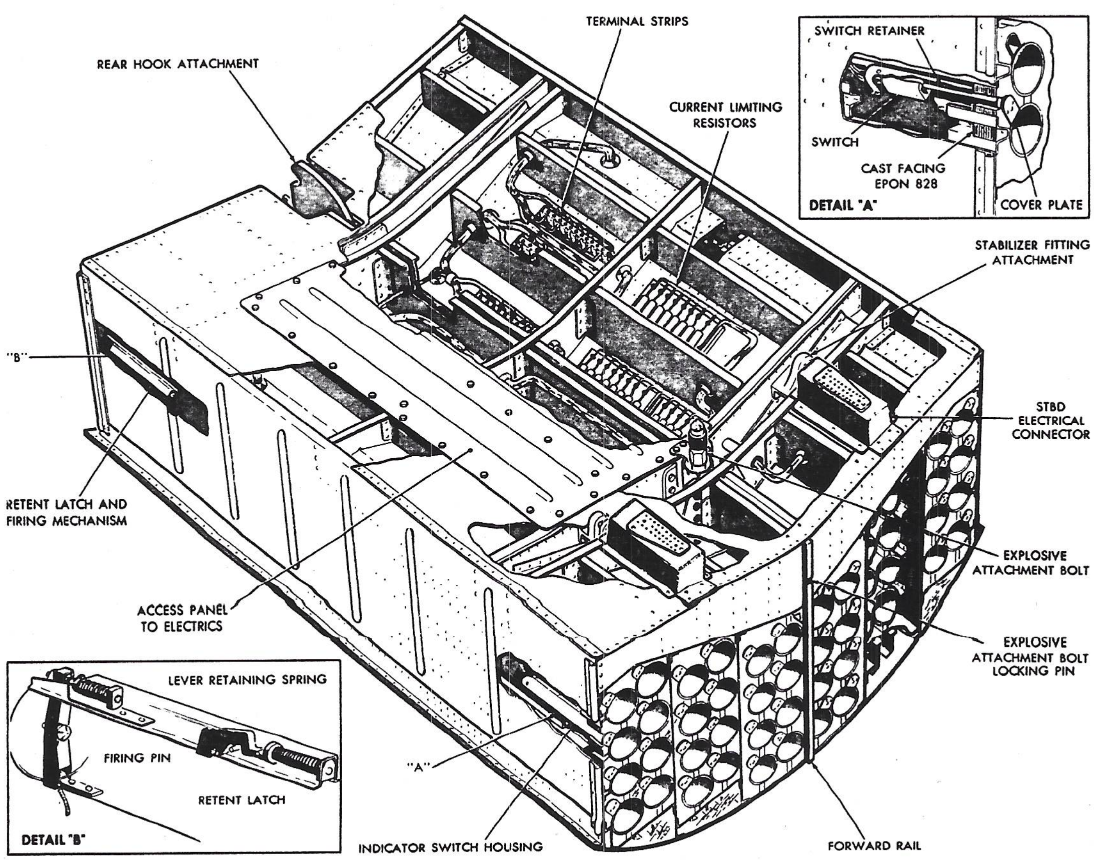
It was proposed to install eight Falcon GAR-1A or GAR-1C, or a combination of both, in a package container which fitted into the armament bay of the CF-105. This container would have included all actuating linkages, hydraulic accumulators and electrical connections necessary for functioning when removed from the aircraft. The container was designed for the quickest possible removal and replacement. It would have been interchangeable with the Sparrow container. The missile launcher lowering and raising linkage was hydraulically operated and there was a separate mechanism for each missile. The linkage would also open and close the doors and was designed to raise or lower a missile in 0.5 sec. The missiles were carried in lines of four abreast and angled at 3 degrees 20 min. to one another and 4 degrees nose down to the fuselage datum in the launching position. Facility was to have been provided to fire salvos of four or eight missiles. To achieve the specification performance and because of missile temperature limitations and the kinetic temperature rise due to speed, it was essential that missiles carried by the CF-105 be internally stowed. The opening of doors at high aircraft speeds involves the probability of buffeting being encountered. Auxiliaries, associated with the missiles, should be located close to them but are sensitive to vibration, therefor, they should not be located in the missile bays where they would not only be subjected to sudden vibration but air blast, pressure and temperature variation, but in a separate compartment where they would be shielded from these effects. It was also decided that the aircraft structure would be sufficiently strong enough to absorb the pressures and blast created by the opening of the missile doors, and not the missile structure itself.

Layout work showed that there was sufficient room between the front of the electronics bay, (STN 255) and the rear of the armament bay, (STN 485) was adequate to contain all the electronics and armament being considered, but would leave less space in the armament compartment for future development, such as the installation of the Sparrow missiles. It was decided however that the electronics bay would be extended to incorporate the missile auxiliaries but retaining however the facility of rapid removal of both electronics and missile packs in order to accommodate alternative armament.



CF-100 VENTRAL ROCKET PACK.

DETAILS OF VENTRAL ROCKET PACK.



MISSILE AND PACK DEVELOPMENT.

In addition to the development of the C-105 aircraft airframe, the Falcon missile and pack design also had to be developed.

Avro therefore proposed a program which was based on a logical step-by-step method, in which Stage One was to be completed and the results incorporated in the Stage Two specimen before Stage Two was commenced, and so on. On that basis, the program so stated is as follows:-

1. Single Missile Mock-up. Working model of actuating linkage for one missile in wood. To be kept up-to-date throughout the development program, incorporating changes as they were made. Mock-up constructed and kept up-to-date.

2. Single Missile Ground Working model of actuating linkage for Test Rig. One missile in metal. Capable of actuation at representative lowering speed. Mock-up to be constructed and full operation by the end of February 1955.

3. Wind Tunnel Tests. Model of aircraft with missiles attached and at various positions ahead of launchers. Tests commenced in March 1955.

4. Full Package Mock-up. Package mock-up in metal and wood containing actuation gear for 8 missiles. Capable of going through attack sequence at slow speed. To be manufactured by the end of April 1955.

5. Airborne Test Rig. Single missile actuating linkage to be installed in fuselage of CF-100.Installation work to commence in March 1955. Expected to be flight ready by May 1955.

6. Rocket Sled Test. Single missile actuating linkage to be installed on rocket sled. Proposed that tests commence in September 1955.

7. Full Missile Package. Full package to preliminary aircraft drawings. Proposed completion date of specimen December 1955. Static firing tests January 1956. If practical, specimen to be fired on rocket sled in March/April 1956.

Conclusions.

It was considered that for Avro to meet their objective of the CF-105 aircraft being ready for operational evaluation at the time the first aircraft were to be handed over to the RCAF, that the flight development program must be started with a missile installation which had as much development as was possible in the preliminary development program.

This outline of the proposed development program was presented. It was proposed to use the wind tunnel, mock-ups, ground test rigs, an airborne test rig and a test specimen mounted on a rocket propelled sled.

It was postulated that each of these stages was essential to attain the desired end, and that elimination of any one of the stages would interfere in the achievement of this aim.

History has recorded that the above was never completed as laid out as the RCAF changed its requirements constantly.

THE FALCON MISSILE.

The Hughes Falcon series of missiles is one of the largest and most varied to exist under a single name. Since the inception of the Falcon in 1950, it has been developed to accommodate several forms of guidance, varying warheads and its use has spread to the Armed Services of many nations. For this reason, each main version or sub-group is treated individually.

FALCON AIM-4 (GAR-1).

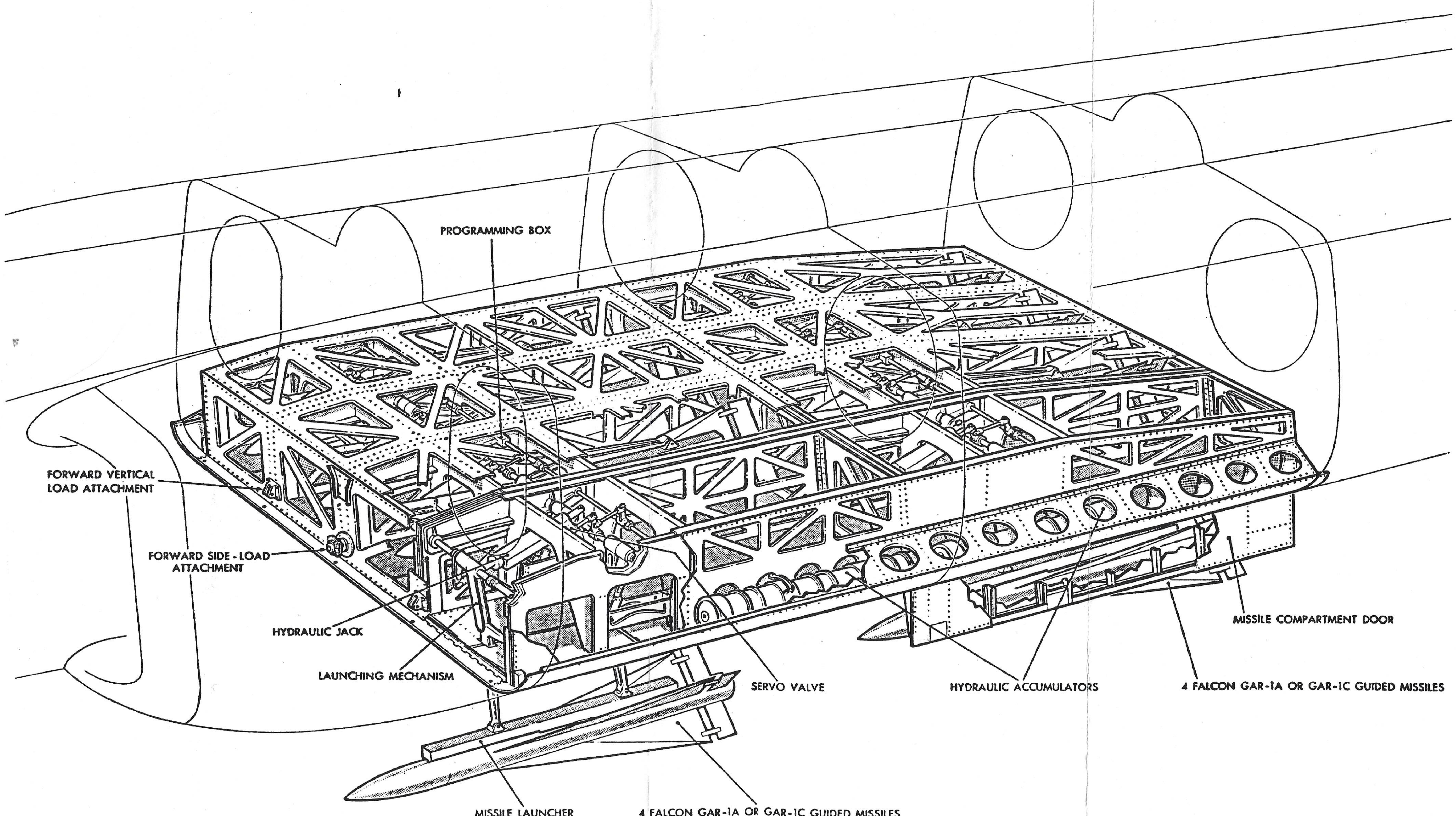
Originally developed as a joint venture by Hughes and the USAF with work starting on the project in 1947 with the first production models appearing in 1954. About 4,000 rounds were produced until development produced the AIM-4A (GAR-1D) of which about 12,000 rounds were manufactured. In operation, aircraft A1 radar is used to direct the aircraft to the missile launching point, taking into account the strength and stability of reflected radar data from the target and the missile's tracking capabilities, after which the radar seeker head in the missile causes it to home onto the reflected energy from the target. This entails the launch aircraft to keep the target in radar 'view'.

AIM-4A

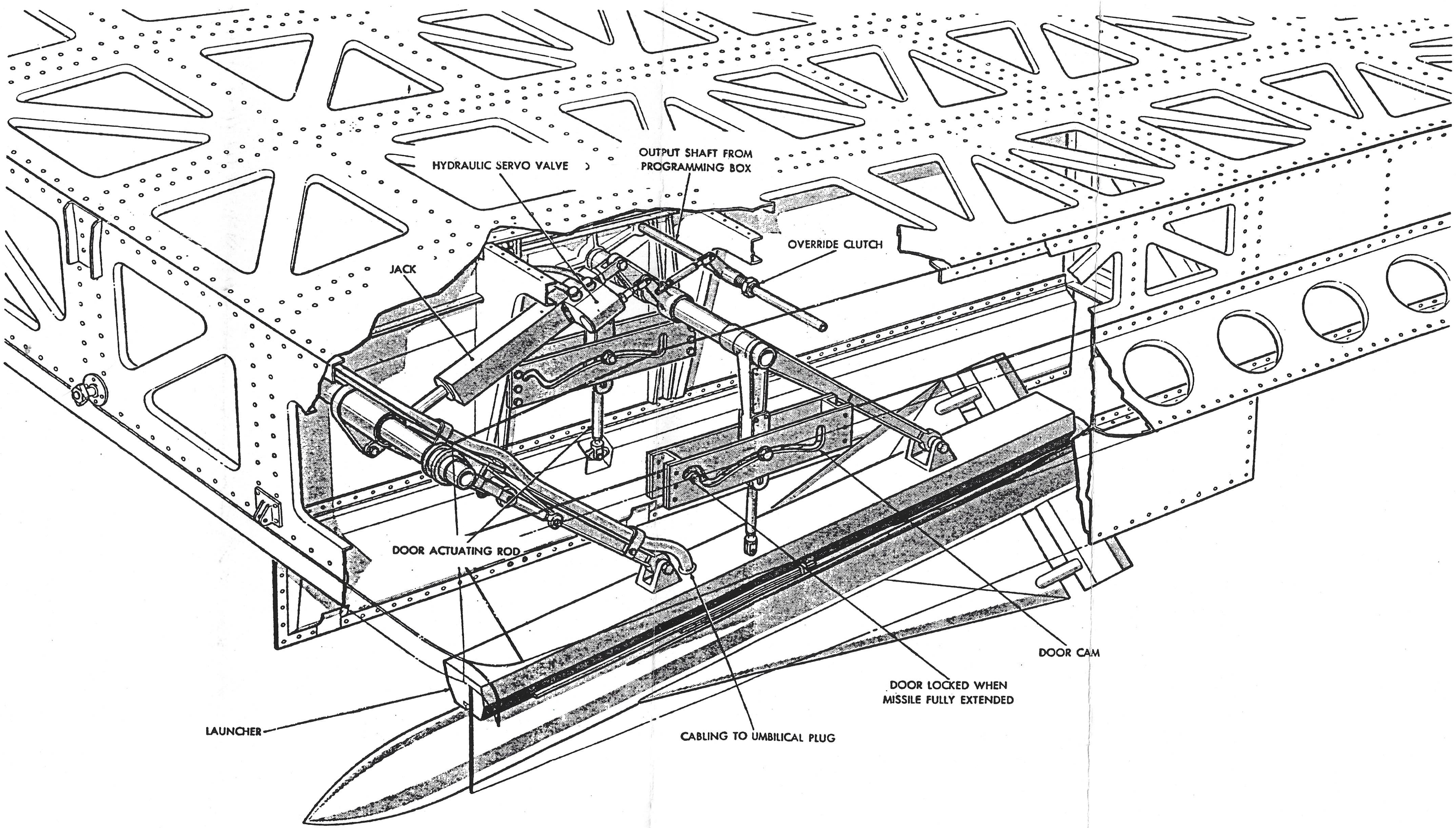
Length................7' 2"
Span...................24"
Diameter............6.4"
Weight...............140.5 lbs.
Range................. -
Speed................. -
Propulsion.......... -

FALCON AIM-4C (GAR-2).

Similar to the AIM-4A missile but with an infra-red guidance system instead of semi-active radar homing. The launch aircraft was guided to the target by



ARMAMENT INSTALLATION FOR FALCON GAR 1A OR 1C.



SINGLE MISSILE INSTALLATION. FALCON.

AI radar and ground tracking information to bring it within acquisition range of the missile's infra-red homing system. Unlike the radar guided AIM-4A version, after missile launch the attacking aircraft is free to break-off the engagement. The missile also possessed had a rear aspect attack capability. The AIM-4C was introduced in 1956 and some 16,000 rounds were manufactured before an improved model, the GAR-2A was introduced with improved infra-red equipment to give a wider operational environment. Over 10,000 rounds of this model were built. Dimensions and weights were similar to those of the AIM-4A.

FALCON AIM-4D. (GAR-2B).

Similar to the AIM-4C, but with the infra-red homing head of the larger AIM-4G Super Falcon. This gives better performance against high speed manoeuvring targets and confers all-aspect attack capability.

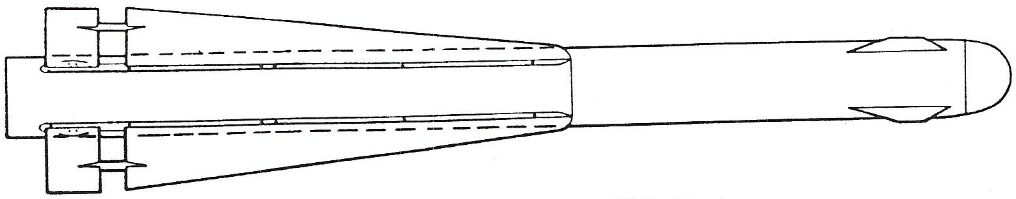
This version was selected as USAF standard at the time and thousands of the earlier models were up-graded to this new standard. The dimensions were similar to those of its forebears, but the weight was increased to 60 kg (132 lb). It had a solid fuel motor with a speed of Mach 4.

AIM-4D

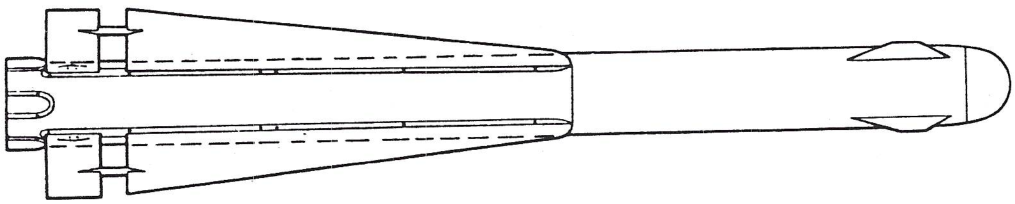
Length................6' 6 3/4"
Span...................20"
Diameter............6.5"
Weight...............134.5 lbs.
Range..................5 - 6 mi.
Speed..................Mach 4
Propulsion.........Thiokol M58A2 solid rocket
giving 3,900 lbs. thrust.

FALCON AIM-4E AND 4F (SUPER FALCON). (GAR-3).

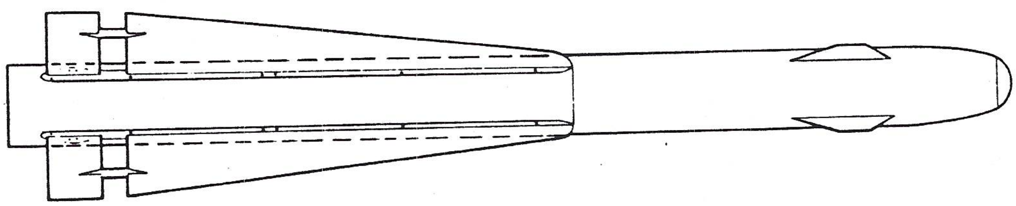
These two missiles represent an interim stage in the development of the Falcon series, coming between the AIM-4A and 4C and the AIM-26 models. In general configuration the AIM-4E more closely resembles the 4F. This was equipped with an improved radar guidance system providing increased accuracy and greater resistance to ECM. A new solid fuel, two level thrust rocket motor was installed to provide a high launching thrust followed by a lower level thrust to sustain missile velocity. An external feature was a 10 cm. probe fitted to the nose to improve missile aerodynamics. About 300 rounds were produced before it was replaced by the AIM-4F (GAR-3A).



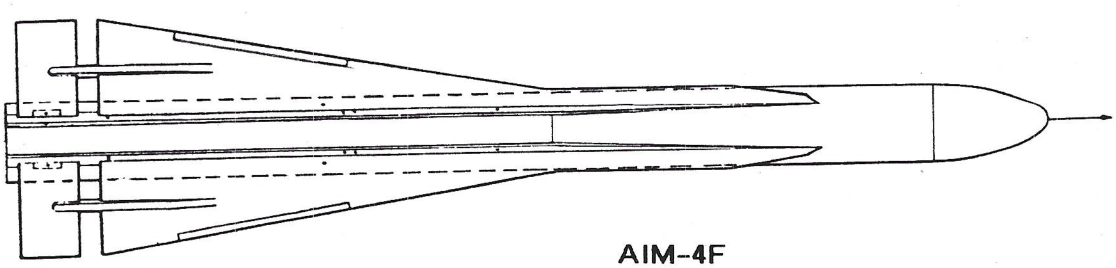
AIM-4A



AIM-4C

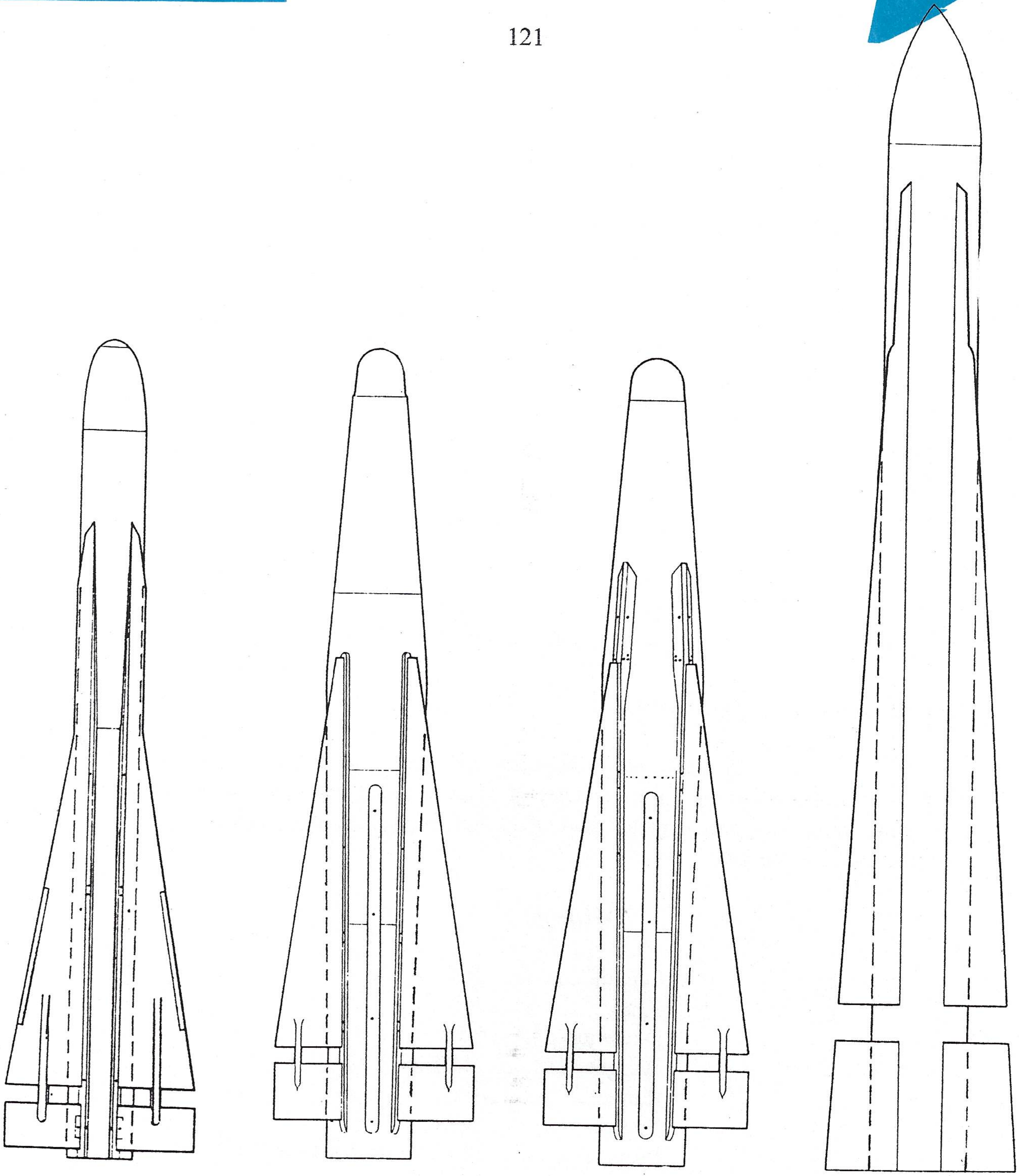


AIM-4D



AIM-4F

THE FALCON MISSILE FAMILY - 1



AIM-4G RB-27 AIM-26 AIM-47

THE FALCON MISSILE FAMILY - 2

AIM-4E

Length...............6' 6.75"
Span..................20 "
Diameter...........6.5"
Weight..............134.5 lb
Range................15 km
Speed................Mach 3
Propulsion.........Thiokol M60 solid rocket.

AIM-4F (Shown)

Length...............7' 2"
Span..................24"
Diameter...........6.57"
Weight...............150 lb
Range................15 km.
Speed.................Mach 3
Propulsion.........Thiokol M60 solid rocket.

FALCON AIM-4G (SUPER FALCON) (GAR-4A).

The AIM-4G is the infra-red counterpart of the AIM-4F missile. It is equipped with an infra-red detector system which enables it to lock-on to smaller targets at greater ranges than the earlier Hughes infra-red missiles and was introduced in 1959/60.

AIM-4G

Length................7' 2"
Span...................24"
Diameter............6.57"
Weight...............144.5 lb
Range................10 mi.
Speed.................Mach 3
Propulsion.........Thiokol M60 solid rocket.

FALCON AIM-4H.

This is a developed version of the AIM-4D which incorporates a laser proximity fuse, a new warhead and increased manoeuverability with the object of improving close range combat capabilities. The proximity fuse is installed in quadrants around the missile and produces a disc-shaped detection zone perpendicular to the missile axis. A solid state laser is used to detonate the warhead when the target is within a predetermined lethal range. After up-grading the AIM-4D missiles the USAF gave the new model the designation AIM-4H.

FALCON AIM-26 (GAR-11).

The AIM-26 versions of the Falcon, first appeared in 1960 and were developed by a major program to improve the capability of this successful series of missiles, the object being to achieve reliable head-on attack with radar homing instead of infra-red, the main advantage being all-weather capability and longer range. The warhead was nuclear thus giving a greater kill ratio with a 'near miss' than that with a conventional warhead.

AIM-26B

Length..............6' 9.5"
Span.................24"
Diameter...........11.5"
Weight..............253.5lb
Range...............10 mi.
Speed................Mach 2
Propulsion.........Thiokol M60 solid rocket giving 5,840 lb. thrust.

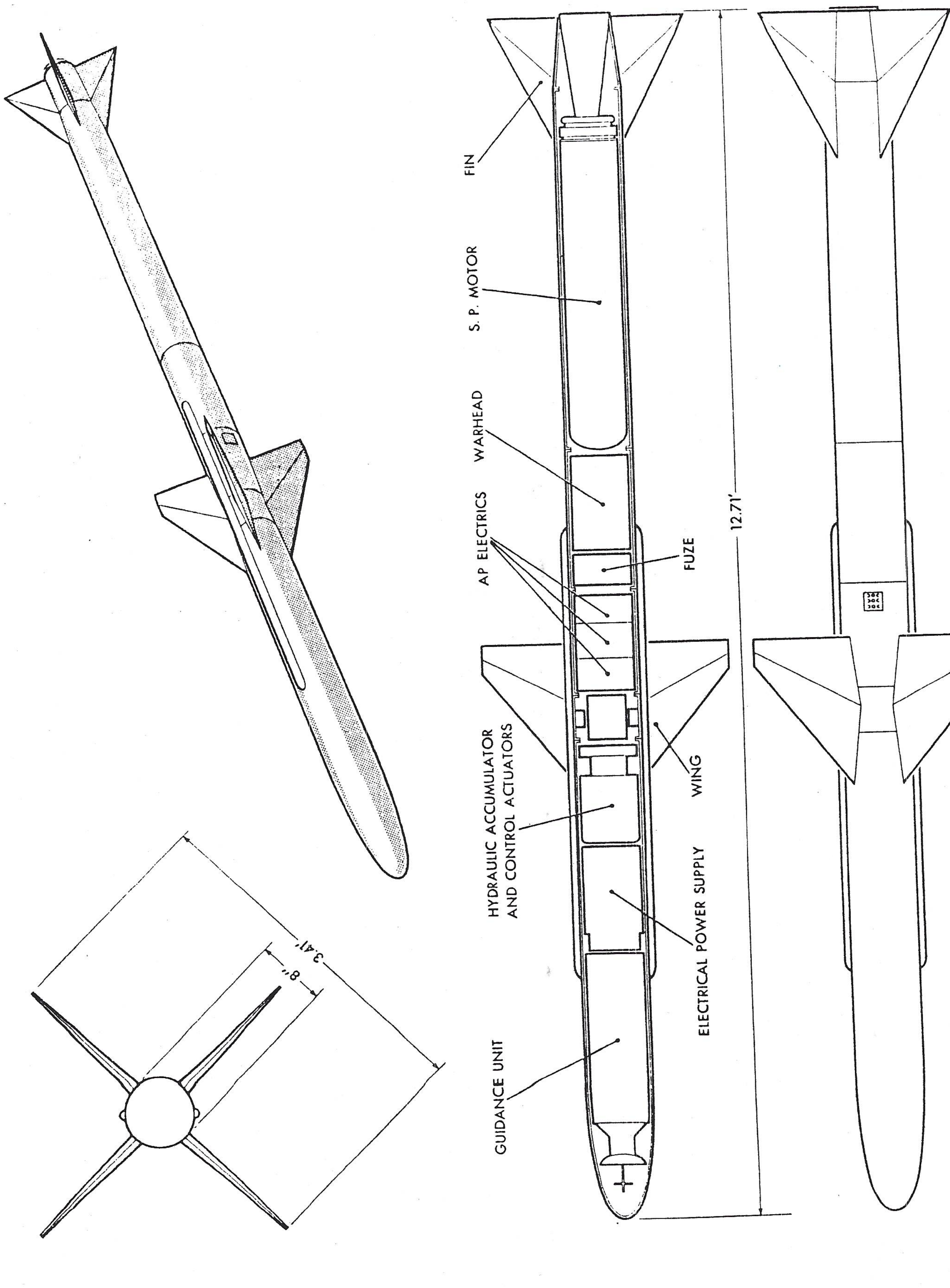
FALCON AIM-47 (GAR-9).

The AIM-47A was developed for the USAF as the GAR-9 as part of the YF-12A Mach 3 defence interceptor program. The missile is guided by a semi-active radar homing head using the Hughes AN/ASG-18 fire control system. It is by far the largest in the Falcon family and was capable of carrying either a nuclear or conventional warhead and has been credited with a speed of Mach 6 and a range of 100 km. It is not known how many were built.

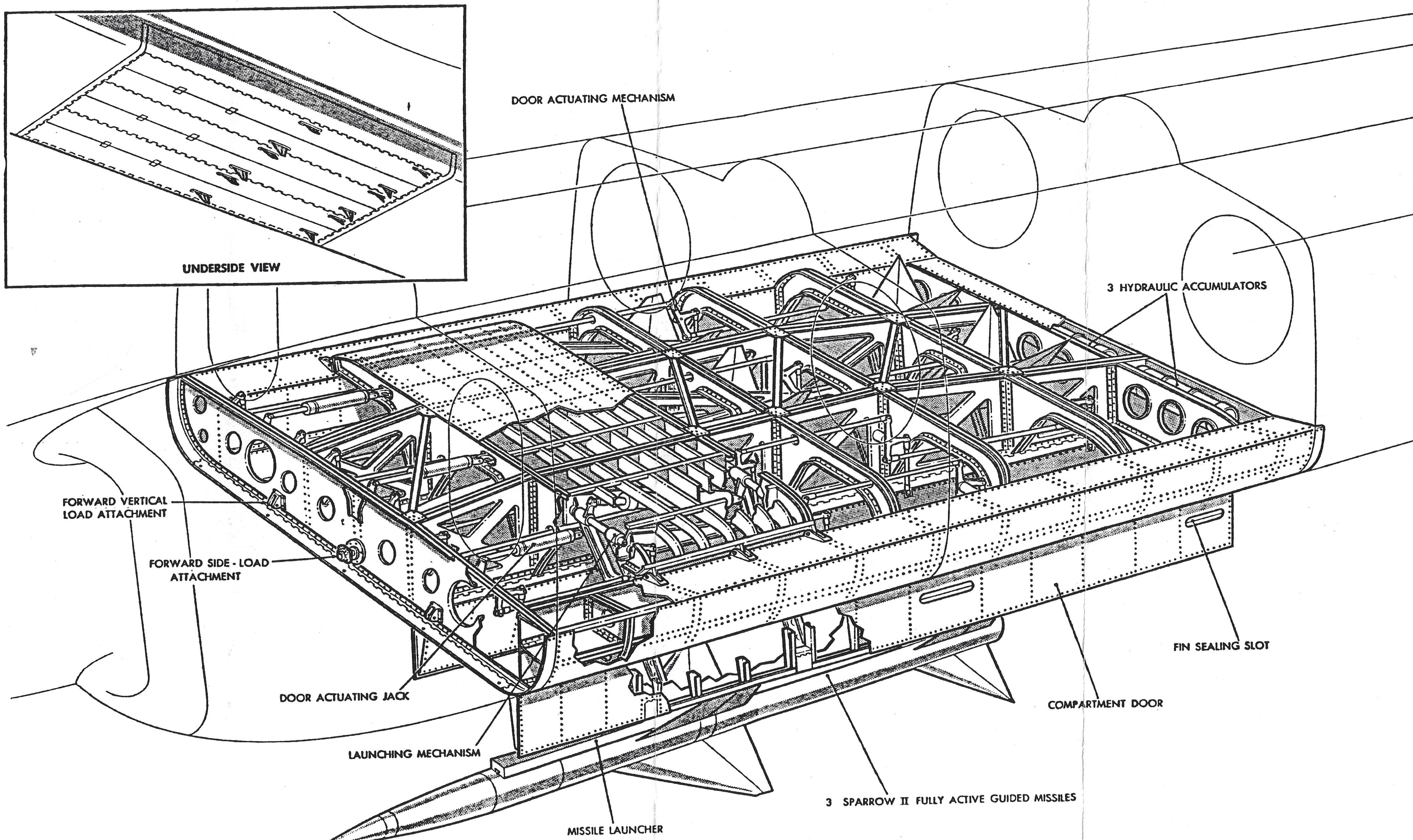
AIM-47A

Length.............10' 6"
Span................33"
Diameter..........13.18"
Weight.............798.6 lb
Range.............. -
Speed...............Mach 6
Propulsion......... -

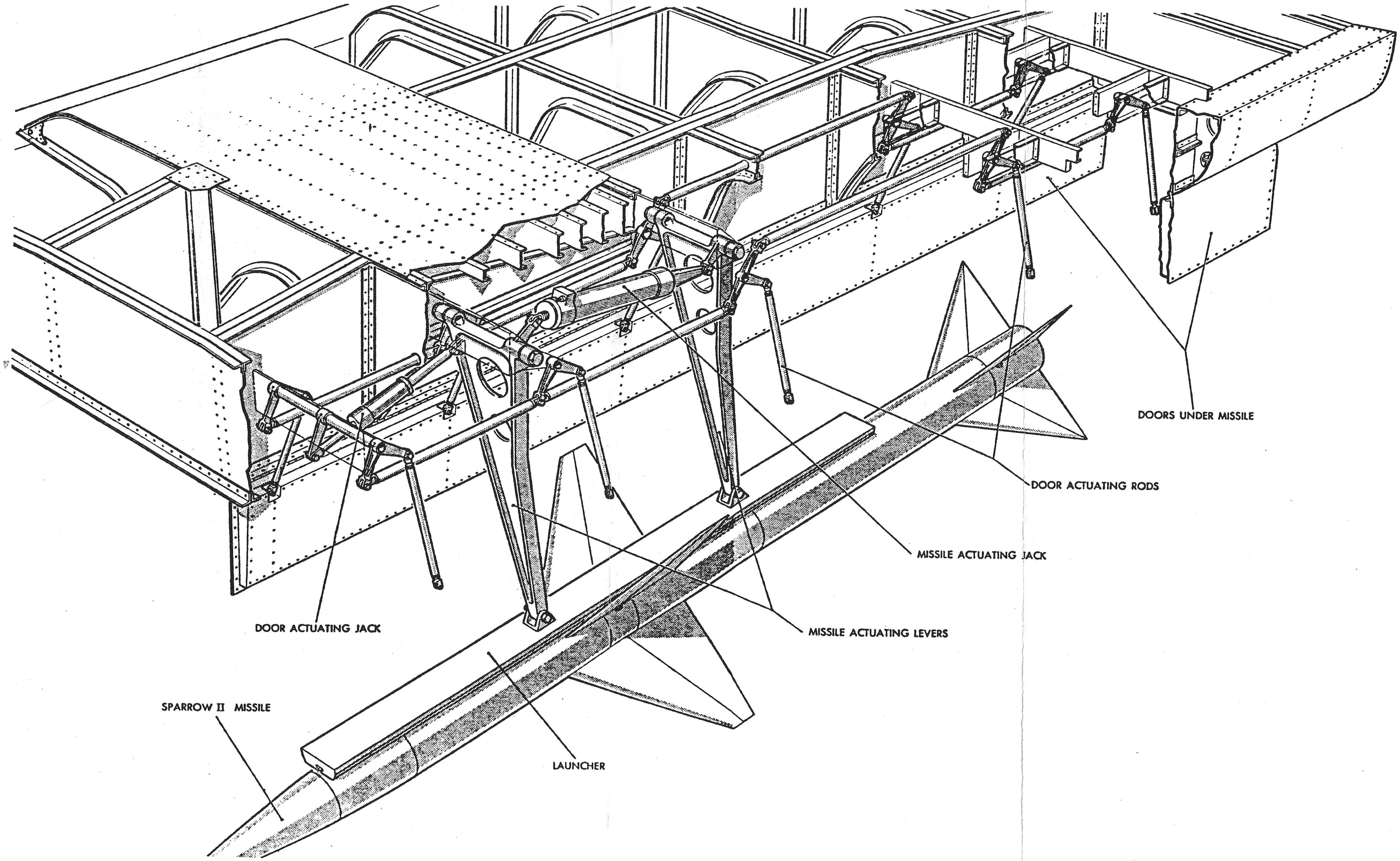
The Falcon at the time, 1954, had temperature limitations of 0 degrees F to 130 degrees F, and certain critical components within the missile were held to approximately 50 degrees F by heaters within the missile.



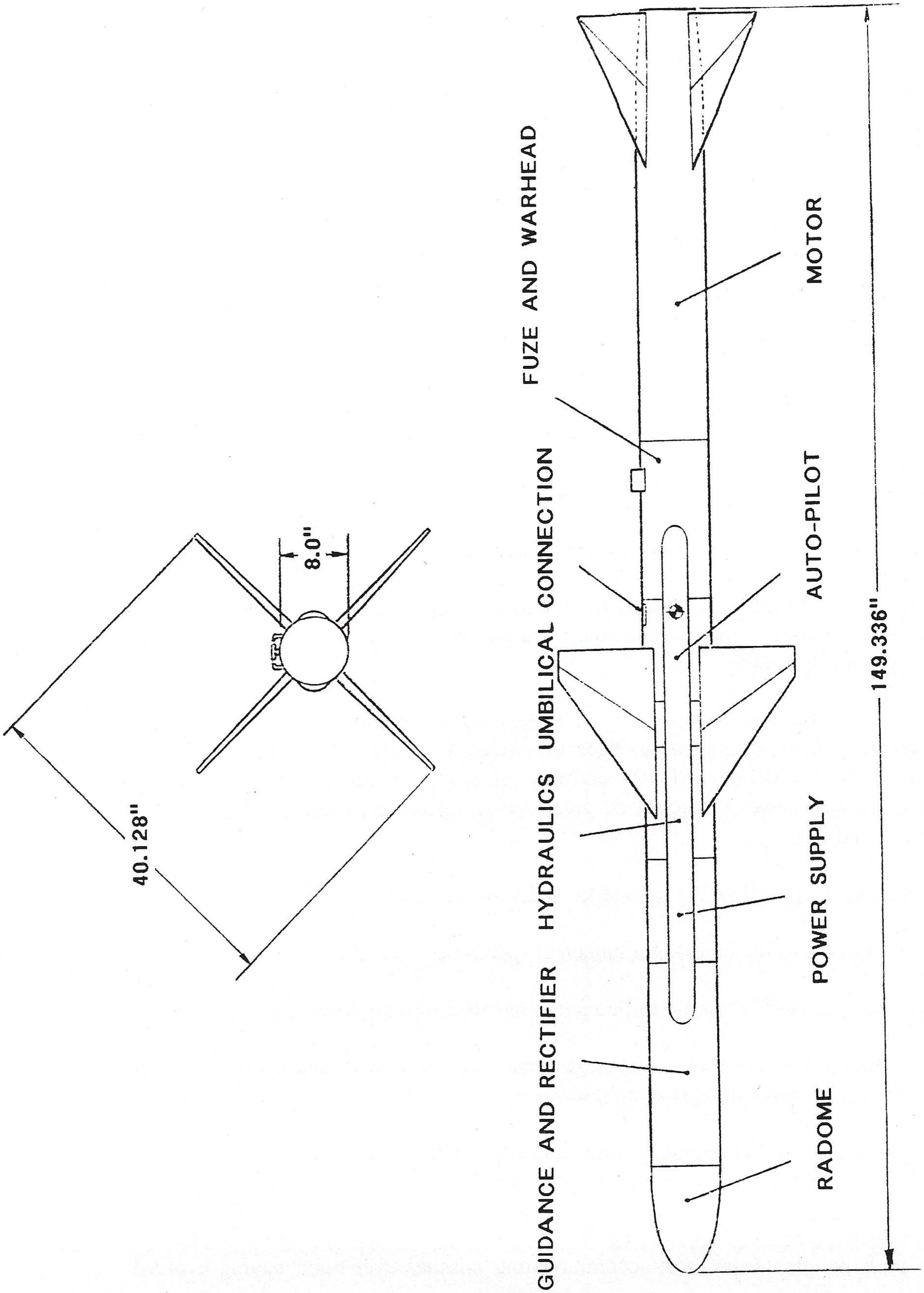
THE SPARROW 2 MISSILE



ARMAMENT ISTALLATION FOR SPARROW 2.



SINGLE MISSILE INSTALLATION. SPARROW 2.



THE SPARROW 2D MISSILE

In Canada at the time, (1953-54) the Falcon was known as the GAR-1A (Semi-active radar seeker) and GAR-1C (Infra-red). It is worthy to note here the development of the Falcon, as it was destined to be carried by the C-105 and later, to re-appear with the Arrow 2 in 1958 as a partial replacement for the canceled Sparrow 2.

THE SPARROW 2 MISSILE.

The Sparrow 2 is a fully active air-to-air guided missile weighing 413 lbs. at launch. It is 155.5 inches in length, has a body diameter of 8 inches and a wing span of 40 inches. It has temperature limitations of 0 degrees F to 130 degrees F, but during readiness periods and use, certain critical components are maintained at operating temperature by internal heaters.

The missile is equipped with two hooks and a button for attachment to its launcher. The launcher is of the rail type and weighs approximately 36 lbs. A detent mechanism is contained in the launcher.

Missiles are normally ripple fired at intervals of approximately 1/2 second. The Sparrow 2 is designed for external carriage under the wings of aircraft flying at subsonic and supersonic speeds and for launch at altitudes up to 60,000 ft. Being fully active and guided from launch, the missile requires to be locked on to the target prior to launch.

The problem of stowing three of these missiles internally in the CF-105 and extending them for launch has been investigated in detail. The suitability of the missile for use with the CF-105 has however still to be established, and Avro was anxious that Douglas Aircraft be given the go ahead to proceed with studies to determine this.

Among the points which require to be determined are:-

1. Suitability of the missile for launch at speeds up to M=2.0

2. Suitability of the missile for launch in the 50,000 to 60,000 ft. region.

3. Effect of the length of the fuselage ahead of the missile blanking off the target during an attack and preventing lock-on.

4. Possibility of locking the missile controls during an adequate period immediately after launch to prevent collision with the forward portion of the fuselage.
   The Sparrow, with Douglas as the prime contractor at this time, later to have a Raytheon homing head and be of General Dynamics manufacture in the US, is perhaps one of the most accommodating missiles ever built, having evolved

through beam-riding and active-radar versions in the US to reach the later versions semi-active variants. The AIM-7A Sparrow 1 had been briefly deployed from 1955 on the US Navy's McDonnell F3H Demon fighters until replaced by the semi-active version. The active radar version, the AIM-7B Sparrow 2 was canceled in 1957, (hence the demise of the Canadian Astra system). The Sparrow 3 series has since progressed through the AIM-7D,-7E (Sparrow 3B) and -7E2 to reach the AIM-7F, and updated version developed for the new generation of USAF and USN fighters. The Sparrow is a single stage missile powered by a solid propellant rocket motor and is steered by mid-body wings, and homes onto radar energy which is emitted by the launch aircraft and then reflected back from the target. The AIM-7F, development of which began in January of 1972, entered service in the mid-seventies and incorporated a number of improvements. The maximum range was virtually doubled and a heavier warhead was carried. A later version was equipped with an advanced mono-pulse seeker (AMS), Raytheon being selected as the prime contractor for this homing head. The AMS entered service in the early 1980's and had greater resistance to electronics counter-measures and allowed the Sparrow to snap down and intercept targets flying against a background of clutter. Production of the AIM-7F was shared by Raytheon and General Dynamics with some 19,000 missiles being built for the USAF and USN by 1985.

The particulars of the Sparrow 2 missile (1955) are as follows:

Length................12.6 ft.
Span....................3 ft. 4 in.
Diameter............8 in.
Weight...............389 lb.
Range.................2.8 - 4.5 mi.
Speed..................Mach 2 - 2.5.
Warhead..............45 lb. fragmentation type.
Proximity fuse.
Engine................Aerojet solid fuel
7,800 lb. thrust.

The particulars of the AIM-7E2 are as follows:

Length................12 ft.
Span....................3 ft. 3 in.
Diameter............8 in.
Weight...............450 lb.
Range................30 mi.
Speed.................Mach 4.
Warhead............66 lb continuous rod.
Propulsion.........Aerojet Mk52 or Rocketdyne Mk38

The particulars of the AIM-7F are as follows:

Length................12 ft.

Span....................3 ft. 3 in.
Diameter.............8 in.
Weight................500 lb.
Range..................62 mi.
Speed...................Mach 4.
Warhead..............88 lb. continuous rod.
Propulsion..........Hercules Mk48 or Aerojet Mk65.

Today, the Sparrow has been updated by the state of the art. The AIM 120 AMRAAM was developed by the Hughes Aircraft Corporation in time for "Desert Storm", where three combat firings resulted in two kills, thus demonstrating its effectiveness.

There followed the AIM 120C Compressed Carriage AMRAAM which has cropped wings and fins together with a slightly smaller body diameter, thus enabling it to be carried by the new USAF F-22, a fighter slightly smaller than the Arrow.

The F-22 has three weapons bays. Two are located immediately behind the cheek intakes, each covered by two separate doors and containing an AIM-9 "Sidewinder" missile. A third main weapons bay is located on the underside of the fuselage and can carry four to six of the new AIM-120C AMRAAMs. This main bay is covered by two hinged doors, similar in design to those of the F-106, each consisting of two lengthwise fold back panels. The AAMs are carried on trapeze-like carraiges. Such an arrangement could have been carried by the Arrow today.

Details of the F-22.

Length......................64 ft - 6 inches.
Span......................... 43 ft - 0 inches.
Height.......................17 ft - 9 inches.
T/C ratio....................3.8% at root.
Speed.........................Mach 2.2.
Service Ceiling.........65,000 ft. plus.

Details of the AIM-120C AMRAAM missile.

Length......................143.78 inches.
Span.........................20.70 inches.
Body Dia..................7.0 inches.
Weight.....................344.3 lbs.
Range.......................35 - 47 miles.
Speed.......................Mach 4.
Propellant................Hercules solid rocket.
Warhead..................48 lbs HE directed fragmentation.
Steering..................Tail fins.

For comparison purposes, illustrations of the F-22 are provided.

MISSILE ATTACK MODE.

Because of the low-kill probability associated with firing one Sparrow 2 missile (less than 0.5), it was proposed that there shall be one attack mode only and that this would be ripple firing of all three missiles. The slinging, stowing and firing of the missiles was to be done in a similar manner to that of the Falcon missiles.

ALTERNATE ARMAMENT.

The packages presently proposed for both the Falcon and the Sparrow would pick up on identical aircraft fittings and would be mechanically interchangeable. To change the armament of an aircraft would involve changing the auxiliaries associated with the missiles.

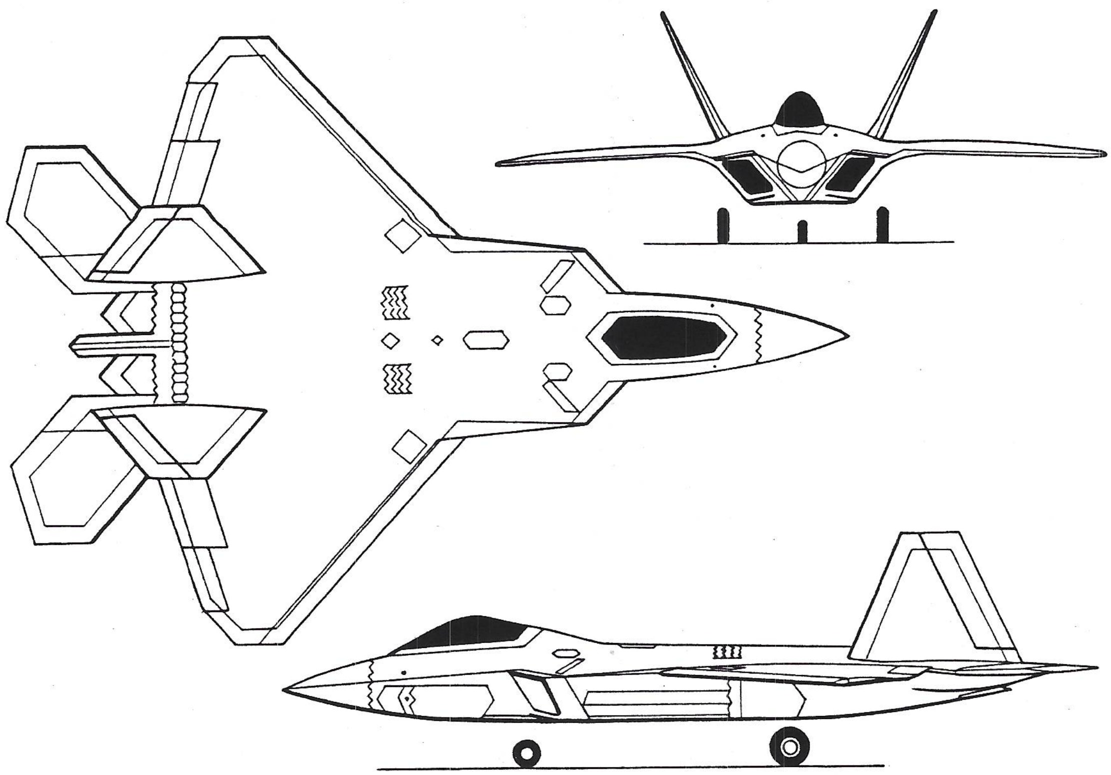
TIE-IN WITH FIRE CONTROL SYSTEM.

The items comprising the missile tie-in to the fire control system would be housed in the electronics compartment forward of the armament bay. The crate containing these items would be mounted on the starboard side of the compartment. By opening the door through approximately 90 degrees, the working surfaces of all the items would be exposed for trouble shooting.

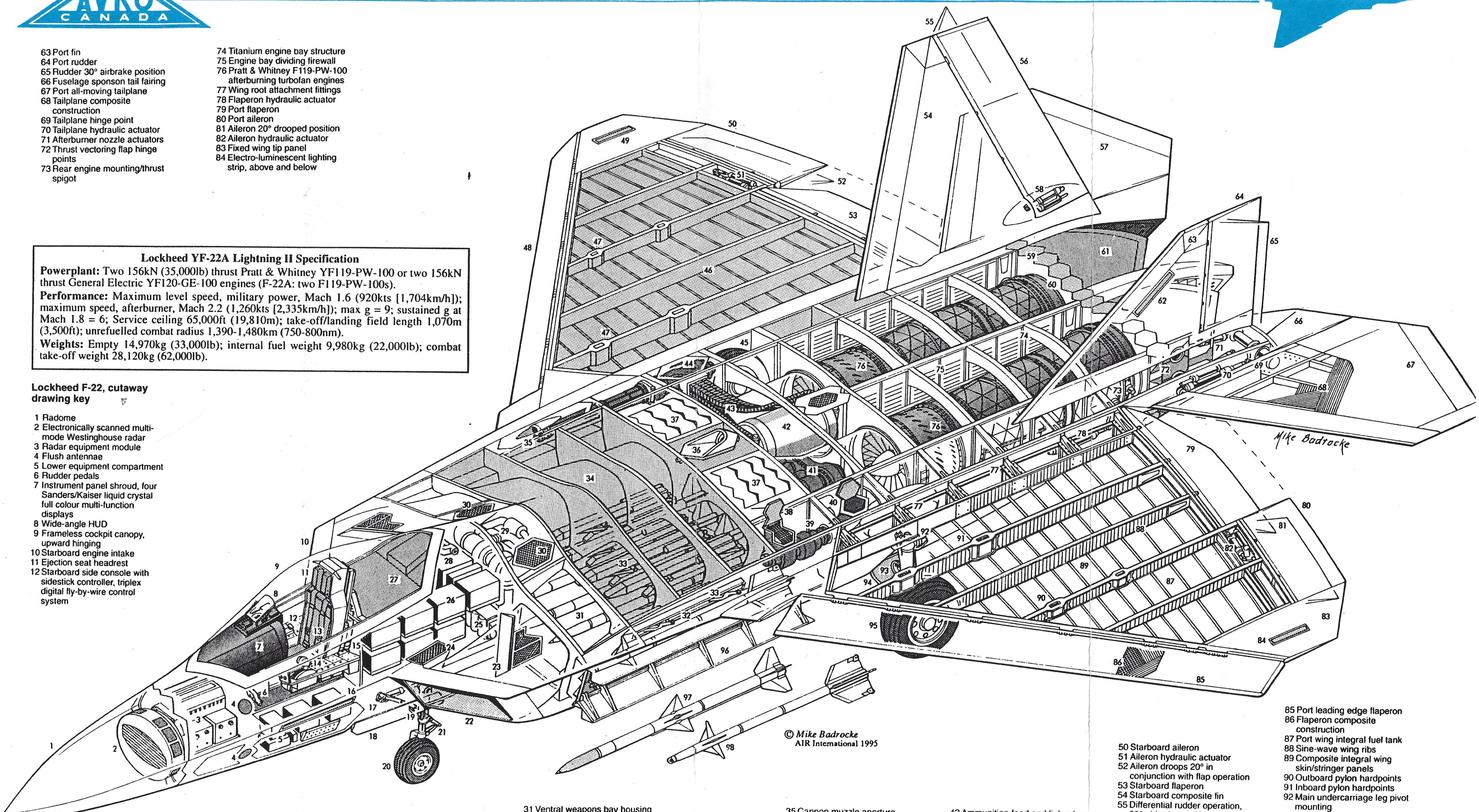
SERVICING AND RE-ARMING.

Although a packaged armament installation introduces the possibility of re-arming by changing packages, Avro was not at that time certain that this is the optimum method of re-arming. In the design everything possible was done to ensure rapid interchange. It was the intention to offer the package into the aircraft by lifting it vertically on a dolly into the armament bay. The dolly would be raised by means of cables attached to the aircraft fuselage. The alternate method of re-arming would have been to load individual missiles on to the launchers. Raising and lowering controls would have been provided in an accessible position on the pack. If ground electrical and hydraulic supplies are plugged in, the missile launchers could be raised or lowered at about one fifth the normal operating speed. If any servicing or inspection was required inside the bays the missiles and/or doors could be stopped at any part of their stroke by releasing the control button. Visual evidence of firing circuit safety would have been be provided by a plug containing all firing leads which could hang below the aircraft skin during re-arming and servicing. This plug was be located in the same region as the control buttons. Any major servicing or maintenance work on the package could be done in the hanger after removal of the package from the aircraft. By connecting hydraulic and electrical supplies the linkages could be functioned when the package was mounted in a servicing stand.

The real work in the design of a complex aircraft such as the C-105 which was to become Arrow, begins only after the basic concept is formulated and accepted. The many trials, tests, decisions, indecisions, frustrations, differences of opinions, delays, changes etc, that were encountered on the rocky road to perfection are investigated in the next chapter, "Refining the CF-105". For reasons of the wealth and plethora of information involved, a tabulated presentation is given so that the reader can work progressively through the events as they happened.



3 Views of the Lockheed F-22A.



Lockheed YF-22A Lightning II Specification

Powerplant: Two 156kN (35,000lb) thrust Pratt & Whitney YF119-PW-100 or two 156kN thrust General Electric YF120-GE-100 engines (F-22A: two F119-PW-100s).

Performance: Maximum level speed, military power, Mach 1.6 (920kts [1,704km/h]); maximum speed, afterburner, Mach 2.2 (1,260kts [2,335km/h]); max g = 9; sustained g at Mach 1.8 = 6; Service ceiling 65,000ft (19,810m); take-off/landing field length 1,070m (3,500ft); unrefuelled combat radius 1,390-1,480km (750-800nm).

Weights: Empty 14,970kg (33,000lb); internal fuel weight 9,980kg (22,000lb); combat take-off weight 28,120kg (62,000lb).

Lockheed F-22, cutaway drawing key

1 Radome
2 Electronically scanned multi-mode Westinghouse radar
3 Radar equipment module
4 Flush antennae
5 Lower equipment compartment
6 Rudder pedals
7 Instrument panel shroud, four Sanders/Kaiser liquid crystal full colour multi-function displays
8 Wide-angle HUD
9 Frameless cockpit canopy, upward hinging
10 Starboard engine intake
11 Ejection seat headrest
12 Starboard side console with sidestick controller, triplex digital fly-by-wire control system
13 Pilot's 'zero-zero' ejection seat
14 Engine throttle lever, Hands on Throttle and Stick (HOTAS) controls
15 Canopy jack
16 Electro-luminescent lighting strip
17 Nose undercarriage breaker strut and retraction jack
18 Nosewheel doors
19 Taxying lights
20 Forward retracting nosewheel
21 Torque scissor links
22 Port engine fixed geometry air intake
23 Intake suction relief door
24 Boundary layer air spill duct
25 Air system heat exchanger
26 Main avionics equipment bay
27 Canopy rear deck, structural provision for two-seat version
28 Canopy hinge point
29 Air conditioning equipment bay
30 Heat exchanger spill ducts
31 Ventral weapons bay housing four AIM-120 AMRAAM missiles, two of which can be replaced with 1,000lb Joint Direct Attack Munitions (JDAM)
32 Lateral weapons bay housing single AIM-9 Sidewinder
33 Hinged pantographic missile launchers
34 Forward fuselage integral fuel tanks
35 Cannon muzzle aperture
36 Rotating flight refuelling receptacle
37 Secondary air intake doors
38 Hinged APU intake
39 Allied-Signal airborne Auxiliary Power Unit (APU)
40 APU exhaust
41 Airframe mounted accessory equipment gearbox
42 Ammunition magazine
43 Ammunition feed and link return chutes
44 M61A2 20mm six-barrel rotary cannon
45 Starboard mainwheel, stowed position
46 Starboard wing integral fuel tank
47 Wing pylon hardpoints
48 Starboard leading edge flap
49 Electro luminescent light strip
50 Starboard aileron
51 Aileron hydraulic actuator
52 Aileron droops 20° in conjunction with flap operation
53 Starboard flaperon
54 Starboard composite fin
55 Differential rudder operation, 30° airbrake position
56 Starboard rudder
57 Starboard all-moving tailplane
58 Rudder hydraulic actuator
59 Nozzle sealing plates
60 Two-dimensional convergent/divergent afterburner nozzle
61 Upper thrust vectoring flap
62 Electro-luminescent lighting strip
63 Port fin
64 Port rudder
65 Rudder 30° airbrake position
66 Fuselage sponson tail fairing
67 Port all-moving tailplane
68 Tailplane composite construction
69 Tailplane hinge point
70 Tailplane hydraulic actuator
71 Afterburner nozzle actuators
72 Thrust vectoring flap hinge points
73 Rear engine mounting/thrust spigot
74 Titanium engine bay structure
75 Engine bay dividing firewall
76 Pratt & Whitney F119-PW-100 afterburning turbofan engines
77 Wing root attachment fittings
78 Flaperon hydraulic actuator
79 Port flaperon
80 Port aileron
81 Aileron 20° drooped position
82 Aileron hydraulic actuator
83 Fixed wing tip panel
84 Electro-luminescent lighting strip, above and below
85 Port leading edge flaperon
86 Flaperon composite construction
87 Port wing integral fuel tank
88 Sine-wave wing ribs
89 Composite integral wing skin/stringer panels
90 Outboard pylon hardpoints
91 Inboard pylon hardpoints
92 Main undercarriage leg pivot mounting
93 Landing lamp
94 Mainwheel leg door, upward hinged mainwheel
95 Port mainwheel
96 Lateral weapons bay doors, open
97 AIM-120 Advanced Medium Range Air-to-Air Missile (AMRAAM)
98 AIM-9L/M Sidewinder air-to-air missile