THE AVRO ARROW

To Doug & Dowette
Best Wishes
Love Dugelby

A BOOK BY

THOMAS B DUGELBY

CHAPTER 3

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REFINING THE CF-105. 3

CF-105 GENESIS.

After the optimum size and basic configuration of the aircraft had been selected, Avro then embarked on the task of the design, testing and production problems of such a sophisticated airplane.

The following tabulated account of events will no doubt give the reader an insight to the many problems and frustrations encountered.

SCHEDULE OF EVENTS. Sept/53 - Dec/54.

Sept/53

- Release of preliminary project schemes to drawing office commenced.

- Orenda Engines meeting to discuss P.S.13 installation in C-105.

- Amendment No.1 to Ministerial Direction received. Time limit extended to Nov.30/53.

Oct/53

- First flight of production CF-100 Mk4.

- Amendment No.2 to Ministerial Direction received. Financial authorization increased to $500,000. Time limit cut back to Oct.20/53. This effectively canceled the program, due to Avro/NAE controversy an 2 x 30" engine philosophy. DDP officially stopped further work on C-105 as of Oct.20/53, but authorized Avro to maintain a small staff to be charged to overload until further decision.

Nov/53

- NAE issue report LP-87 "Assessment of the Performance Charactoristics of the proposed Avro C-105/1200 All-Weather Supersonic Fighter Aircraft". Study of Avro brochure P/C-105/1 May 1953.

(a) Considerable differences between NAE and Avro drag estimates.

(b) Aircraft fails to meet RCAF combat performance based on NAE drag.

(c) Aircraft fails to meet RCAF minimum combat radius. Found to be only 142 naut.mi. with 12,400 lb. fuel, RB-106 and NAE drag.

- Note on Falcon kill probability. Micro-wave salvo achieves 90% probability under

most circumstances.

Dec/53

- Manufacturing Division state advantages of manufacturing C-105 aircraft on a production basis including prototypes and development aircraft.

- Avro submit proposal to RCAF for design, development, tooling and manufacture of two prototype aircraft. This amounted to confirmation of the $22,925,000 requested in June/53 for the costs up to first flight of the second aircraft. Engineering estimate total cost of program to be $22,664,513, Nov/53.

- Amendment No.3 to Ministerial Direction received. Time limit extended from Oct.20/53 to Oct.23/53 to pick up end-of-week costs.

Mar/54

- Amendment No.4 to Ministerial Direction received. Reinstated C-105 program to design, develop and manufacture All-Weather Fighter To specifications AIR 7-3 and AIR 7-4 (advance data received). Manufacturing program authorized but number of aircraft not specified. Financial authority $1,325,000 cum. (increase of $825,000). Time limit Mar.31/54 (1 month) due to lack of commitment authority.

- Avro internal policy to proceed with P.S.13/Gyron studies.

- United Kingdom engine situation reviewed by G. Hake and RCAF.

- Orenda/Avro meeting to discuss P.S.13 final nozzle.

- About this time, RCAF studied all prospective engines for C-105 and concluded that the Rolls-Royce RA.19R most suitable for prototype with RB-106 for production version. RCAF omitted P.S.13 in study.

- Second Development and Co-ordination Committee decides:

(a) The design of the C-105 should continue to be based on the RB 106 and J 67 class of engine keeping in mind that the P.S.13 may come along.

(b) The higher mass flow J 57 may power the prototype aircraft and perhaps some production aircraft.

(c) Data on the higher mass flow J 57 engine to be sent to Avro.

- Avro review engine situation:

(a) RB 106-not ready for prototype.

(b) B.OL.4-Bristol do not promise full a/b.

(c) J 67-should be ready for prototype and production versions.

(d) P.S.13-good on paper but - could not be ready before fourth aircraft.

(e) Gyron too big, duct/nacelle problems, subsonic performance only, without after burner.

(f) J 57-suitable for prototype-performance well below specification. With the J 57 however, conversion to the RB 106 not too difficult if increased and revised mass flows of J 57 are achieved.

- RB 106 weights increasing (1,600 lb-2 engines). C-105 gross design weight now up to 56,000 lb.

- Engine intake throat area fixed at 5.3 sq.ft. for J 67 engine.

- Prototype to be designed for J 67 only. Need not accommodate P.S.13.

- Fourth Development and Co-ordination Committee decides that from an inspection of the J 67 engine installation drawings the scheme was satisfactory.

- Missile launch not provided for in hydraulic system though power was available if necessary. Feed into main power control hydraulic system with reduced response during missile firing.

- Certain decisions on C-105 components. Control actuated by 4,000 psi hydraulic system from 4 pumps, two per engine. Additional pump for services, (undercarriage, dive brakes, etc).

April/54

- Amendment No.5 to Ministerial Direction received. Financial authority increased to $1,703,600 (increase of $378,000). Time limit extended to Mar.31/55 which re-activate the program by removing the original one month time limit.

- Amendment to Ministerial Direction received. Time limit in Amendment No.3 (to Oct 23/53 and Mar.1/54 were not previously authorized by DDP).

- Seventh Steering Committee agrees to two prototypes inadequate. Request Avro proposal for increased number.

- Estimated date of first flight of prototype to Sept./56. (In Dec./52 it was estimated at Jan./56).

- Design temperature limits proposed as 20 minutes at 250 degrees F at one hour intervals for 1,000 cycles. Maximum limit 10 minutes at 380 degrees F.

- Decision to use Martin-Baker light weight seat.

- A/C F.R.Banks suggests RB 106 will not be ready in time for C-105. Advises Olympus or Gyron as best substitutes. Bristol not prepared to provide full re-heat, therefore Gyron remains. Mass flow similar to P.S.13 and conversion to production P.S.13 versions of C-105 should consequently be simplified.

- Engines for prototype will be Curtiss-Wright J 67 due to earlier development than other engines and under pressure for the F-102. Available May/55. Gyron mass flow requires major duct re-design, no afterburner. J 75 is heavy (6,100 lb.) and has fixed nozzle. Not ready in time for C-105. A re-evaluation of C-105 with J 67 engines was asked for by CAS before engine orders placed. Required for Mar./56.

- J 67 engines will not be ordered for prototype aircraft until further meeting with RCAF on May 10. Metal mock-up ordered immediately.

- Avro writes specification for Curtiss-Wright J 67-W1 engine mock-up.

May./54

- Statement on armament requirements by RCAF primary armament in order of priority:

(1)-Vickers-Red Dean.....(2)-Sparrow 2.....(3)-Falcon

The missiles were selected in order of overall kill probability but availability was converse. No's 3 and 2 available in 1956 and No.1 in 1957. Secondary armament now to be AA rockets with high performance guns with, if possible, Red Dean. Fire control was undefined but the RCAF were then presently interested in a 42" diameter radar antenna instead of 28" antenna proposed.

- At meetings in Ottawa with the RCAF on May 26 and May 27/54, armament and fire control were discussed. Two alternative primary armaments were tentatively specified.

(1) Eight Falcon missiles, either micro-wave or Infra red.
(2) Three Sparrow 2 micro-wave or Infra red missiles.

Engineering for both schemes to progress in parallel. Agreed to delete from AIR 7-4 two large missiles, T-171 guns and a visual sight. Hughes fire control system similar to MG3/E9 shall be used. Larger antenna than 28" diameter presently proposed will be required to improve acquisition range.

- Investigation of 32" diameter antenna. Found to be unsuitable within present space provision and investigation proceeding with 30" diameter antenna.

- J.C.Floyd states that Orenda P.S.13 would receive serious attention if requirements were met.

- Avro outline engine requirements to Wright Aeronautical. One engine for rig-test by Sept./55 and 2 further engines for prototype installation by Apr./56 for flight date July/56. This was acceptable to Wright. Further J 67 data on engine mock-up, specification, fuel system starting, engine mounting etc.

- A/V M.Smith confirms RCAF prepared to order 6-J 67 engines.

- RCAF advise Avro approval from DDP to order prototype C-105, J 67 engine.

- RCAF wish maximum range built into Aircraft.

- Avro ask RCAF to consider requirement for flight refueling.

- Fourth Development and Co-ordination Committee decides as a general policy for the Company, the object should be to keep the weight down if at all possible. If some of the specification requirements appeared to be out of line with this policy, the Company were to raise the points at the meetings for review.

- Following visits to Convair on the F-102 and completion of Project 2 and 3 studies by Design Research Group, C-105 status completely re-examined during May 3-8/54 internal meetings. Single engine Project 2 and 3 studies shown to be optimistic with conclusion that twin engine configuration is optimum for equipment and armament required.

- Design development and initial wind tunnel tests at Cornell have resulted in certain changes to the C-105 wing. T/C now 3.5% at root and 3.8% at tip from 3% throughout, fin now 3.5% at root and 3.8% at tip from 3% throughout. Wing has stabilized in the high position at 1,225 sq.ft. and 50 ft. span. Fin area to be 138 sq.ft. from 123.6 sq.ft. Crew-2, 2 x J 67 engines plus afterburners, side intakes with ramp and boundary layer bleed. Armament is now 8-Falcon missiles Model E or 3-Sparrow 2 from 6 missiles plus 50 x 2" diameter rockets. The proposed fire control MG3/E9 initially with MX 1179 retrofit. No longer an avionics crate and electronics gear serviced through hatches. Engines withdrawn from the rear. Long range belly tank now fitted (500 Imp. Gal.). In all other respects it satisfies the requirements of AIR 7-4.

-Directive issued by Chief Engineer setting forth design responsibilities, method of issuing information, prototype and test specimen, manufacturing arrangements, flight-test responsibilities etc.

- Amendment N0.7 to Ministerial Direction received. Financial authority increased to $4,322,600 (increase of $2,619,000).

- Proposal A.D.14 submitted to DDP for design development and manufacture of two prototype C-105 aircraft. Financial forecast to first flight of second prototype $22,925,000-Feb/57. Tooling excluded and separate (A.D.13) proposal submitted. Financial forecast $9,250,000.

- All equipment to be designed for operation up to 60,000 ft.

June/54

- Avro received from RCAF "Operational Requirement for Fighter Aircraft". DRG carry out CF-105 performance comparison based on the OR.

- Preliminary forecast of expenditures to 1960 given to DDP and RCAF for planning purposes. Financial forecast showed additional continued development for 57/58, 58/59, 59/60 at a rate of $6,000,000 per year.

- C-105 engineering commenced planned overtime at the rate of 1 1/2 hours per day.

- Sixth Development and Co-ordination Committee meeting decides:

(a) Avro to continue with the "V" type windscreen for the prototype C-105.

(b) Avro to continue investigations on other configurations to provide background in case the "V" type is unacceptable.

(c) ARN-6 radio compass to be engineered as a permanent installation with suppressed antenna.

(d) Avro to investigate and report on the problem of installing both the ARA 25 and ARD 10 homers.

(e) There is no requirement for chaff dispensers in the C-105.

(f) The one minute scramble time to govern and not the ten second start.

- Avro issue "Proposed E9/MG3 type fire control system configuration for C-105". (Falcon missile version).

- Avro requested to report on case for conducting structural tests at plant rather than at NAE. (Forwarded July 27/54: suggesting fatigue testing at NAE).

July/54

- Tenth Steering Committee states that upon approval of model specification AIR 7-4 revision will be discontinued. (Model Spec. target date Jan 1/55).

- Amendment No.8 to Ministerial Direction received. Financial limit on wind tunnel work deleted since Avro over-expended wind tunnel funds. (limit of $50,000).

- Avro decision (subject to DDP approval) that sub-contract order be given for eight sets of wings.

- Introduction of glass-cloth lofting into Drawing Office. Expected to reduce parts change risk to minimum and falicitate rapid production.

- Avro, following recent criticism of drag estimates, reviews C-105 drag and compares RAE, NAE, Avro Manchester and Avro Canada figures reduced to same configuration. Reasonable agreement subsonic. RAE estimate subsonic drag (1.4 M.N.) 42% higher than Avro Canada and Avro Manchester 103% higher. Avro Canada does not believe "Area Rule" will materially contribute to reduced drag on the C-105.

- Confirmatory letter from A/V/M Plant following armament and fire control meetings May 26-27/54. Avro authorized to make engineering study of problems of fitting Sparrow and Falcon missiles to the C-105. Authorization to proceed with interim fire control system (MG3/E9) with MX 1179 retrofit. Every effort to be made to increase radar acquisition from 25 miles 80% of the time.

- Design in progress of new nose to accomodate 30 inch diameter antenna.

-The C-105 armament bay will be designed to accommodate quickly interchangeable crates containing either three Sparrow 2 or eight Falcon GAR-1A or IR equivalent.

- Proposal for "Armament Firing Sequencing" issued.

- Avro concerned that P.S.13 reheat less than J 67 and therefore not likely to provide sufficient reheat boost. Due to tight C-105 schedule Orenda not certain P.S.13 can be brought into line in time, but will try.

- Eighth Development and Co-ordination Committee meeting decides:
(a) No airframe (wing and fin) de-icing to be installed in the C-105.

(b) Avro to continue investigation into the problem of de-icing on a design study basis in case it should be decided at a later date that airframe de-icing should be required.

- Outline of aircraft allocation and test program for:

(a) Fire control system - 2 aircraft.

(b) Flight control system - 2 aircraft.

(c) Telecom. and Nav. aids - 2 aircraft.

(d) Weapon development - 4 aircraft.

Aug/54

- C-105 Presentation to USAF in Baltimore. Extract received of preliminary USAF "Design Specification for Long Range Interceptor". DRG evaluate C-105 against this specification. Avro receive MIL-C- 5011A "Standard Aircraft Characteristics and Performance".

- Investigations proceeding with enlarged nose to accommodate larger radar scanner.

- Design diving speed is affirmed by J.A.Chamberlin as M = 2.12 which corresponds to 248 degrees F on an NACA Standard Day. This figure is basis for calculations.

- Decision to open all armament bay doors during missile extension, regardless of number of missiles to be released, in order to localize adverse pressure.

Sept./54

- Eleventh Steering Committee decides:

(a) Costs of maintenance of CF-100 aircraft to be used on C-105 development to be charged to flight test vehicles funds.

(b) Costs of modifying aircraft, installing the necessary equipment and instrumentation and flying the aircraft to be charged against the C-105 development funds.

- Proposal AD 15 submitted to DDP Sept 24/54 for design and development of C-105 airplane. Financial forecast $19,750,000 up to flight of second aircraft. Separate proposal submitted for tooling and manufacture (AD 16). Tooling forecast $18,250,-000. Manufacturing forecast for 11 aircraft $24,749,060, for 40 aircraft $61,253,435. Engineering cost for AD 15 was $18,960,000. Forecast for 55/56 was $7,195,200.

- Tool Design meeting with representatives from sub-contractors. H.R.Smith outlines Avro plan for C-105 tool contracting and the "Rules".

- Cook-Craigie Policy reflected in estimate given to RCAF and DDP, per AD 15 and AD 16.

- Sir Roy Dobson expresses opinion that by 1959 every high altitude interceptor

fighter would be fitted with a rocket as well as ordinary gas turbine motor(s). Avro studies showed that rocket motor(s) entirely unsuitable for long range version.

- RCAF concerned with Avro reticence to investigate "Area Rule" thoroughly.

- Fin area increased 15% from 138 sq, ft. to 158.75 sq.ft. New larger diameter nose to accommodate increased antenna (38" diameter) size has considerably reduced directional stability with 138 sq,ft. fin.

- RCAF request (instruct!) Avro to 'carry out a proper and immediate investigation in the application of Area Rule to the C-105'.

- Avro decision to proceed with Sparrow engineering and mock-up installation.

- Hughes estimate that MX 1179 will be delayed for two years. Scheduled to fly in prototype form in the prototype F-102 in 1957. Production MX 1179 systems in 1958. Hughes intends to develop a 40" diameter antenna for use with the MX 1179. This is the main delay in the system. Hughes proposed radar fire control (MG3/E9) for the early C-105 aircraft will accommodate only the Falcon GAR-1 missile and will utilize a 23 1/2" diameter antenna.

- Draft of proposal for the installation of eight Falcon missiles in the C-105.

- Unlikely radar equipment will be suitable for operation above 50,000 ft. Similarly RCAF supplied equipment unlikely to perform satisfactorily above 50,000 ft.

- Decision made to increase fin t/c to 4% throughout from 3.5% root and 3.8% tip, due to structural and aero-elastic problems in the 15% larger fin area.

- Tenth Development and Co-ordination Committee decides:

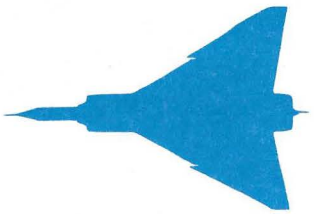
(a) Avro to locate vital components, as much as possible, in spots where their vulnerability is relatively low.

(b) RCAF to allocate CF-100 No. 18107 to Avro on loan for flight test purposes for C-105 flying control system evaluation.

Oct./54

- Avro receive advance copy of AIR 7-4 Issue 2 "Prototype Supersonic All-Weather Interceptor Aircraft Type C-105".

- Amendment No.9 to Ministerial Direction received. Financial authorization increased to $6,842,000 (increase of $2,519,000).



- Eleventh Development and Co-ordination Committee decides:

(a) AFHQ to advise Company of the use of UHF homer as a final approach aid.

(b) Avro to be responsible for the special equipment to be used with the aircraft subject to the conditions detailed in AIR 7-4.

(c) Optimum aircraft performance to be given top priority over other aspects.

- RCAF ask for study with 4 Sparrow missiles carried externally under the wings. Assumed max. allowable missile temperature 130 degrees F.

- C-105 Engine situation critically reviewed with RCAF. Avro requires 21 J 67 engines by the end of 1956 and 39 by the end of 1957. USAF indicated J 67 not available to Canada before Jan./58. Alternative engine proposals for the Gyron, J 75, J 57, BO 16 and P.S.13. Summarized in reference. Meeting agreed to design for J 67 using the J 57 for early experimental airplanes in necessary and ultimately use the P.S.13. Small number of J 67 engines might be available for prototype aircraft which, it was agreed, should be ordered now, also investigate the value of preliminary aircraft evaluation if fitted with J 57 engines as an interim measure.

- Decision to install Pratt and Whitney J 57 in first eight aircraft with speed (thrust) limitation. Install Curtiss-Wright J 67 as soon as available.

Nov./54

- Advance notice of AIR 7-4 amendment to call up recording test instruments on designated aircraft.

- Engineering indicates in discussions that financial costs for 55/56 might be exceeded (by a small amount). No confirmatory documents provided. No action taken.

- Estimated date of first flight of prototype is June/57.(In May /54 it was Feb./57).

- Design status at this time. Fin area up to 158.75 sq,ft. from 138 sq,ft., fin t/c 4% throughout from 3.5% root and 3.8% tip. Wing incorporating 5% notch, 6 inches wide and outboard 10% leading edge extension. Re-distribution of wing skin thickness is required to increase stiffness. Eight Falcon missiles now GAR-1A from Model E.

- RCAF/DRB/NAE/NACA meet at Langley Laboratories to discuss C-105 design problems. Avro estimate of supersonic drag considered highly optimistic.(Likely to be 50% higher). Negative camber is suggested unusual. NACA prefer positive camber in order to reduce drag due to lift. C-105 fineness ratio considered low (9 to 11 preferable to 7 realized). Electronic stability control not favorably received.

NACA suggest elevons more suitable than elevator/aileron to reduce trim drag and increase reversal speed. Suggested meeting with Avro arranged.
- Information requested on performance penalty involved in external underwing installations of Sparrow 2. (Taken to AFHQ by G.R.Oscar, Nov.12/54).

- Hughes present integrated fire control system proposals at AFHQ with Avro representation). Avro discuss fire control system and armament with RCAF on Nov.4 and 5/54. Up to this point A/V/M Plant's letter dated July 6/54 prevailed.

- Specified fire control system was MG3/E9. Study installation of both Falcon GAR 1A and Sparrow 2. Resulting from Nov.4 and 5/54 meeting, Avro understand A/V/M Plant's letter modified as follows:

(1) Proceed with installation in Hughes brochure No. 0525 (MX 1179) instead of MG3/E9 system.

(2) Proceed with installation of Falcon and Sparrow on equal priority.

(3) Flight control system, forming part of the integrated fire control system, but excluding damping functions, is agreed between Avro and RCAF to be a Hughes responsibility, in line with Hughes proposal. Avro propose placing contract with HAC for design study of system.

- It is intended that MX 1179 system shall fit into the same place as the MG3/E9 system.

- RCAF have settled on MX 1179 system (modified). Certain long range interceptor characteristics will be introduced into this system. It is understood that MX 1179 will be available as soon as MG3 with installation data ready in summer 1955. Anticipated that Hughes will be given the autopilot contract with either Hughes or Minneapolis supplying the damping system.

- RCAF accept in principle Falcon and Sparrow installations submitted Oct.20/54. Deletion of IR Falcon under consideration. There is a requirement for missile jettisoning.

- Avro issue "Preliminary Requirements for C-105 Automatic Flight Control System".

- Avro require CF-100 Mk.4 with operating yaw damper system by Jan.28/55 for trial installation of Falcon missile and equipment with air launching later.

- Avro/RCAF armament sub-committee meeting. Falcon and Sparrow missiles installation reviewed. CArm CF-105 study of optimum aircraft-weapon-fire control system in progress. Preparation time for Falcon is 15 seconds, then lowered and fired

in 0.5 seconds.

- Missile jettisoning is a requirement for the C-105. Avro did not plan to design for this. (Later agree to jettisoning).
- RCAF comment on armament - 4 allied system. Avro to proceed with the Falcon and Sparrow installations on equal priority. RCAF accept HAC fire control brochure N0.0525 in principle but with many modifications.

- A note on the engine situation suggests that J 75 more reliable than J 67. After-burner on J 75 has two positions and has run successfully at design thrust (1,700 degrees K). J 57 afterburner has run for 33 minutes.

- RCAF confirm Avro proposal to base stress analysis acceptable to AFHQ on 'limit load configuration'.

- RCAF towing requirement for C-105 received.

- Drop tank designed for 4 radians/sec. roll rate.

- RCAF are in favour of Maxaret anti-skid units for C-105.

- Equipment service life in most cases based on equivalent MIL specifications.

- NAE tests indicate that wing de-icing is not required for C-105.

- RCAF advise requirement for turn around time is same as USAF. (4 Aircraft in 15 minutes) AIR 7-4 requires one aircraft turn around in 5 minutes.

Dec./54
- RCAF advise Interchangeability Spec. MIL-1-8500A, Jan./54 has been accepted by RCAF as pertinent to C-105. AIR 7-4 will be amended.

- C-105 program delayed until DDP satisfied that the C-105 is satisfactory from a technical viewpoint, DDP question drag estimate. Discussions held and performance figures checked with NACA.

- Decision made that 300 milliseconds is maximum time that armament bay doors should remain open.

- Avro/RCAF/NACA meet at Moffett Field, California Dec. 9-10/54 to discuss C-105 design problems. Supersonic drag criticized by NACA who think that the drag coefficient to be 0.025-0.030. Avro estimate 0.016. NACA suggest 0.02 is optimum for airplane class.

- Preliminary 'Area Rule' study of drag coefficient indicates that:

(a) Bluntness of exterior shape of intake duct lip should be reduced.

(b) Dorsal fin aft of canopy to exhaust port for air conditioning system should be dished about 4 1/2 inches.

(c) Lower fuselage surface between stations 215 and 368 should be dished about 2 inches.

- Definite decision to change fuselage lines for 'Area Rule' benefits (as indicated above).

- Fuselage weight reduction due to 'Area Rule' plus 400 lb. fuel (revised J 67 estimate)-1,953 lb.

- Avro/RCAF/NACA meetings in Washington Dec.20-21/54 to discuss C-105 design problems. NACA generally in agreement with Avro design philosophy though there was some disagreement with respect to drag. NACA regarded 'Area Rule' as useful and suggested its application to the C-105 might reduce the supersonic drag to the present Avro figure (0.0184). NACA figure that without 'Area Rule' based on proprietary information that the drag coefficient to be between 0.025 and 0.030. NACA claim 0.020 represents - very good design.

- RCAF wish confirmation that only Phillips head screws will be used on the C-105. (Confirmed Jan.6/55 DND file)

- Arrangements for direct Avro/Douglas/Hughes/Douglas communication on Sparrow 2 Avro to request Hughes to obtain USAF permission to work directly with Douglas (other action being taken RCAF-USN).

- RCAF advise requirement for optical gunsight in prototype deleted AIR 7-4 Iss.2. Emergency sighting device might be necessary with ECM and was the responsibility of whoever developed the weapons system.

- Decision that 6 only, not 8, Falcon missiles will be installed.

- Decision made to revert to 8 Falcon missiles (4-IR and 4-Micro-wave). Sparrow missiles may increase to 4.

- Provision for 8 missile attack will not be made. Provision for 4-IR missiles will be made only in one row.

- Avro comments on Hughes proposal for I.E.S. dated Dec.23/54.

- Avro seek RCAF approval of "Interim Electronic Equipment Installation" necessary for first 5 pre-production aircraft before complete MX 1179 equipment is available.

This will enable preliminary flight test work to go ahead.

- Reported that Curtiss-Wright J 67 has achieved 21,500 lb. thrust for a short duration. Specific consumption high.

- Orenda/Avro meeting to discuss scale model intake duct tests and nacelle configuration for P.S.13.

- The inboard wing skins will be reduced in thickness. Structure weight saving 1,650 lb. plus fuel saving of 500-600 lb.

- Proposed equipment list first forwarded (Iss.5) to AFHQ and DDP with cautionary letter and marked 'Preliminary - Not for Official Use'.

- RCAF ask for Avro compliance with ABC Air Standardization Agreements 17/1 to 17/12 inclusive.

- RCAF tentative estimate of pre-production C-105 aircraft for evaluation. Total number represents 29 aircraft, of which 11 would be required by Avro and 18 by RCAF. Preliminary details of 8 phase program for these aircraft.

During this period, Avro was plagued with indecisions, not only from the RCAF but between NACA, NAE and the RAE, regarding the Company's design philosophy. Subsequent events and tests of course proved that they were indeed on the right track.

One of the big stumbling blocks of course was that the RCAF could not make up its mind to a firm commitment on weaponry. First of all they wanted 6 - Falcons and varying numbers of FFAAR. Then the rockets were scrapped and the Falcons increased to 8 in number. The next thing was an alternate load of Sparrow 2 missiles that were being developed by the US Navy with Douglas as prime contractor. These differing missiles of course required different fire control systems. First the MG3/E9 was considered for the Falcon and then the MX 1179 for the Sparrows. Each presented its own problems and necessitated re-design of the electronics and armament bay several times which of course, greatly added to the cost of the programme. The RCAF of the period wanted to go first class with everything but unfortunately, they had a "champagne taste with a beer pocket book". It was to a great extent ultimatly this attitude together with a total integrated fire control system that was to contribute to the cancellation of the Arrow project on Feb.20/59. But, we are getting ahead of the story!.

Schedule of events. Jan./55 - Sept./55.

Jan/55

- RCAF decide that the C-105 will be designed in accordance with AND 10068 rather than E075-40-10. (Avro already doing this).

- Between Jan. and Apr./55 it became more apparent that with increased scope of work, expenditures would exceed forecast shown in AD 15, issue 1 ($19,750,000). Series of Management meetings held to determine if estimated increase in costs was correct and if so, if any steps could be taken to reduce expenditures. DDP not advised officially until forecast changes were confirmed. Number of aircraft was increased from 2 to 5 and program by engine and other changes.

- Hughes proposal Dec.23/54 for IES, including flight testing and the assurance of a satisfactory system for the RCAF. Costs - $15,322,279 covering a period through Dec./58.

- Noted that stability marginal at speeds above 250 + kts. EAS with landing gear down.

- Report 7-0400-05 Weight Summary and C.G. Position Issue 10 forwarded for AFHQ (and subsequent issues at monthly intervals).

- Requirement is for 3 Sparrow missiles only. Will provide for 4 only if necessary.

- Armament meeting with RCAF conclusions:

(a) Probability of C-105 making two passes very slight.

(b) Probability of kill for Sparrow likely to higher than that for the Falcon. 'Look' angle still to be investigated.

(c) Probability of kill proposed 3 Sparrow and 6 Falcon missiles not satisfactory.

(d) DOR require provision for 8 I.R. or Micro-wave missiles capable of firing in one pass.

(e) RCAF feel aircraft weight reductions at expense of operational versitility.

(f) RCAF agree to obtain Falcon for test purposes and endeavour to obtain use of CF-100 aircraft.

- RCAF/Avro armament systems sub-committee meeting. Memorandum from DOR,

ref. 1038 CF-105-180(DOR) Dec.15/54 was tabled by RCAF giving armament details:

(a) No requirement exists for firing 2 I.R. Falcons from rear row and 2 Radar Falcons from front row simultaneously.

(b) A requirement exists for the C-105 to be capable of carrying:

(1) A load consisting of 8 I.R. Falcons.

(2) A load consisting of 8 radar Falcons.

(3) A load consisting of 4 I.R. plus 4 radar Falcons.

(4) The C-105 must be capable of releasing all eight Falcon missiles on one pass.

- Provision must be made to jettison all missiles. Suggested the CArm does not agree with philosophy of separate damping system. Should be included in integrated system.

- Philosophy on Avro/Hughes dealings on MX 1179 Fire Control System. Form of development contract. What Avro expects of HAC with respect to:

(a) Integrated Electronics System.

(b) Falcon missile installation.

(c) Sparrow missile installation.

(d) Damping system.

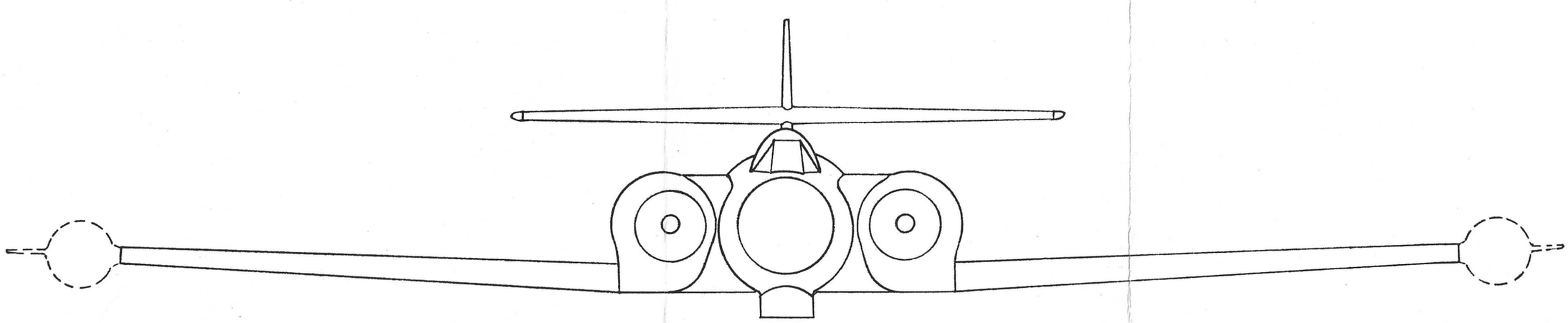
- Armament group issue "Proposal for Internal Installation of 4 Sparrow 2 Missiles".

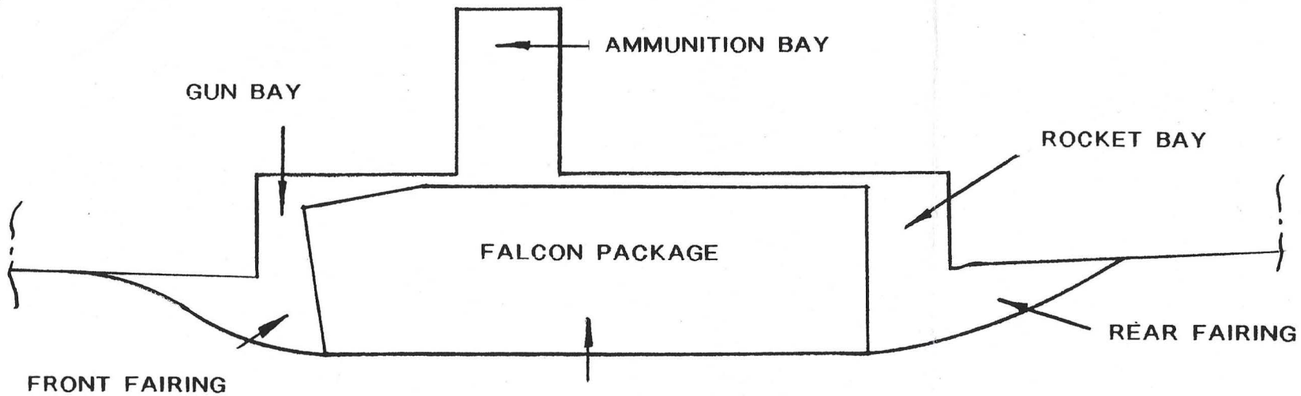
- Decision to adopt the Pratt & Whitney J 75 engine for early prototypes due to delays with the Curtiss-Wright J 67.

- 15th Development and Co-ordinating Committee meeting decides: Avro to use magnesium skins in the fuselage of the C-105.

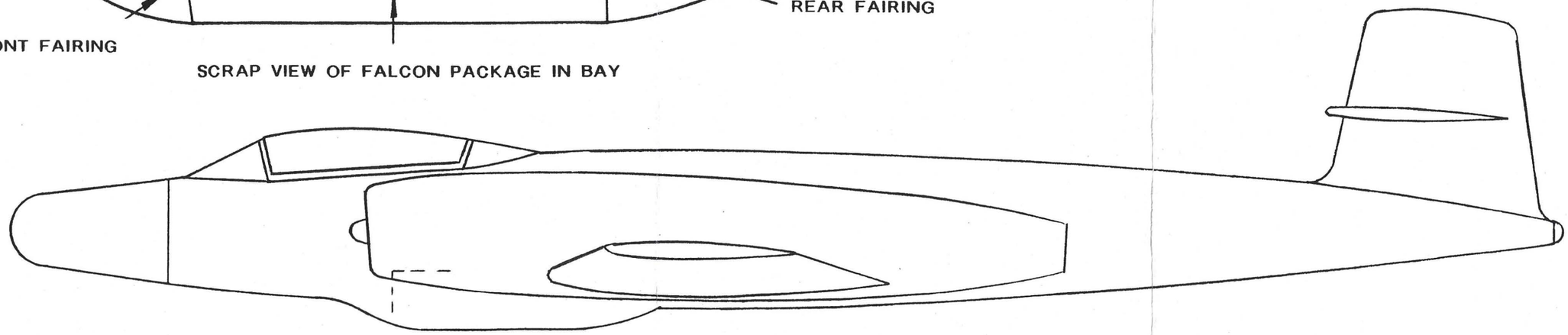
- Stress anticipate increasing airplane weight will require a load factor reduction from 7.33 to 6.9. This is not acceptable and hope that slight structural modifications will be made to maintain the factor at 7.33.

- Recommended seat load factors received through RCAF from IAM.





SCRAP VIEW OF FALCON PACKAGE IN BAY



SKETCH OF PROPOSED CF-100 EQUIPPED WITH ONE FALCON MISSILE

- In general, minimum equipment life to be designed for 500 hours.

- 15th Development & Co-ordinating Committee meeting decides:

(1) That Avro are to proceed as outlined in their proposal for interim radio and navigation equipment, pending completion of DATel review.

(2) At this time it did not appear necessary to carry out full scale flight test development programme using a CF-100 with a C-105 windscreen.

(3) Avro's proposal to clear one side of the 'V' windscreen was acceptable but it was desirable to clear both sides if possible.

(4) The use of four automatic disconnect couplings of the same type and to US standards was acceptable.
(5) The deviation to AIR 7-4 to allow the couplings for engine starting to be located at the engines and not adjacent to the air conditioning couplings was acceptable.

Feb/55
- RCAF would like the integrated electronics system installed in all delivery airplanes. They insist upon the installation in the 14th and subsequent airplanes and hope for its inclusion in the 12th and 13th airplanes.

- RCAF outline requirements for C-105 model Specification and accept interim model spec.

- Draft specification AIR 7-4 for development of an integrated electronics system brought for Avro consideration prior to discussions with USAF and Hughes.

- Reliability of damping system should be considerably higher than other electronic equipment and on a par with engine reliability, because:

(a) In certain circumstances the C-105 is unsafe without a damper.

(b) Considerable opposition to (a) above in the RCAF. Concern expressed with primary system tied to a digital computer with predicted failure of the order of two hours.

- It is planned to install the J 75 in place of the J 67 on first and subsequent airplanes. (Earlier availability than other engines). It is believed that the Orenda P.S.13 will eventually be installed in the 14th and subsequent aircraft. Design work on the J 57 discontinued.

- Forwarded to AFHQ brochures on:

(1) C-105 Dive Brake Performance.

(2) C-105 - A Note on Stability.

(3) Preliminary Wind Tunnel Tests on the Effect of Icing.

- 'Area Rule' study completed necessitating design changes to reduce supersonic wave drag:

(a) Thinner intake lips.

(b) Contoured aft fuselage.

(c) Fairing aft of tail pipes.

- RCAF specification for electronic system calls for addition of equipment above the anticipated. Particularly alternating current power supply after both alternators have ceased functioning.

- Avro make proposal to work direct with Douglas on Sparrow and modify MG2 system. Complications between Hughes and Douglas would then be avoided.

- Draft specification AIR 7-5 for development of integrated electronic system brought for Avro consideration prior to discussions with USAF and Hughes.

- RCAF expresses interest in missile development using the supersonic track sled at Inyokern on Edwards AFB. Ask Avro to prepare detailed program.

- J 75 engine dry weight - 6,100 lb. P.S.13 dry weight - 4,500 lb. approx.

- Pratt & Whitney report that 5 - J 75 engines built to date. They have grossed 700 hours running time including 70 hours in altitude chamber when 70,000 ft. simulated altitude achieved. Four separate 50 hour tests at 23,500 lb. thrust. Engine bare weight 6,100 lb. First flight in B-45 scheduled March/55. Supersonic flight will be in F-105. Reported also engine build program, mock-up availability, performance data, fuel inlet temperature and stressing data.

- Avro asked to confirm that the C-105 development program now approved for $19,750,400 includes development costs associated with armament, ground handling and readiness equipment. Avro indicate J 75 data sufficiently complete to commence design development.

- Avro recommend RCAF adoption of the MIL-S-5701 landing weight definition in lieu of that in AIR 7-4. This would enable a structural weight saving of approx. 100 lb.

- Flying Controls Hydraulic System Brochure H-1 and drawings submitted.

- RCAF require navigator's window to be lower and larger.

- Preliminary report on electrical power supply arrangements forwarded to AFHQ. These cover latest known requirements, including integrated electronic system.

Mar/55

- Copies of second draft of Spec.AIR 7-5 distributed at Avro.

- RCAF inform Avro that Spec. AIR 7-5 (basis of integrated electronic and control system) is issued. Extensive discussion between RCAF and Hughes pertaining to RCAF Spec. and MX 1179 system.

- 15th Development and Steering Committee discusses flight simulator required before C-105 first flight. Agree that Avro is the only firm to do the job, Avro requested to show cost of simulator design and development in proposal for training aids.

- Avro submit contract proposals to Ottawa for:

(a) C-105 development contract.

(b) C-105 tooling contract.

(c) C-105 production contract.

- Following discussion with USAF, J 57 and J 67 engines definitely ruled out as powerplants for C-105. J 75 will be used as interim power plant.

- Impending changes to C-105 configuration presented in considerable detail:

(a) Change from J 57 P-5, to either P.S.13 or B-20 or 21 varients of J 75 tentatively scheduled for 16th aircraft onward.

(b) Changes to fuselage to optimum configuration based on 'Area Rule' which reduced supersonic wave drag from present 0.012 to 0.008. Both changes necessitate considerable re-design which is outlined in memo.

- 17th Development and Co-ordinating Committee decides:

(a) Nosewheel gear to be designed to withstand a towing load of 10,000 lbs. straight ahead and 6,000 lbs. at a 45 degree angle to the side.

(b) Cockpit fire extinguisher requirement canceled.

(c) Avro to provide a centrally located master warning light on the pilot's instrument panel, and to assess the reliability of this warning system.

(d) Replaceable oxygen bottles to be located in a readily accessible spot to allow quick substitution.

- Suggested magnesium skins may be suitable for C-105 since criteria for wing design is likely to be stiffness.

- C-105 runway strength requirements based on USAF Tech. Mem. WCLS-53-13 'Ground Flotation Requirements".

- DOR has ruled that only ground support equipment as required, to enable C-105 to fly (not intercept missions) must be air transportable. This would be an advantage (but not a requirement) for all ground support equipment. Air transportable equipment should be accommodated by C-119 type aircraft.

- RCAF seeks confirmation on electronic equipment environment.

- Brochure H-2 'Utility Hydraulic System' and schematic drawings forwarded to AFHQ.

- RCAFHQ/Avro visit NACA Lewis Labs, Cleveland, to discuss and arrange supersonic wind tunnel tests of intakes and ducts.

Apr/55

- Spec. Inst. 92-1, Issue 3 for development of automatic flight control system signed April 6/56.

- Spec AIR 7-5 Issue 1 for Integrated Elec. System signed April 7/55.

- Preliminary model specification forwarded the AFHQ.

- Purchase order for 4 aircraft increased to 5 aircraft.

- Development Steering Committee request review of fiscal year's expenditure and forecast to complete program to 1960.

- Amendment N0. 10 to Ministerial Direction received Apr.14/55. Financial authorization increased to $7,600,000 (increase of $ 757,600) to Mar.31/55. Manufacture of prototype aircraft deleted and transferred to seperate authority. Subject matter amended to read "Design and Development of All-Weather Fighter to Specification AIR 7-4, Issue 3".

- C-105 program re-scheduled Apr.15/55 retarding first flight 6 months to bring

airframe into phase with engines and integrated electronic system. Scheme B adopted as follows:

(a) Complete schedule has gone back 6 months for first prototype flight.

(b) Engines are available for all aircraft well before scheduled flight date.

(c) 150% Spares are available for first two prototypes.

(d) Only 4 prototype J 75 engines are required. These are twice as expensive as pre-production.

(e) Only 12 of first 15 aircraft are to be powered by the J 75. Numbers 6,7 and 15 are to be powered by the P.S.13.

(f) Aircraft numbers 4 and 5 can be flown to Hughes instead of being shipped.

(g) P.S.13 engines not required until Aug./57, even on 4 months lead time, instead of May/57 with only 1 month lead time for Scheme A.

(h) Hughes electronic system is not required in production quantities until Nov./58 on 5 month lead time, instead of July/58 on 5 month lead time.

(i) The IES to be fitted to the 20th aircraft instead of 24th.

(j) Delivery to squadrons is Oct.59 instead of May.59 - Scheme A.

(k) Fully operative Jan./60.

- Estimated date of first flight of prototype is now May/57, (in Apr./54 it was Sept./56).

- Avro philosophy behind adoption of scaled down Cook-Craigie plan outlined.

- J 75 Engines to be installed in 12 of first 14 C-105 Aircraft. 2 will incorporate P.S.13 engines.(4th and 7th to JCF Apr.20/55). Approval given to order 33 x J 75 engines.

- Review of situation on integrated electronics system not favorable based on present USAF reluctance to permit RCAF via DDP to place letter of intent with HAC. At least six months slippage forecast.

- DDP inform Avro 19 x J 75 engines will be ordered to be delivered between Dec./56 and Sept./57 to cover first 5 aircraft. A further 12 x J 75 engines will be ordered in May/55 to cover Scheme B engine requirements to Jan./58. These 31

engines will come from Pratt & Whitney pre-production run.

- 18th Development and Co-ordinating Committee Meeting decides:

(a) Avro to proceed in accordance with their interim electronics system proposal pending receipt of the Hughes proposal.

(b) Avro accept the MIL-S-5700 series as the structural criteria for the design of the C-105.

(c) The requirement for the installation of Doppler in the C-105 still stands.

(d) Requirement for radar homing still stands.

(e) Two point pressure refueling to be installed in lieu of single point refueling with an estimated saving in weight of 50 lbs. plus saving in mission fuel.

(f) Gravity refueling provision to be deleted, with an estimated saving in weight of 12.5 lbs. plus saving in mission fuel.

- Planned that the C-105 will not operate from airfields above 2,500 ft. Possible emergency at 3,500 ft. and ground handling equipment required for starting at 3,500 ft.

- RCAF reply to letter from R.N.Lindley to W/C Brough Nov.9/54, ref 6117/03/J seeking confirmation of certain armament/fire control points. RCAF do not agree MH and HAC asked to tender for damping system, Hughes only.- RCAF and Avro discuss interchangeability and criticize C-105 canopy release following cockpit mock-up inspection. Jamming of locking bar and reliability of gas cartridge for canopy un-locking are suspect.

May/55

- Avro outline production tooling philosophy to DDP based on one per month aircraft production rate. Eventually four/month.

- C-105 19th Development and Co-ordinating Committee decides:

(a) Financial authority granted RCAF purchase of 21 Falcon (GAR-1A) missiles for early prototype test program. 1st in Sept.1/55, 10 by Dec.31/55, 21 by June/56. One inert, remainder with motors, but no guidance.

(b) Hydraulic system generally satisfactory.

(c) Fuel system requires in particular check on aircraft lateral stability with feed failure from wing tanks. (Subsequently found satisfactory).

(d) Avro urge RCAF acceptance of MIL-5-700 landing weight definition in lieu of AIR 7-4.

(e) Stressing criteria for crew seats to AP 970 IAM and MIL-S-5100. All other crash stressing cases to MIL-S-5100.

(f) Avro confirm C-105 meets 1 minute scramble time from readiness hanger at 2,500 ft, altitude on 100 degree F summer day.

(g) Avro confirm line equipment will be designed to worst ambient conditions, sea level to 5,000 ft.

(h) Discuss installation of VHF in place of UHF. Avro seek early decision meanwhile working on UHF.

(i) CArm will proceed with arrangements for Inyokern sled trials.

(j) Avro making provision for missile jettison.

(k)Avro processing an application for a CF-100 loan for strain gauge instrumentation development.

- RCAF comments on missile installation issued by Avro Feb./55. Agreed development of described installation as rapidly as quality of engineering data permits.

- AFHQ authorized Avro to design and develop (Previously investigate) C-105 missile installation for both Falcon and Sparrow 2.
(a) 8 Falcon GAR-1A missiles or equivalent Infra-red missiles.

(b) At least 3 Sparrow 2 missiles suitably modified for supersonic launch and operation at 60,000 ft. or equivalent Infra-red missiles.

- A/V/M Plant confirms second source C-105 damping system is advisable and recommends Minneapolis-Honeywell.

- RCAF outline CF-105 Armament installation test programme including tunnel tests, CF-100 trial installation and tests and rocket sled tests.

- AFHQ/Avro meeting held to discuss Flying Control Hydraulic System proposal.

- Detail of canopy release system provided (at AFHQ request).

- Amendment No.11 to Ministerial Direction received. May 17/55. Financial Authorization increased to $8,276,632 (increase of $676,632) due to overrun of

$676,632 during '54/55.

- Avro request authority to proceed with metal mock-up.

- Canada and the United States sign an agreement to build and operate a distant early warning (DEW) line as part of an integrated radar defence of North America.

June/55

- RCAF tentatively agree to use MIL-S-5700 definition of landing weight. With P.S.13 as basis for weight definition new landing weight is 45,000 lbs. (Previously 47,000 lbs). RCAF do not agree reduction in brake capacity and weight requirement for brake design remains at 47,000 lbs.

- Forecast of costs given (June 1/55) to RCAF financial (W/C Eward). Development program is forecast to $57,000,000. Forecast for 55/56 is $13,900,000. Fiscal year costs for 55/56 given verbally to DDP.

- Modifications to the wing leading edge as outlined below improve:

(a) Buffet - primarily droop.

(b) Drag - subsonic - primarily droop.

(c) Longitudinal stability - primarily notch and leading edge extension.

(d) Directional stability - primarily droop.

- Wind tunnel tests originally showed unacceptable buffet at values of above 6 degrees. Recent tests (May/55) with modified configuration have increased the critical value of to an acceptable figure.

The necessary changes are:

(a) The wing leading edge inboard of the main gear is drooped nose down.

(b) The notch just forward of the main gear is reduced from 8% to 5%.

(c) The wing leading edge outboard of the main gear has an increased chord and is also drooped down.

- The effect of RCAF policies and indecisions on the design of a fire control and electronics system installation in the C-105:

- CF-105 Arrow drawings released for production.

Jan./May/54
- Two man E9/MG3 pending RCAF decision.

May 27/54
- RCAF decision E9/MG3, two man.

July/54
- HAC suggest auxiliary missile units to be out of armament bay.

Sept./54
- Rumors that RCAF may install MX 1179. RCAF requirement for larger antenna.

Nov./54
- RCAF decides to install MX 1179. Replanning equipment layout, installation design and cable runs commenced.

Nov./54 to present
- No agreement RCAF/HAC on integrated system. Data scant and unconfirmed.

May/55 - RCAF require AN/ARN-21 equipment readily accessible. Re-hash electronics bay layout.

May/55
- RCAF notify two more boxes needed for AN/APX-25. Electronics bay re-design necessary.

- Details of finalized Sparrow configuration and armament proposal evaluation.

- 20th Development and Co-ordinating Committee decides:

(a) A requirement exists to fully retract the missiles after independent loading without necessitating engine starting.

(b) All panels and doors that may have to be removed for DI inspection to be secured with latches or quick release fasteners.

(c) If the circuit breakers are to be used as switches they are to be of the push-pull or toggle type, - preferably the latter.

(d) Avro to proceed with design of the J4 compass installation.

(e) Extension of one runway at Malton to 10,000 ft. is necessary for the first flight of the C-105 and will endeavor to keep up-to-date on progress of discussions between DOT and DND.

(f) There is a technical requirement for a CF-100 aircraft to be allocated to Avro for tele-communication equipment testing.

- Avro receive note from RCAF outlining procedure for armament installation modifications in absence of rigid specification. All modifications to be approved by RCAF.

- Preliminary note on rocket sled testing of Falcon and Sparrow at Inyokern.

- Effect of installing J 75 in lieu of J 67 engines reviewed with breakdown of all design changes.

July/55

- RCAF/Avro meeting to discuss amendments to draft of AIR 7-4 Issue 3.

- C-105 Engineering planned overtime reduced by 1/2 hour to 1 hour per day.

- Avro outline economies to reduce C-105 costs.

- 21st Development and Co-ordinating Committee decides:

(a) It is noted that the sub-committee recommendation that some method of de-energizing the missile launch hydraulic accumulator has been withdrawn on the basis that a manual stop valve be incorporated in the hydraulic circuit.

(b) From a maintenance point of view Camlock fasteners to Spec. NAS 547 to be acceptable to RCAF. Company to continue their investigation with respect to adequate strength of this type of fastener.

(c) The hydraulic system is satisfactory at present.

(d) If it is discovered in flight testing the aircraft that failure of one pump does make a significant difference to the operation of the aircraft, a suitable warning system will have to be installed.

(e) A 12" square window to be installed in the rear cockpit as soon as possible but by at least the 16th C-105 aircraft.

- 'Programming' development to continue for Falcon. Clutch variable orifice to be developed for Sparrow.

- Hughes have run out of money for C-105 damping system. Will continue work on a reduced scale with delivery postponed one day per day of delay in receiving contractual coverage after July 1/55. Hughes estimate $120,000 required to complete work.

- Avro write requirements for C-105 damping system. Approved by Hughes and RCAF.

- Comprehensive note by JCF on means of accomplishing reduced C-105 development costs together with outline of work content in C-105 design. Conclusion that with certain risk acceptance including that of incorporating P.S.13 in 6th and subsequent aircraft, approx. $5,000,000 could be saved from original estimates covering more comprehensive program with less risk.

- Comprehensive outline of revised costs from AD 15 Issue 1 from $19,750,000 to flight of 2nd aircraft in Feb./57 (AD 15 Iss.1 Sept./54) to $40,574,625 to flight of 5th aircraft (AD 15 Iss.2). Original estimate to 40th aircraft was $61,253,435 and now $83,927,676 (increase of $22,675,000).

- Revised brochure AD 16 Iss 2 for tooling and manufacturing programs for C-105 forwarded to DDP. Avro deems it essential to have authority to manufacture up to 11th aircraft now since agreed timing could not otherwise be achieved. Avro presently authorized to build 5 aircraft. Similarly Avro understand that the ultimate program is for 40 aircraft and wish confirmation of this from DDP.

- Avro has no authorization to spend funds in fiscal year '55/56 or beyond.

- B8-A stick grip to be used pending approval and availability of B9.

Aug./55

- Security delays progress of C-105 Sparrow installation. No channel for information interchange between Avro/Douglas and Hughes/Douglas or visa-versa.

- Delays on Hughes MX 1179 system and damping system becoming critical. USAF restricting Hughes work on any but USAF projects. C-105 will certainly be restricted, if damping system unavailable on time. Consideration again given to providing preliminary fire control system MG3/E9.

- Company's proposed Master Warning Light/Indicator system agreed to in principle.

- Avro proposal for engine controls stressing accepted. (Limit torque at each lever 750 lb.ins.)

- Reasons given against re-opening of the question of alternatives to the V-type windscreen.

- RCAF agree revision of cabin pressure scheduling. (Max. Pres. differential 4.5 psi reached at 60,000 ft. approx. instead of 24,000 ft).

Sept./55
- Avro receive AIR 7-4, Issue 3 Spec from RCAF Aug. 31/55.

December./55
- The Canadian Government limited development of the CF-105 to 11 aircraft, subject to review after the first flight.

February./56
- The RCAF inspected the wooden mock-up of the CF-105 Arrow.

August./57
- Canada and the United States announced the signing of an interim agreement to integrate Canadian and United States Air Defences into a single command - NORAD (North American Air Defence Command) - renamed North American Aerospace Defence Command in 1981).

October./57
- CF-105 Arrow Mk1 prototype rolled out at AVRO CANADA at Malton. Russians launched SPUTNIK 1.

March 28./58
- First flight of Arrow 25201.

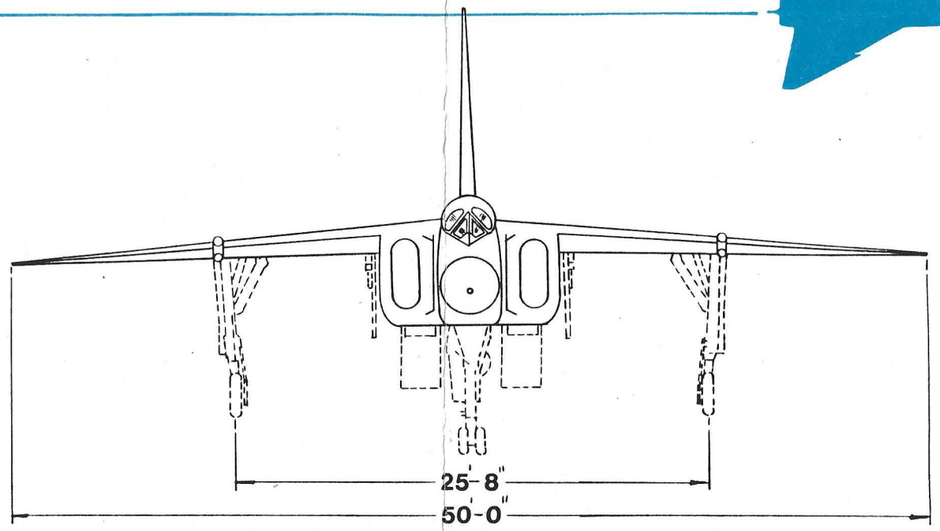
August 1/58
- First flight of second Arrow 25202.

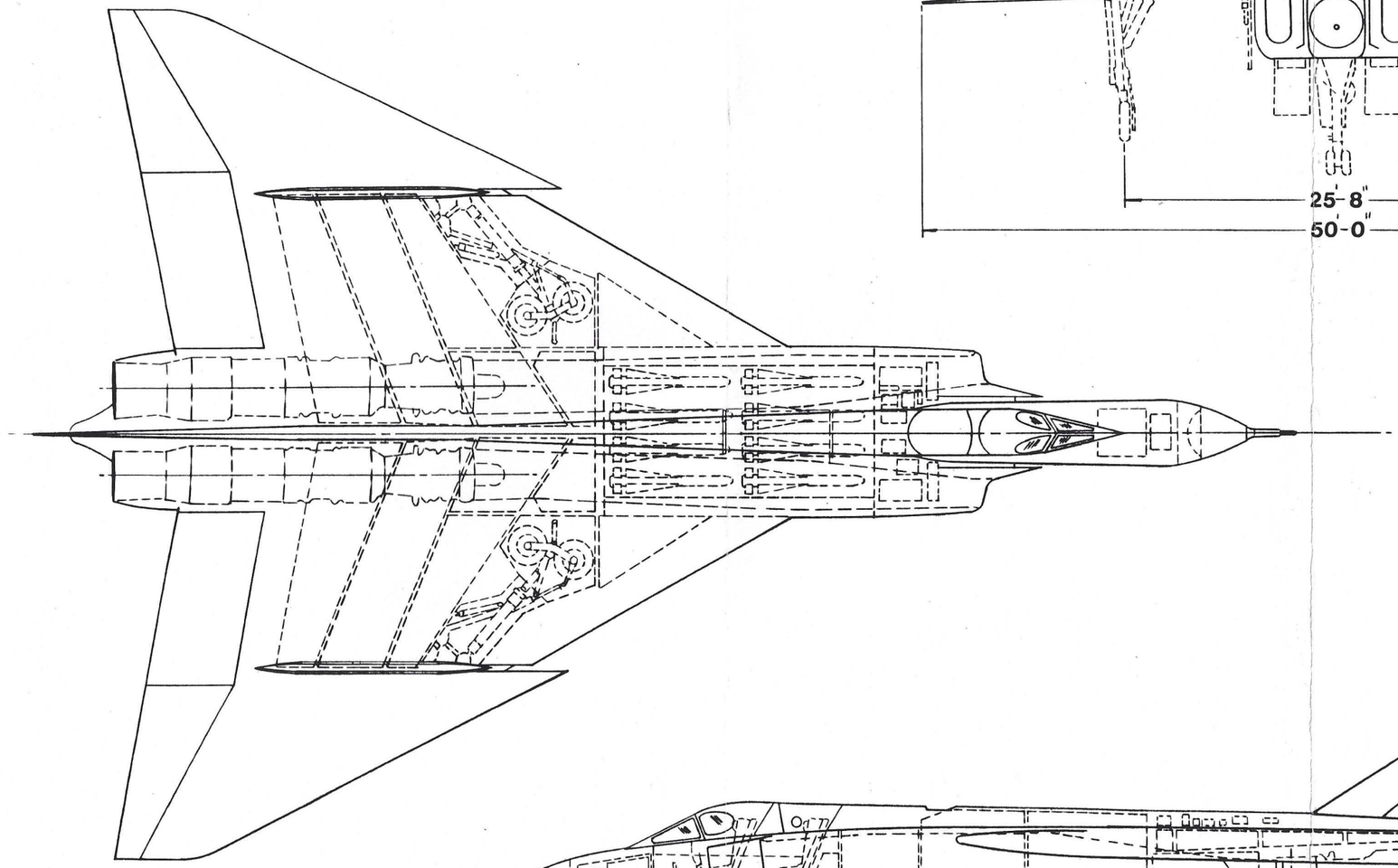
September 22./58
- First flight of third Arrow 25203.

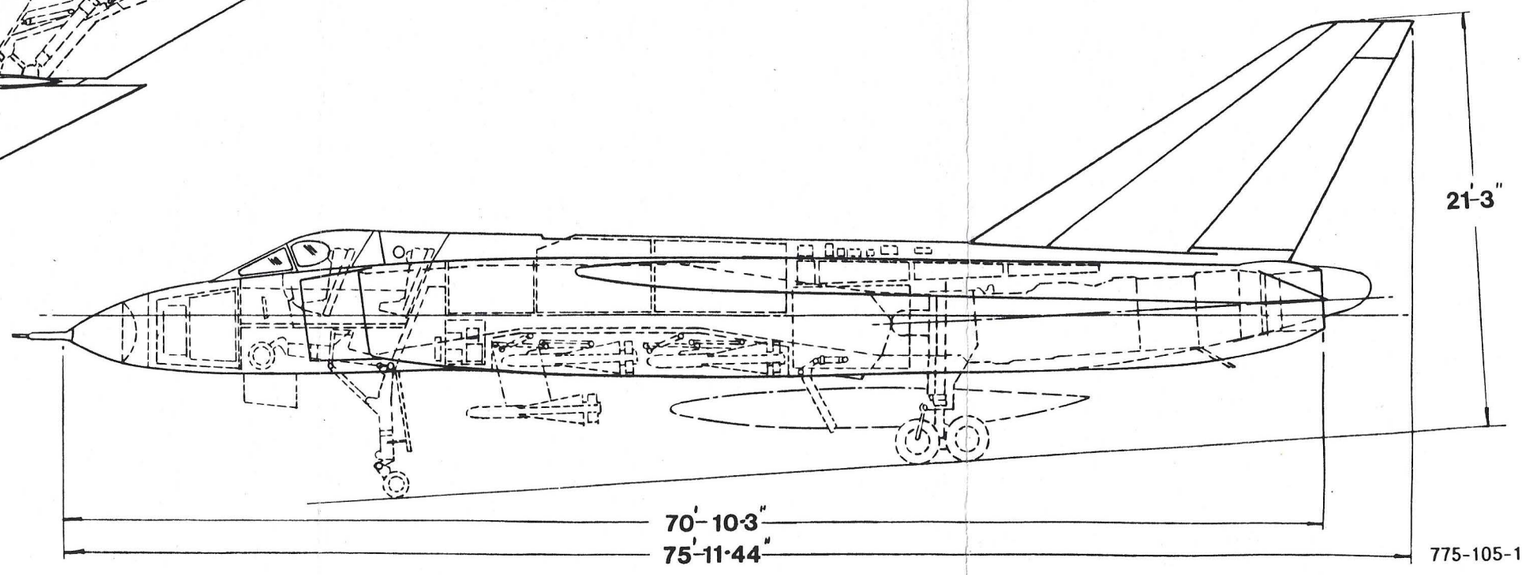
September 28./58
-The Canadian Government announced that the RCAF would be equipped with 2 squadrons of BOMARC missiles. Limited development of the CF-105 Arrow would continue. The decision would be made to go into production in March of 1959. The Sparrow missile together with its fire control system, ASTRA, was also canceled and the Arrow would be equipped with the Hughes Falcon missile and the Genie MB-1 together with the MA-1C fire control system.
October 27./58

- First flight of the fourth Arrow 25204.

January 11./59
- First and last flight of the fifth Arrow 25205.







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February 1./59
- Canada took over the management of the DEW line.

February 19./59
- Arrow 25203 was the only Arrow to fly with an observer, D.E. Darrah - the last ever flight of any Arrow.

February 20./59
- "Black Friday". The Canadian Government canceled the Arrow and the Iroquois engine.

April 22./59
- All CF-105 Arrows, both complete and in building were cut up for scrap, together with all drawings, photographs, records, tools, jigs and fixtures together with 14 Iroquois engines. The scrapping contract bid was won by the Lax Brothers of Hamilton for $300,000. Only the nose section of 25206 was saved together with some components and one Iroquois engine. These items are to be seen in the National Aviation Museum in Ottawa.

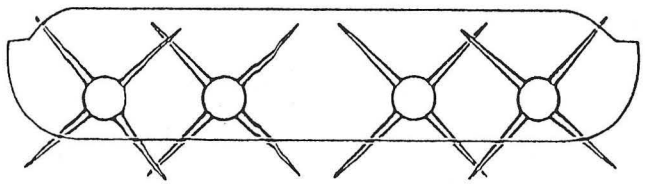
This brings to an end this particular itemizing of events, and from here on we must deal with the Company reports and RCAF requirements as they continued to change.

THE CF-105 ARMAMENT PACK.

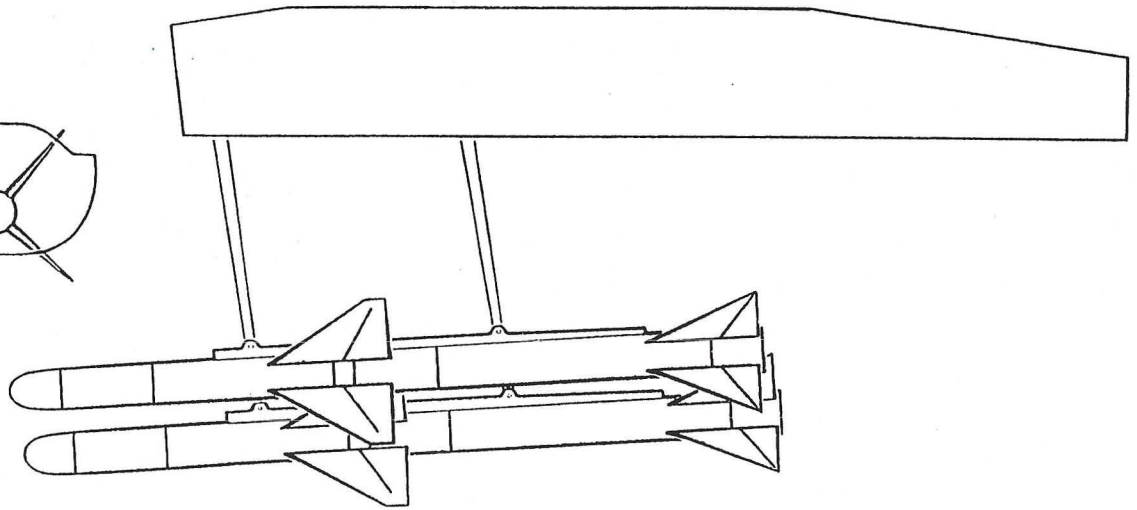
THE INSTALLATION OF 4 SPARROW MISSILES.

During the course of development of the CF-105, the RCAF became more attracted to the Sparrow 2 missile, due to its longer range and better kill probability, and urged Avro to investigate the design of the armament pack with the Sparrow only in mind. It was found by February of 1955 that it was possible to install 4 Sparrow missiles in the armament bay. The difficulty of stowage lay in their large wing span, - 40 inches.

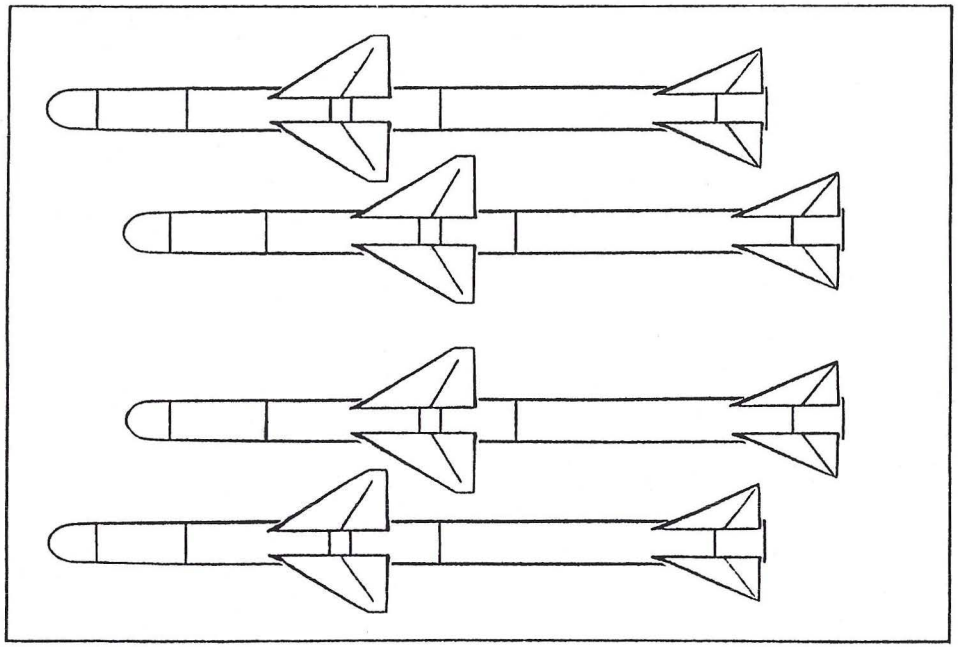
It became apparent that if the size of the fuselage was not to be increased, then the wings must protrude through the underside of the aircraft. Whereas three Sparrow missiles could just be fitted into the fuselage in line abreast, when four missiles were fitted they must be staggered fore and aft in order that their centre lines may be moved sufficiently close together. In the extended position, in order that the fins on adjacent missiles do not collide, the inner and outer two missiles must extend, by different distances. It was possible, in the proposed design, to maintain clearances between adjacent missiles to a minimum of one and a half inches and between the missile fins and package structure to a minimum of one inch. These were considered practical tolerances to work to. In May of 1955, conditional acceptance of this proposal was received by Avro.



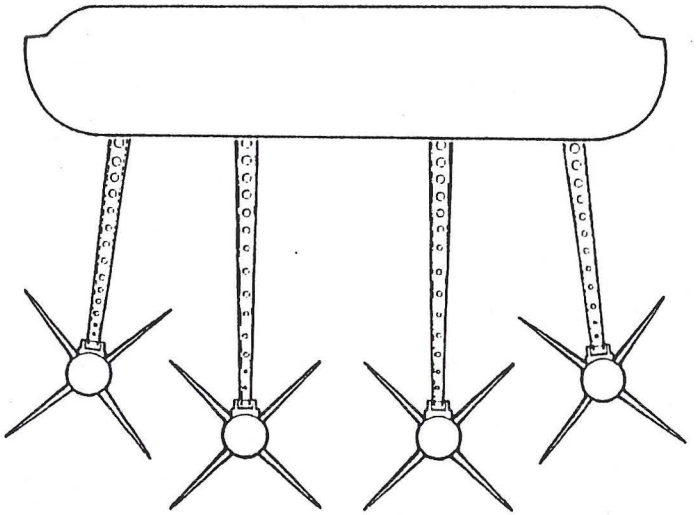
FRONT ELEVATION
MISSILES STOWED



SIDE VIEW-MISSILES EXTENDED



PLAN VIEW - MISSILES STOWED



FRONT ELEVATION-MISSILES EXTENDED

SPARROW MISSILE INSTALLATION. FEBRUARY 1955

Due to the urgency of the program, and the complete lack of data regarding air flow around both the missiles, the aircraft forward fuselage and combinations of both with the missiles lowered, a series of wind tunnel tests were scheduled in Oct./54 and completed in Apr./55. The entire reasoning which led to wind tunnel testing was reviewed, and it was concluded that the only practical technique for obtaining design data was that of extensive wind tunnel tests, which were done for both Falcon and Sparrow missiles.

It was proposed that, in view of the urgency with which design information was needed, that such information be based on static type of analysis. This made a lot of sense as the cost of testing of full size installations in aircraft (CF-100) was prohibitive at this early stage. Jettison tests were done with a .07 scale model in the NAE Low Speed Tunnel in Oct./55, and high speed sled tests were proposed, to be conducted at Inyokern US Navy Establishment.

SPARROW INSTALLATION.

The Sparrow missile itself however, had also been undergoing its own development which included changes to the external dimensions, and it was appreciated that it would have been April,
1956, before the design had stabilized sufficiently to justify the preparation of manufacturing drawings of the installation.

The proposed installation catered for both two and four missile attacks, with only two missiles being extended for firing in the case of a two missile attack. At the time of making the proposal, there was a small wing to body clearance between adjacent missiles. The addition of blisters to the missile body during subsequent development resulted in the disappearance of these clearances.

This matter caused a general re-examination to be undertaken of the proposed installation and to determine what measures could be taken to give the flexibility originally proposed. At the same time, in accordance with an RCAF letter of May 1955, the reduction in weight of the installation was to be given prominent attention.

RE-EXAMINATION OF THE PROPOSED INSTALLATION.

STRUCTURE.

A large proportion of the weight of the original installation, less missiles, was structural weight. The reason for this was that the missiles themselves, plus the necessary clearances, occupied so much of the available space that the space left was inadequate and resulted in an inefficient structure. Because of the space occupied by the missiles, a good roof structure was not possible. The missiles, therefore, had to be spaced to give a heavy keel member down the centre of the installation with two

side box members. To obtain the extra space needed, to give the original performance, by spacing the missiles further apart in the original structure resulted in the virtual disappearance of the structure itself. It was therefore apparent that a major re-positioning of the missiles would be necessary. At the time of this re-examination of the installation, Avro was also conducting a general investigation into the carriage of missiles in a semi-submerged position instead of the more usual fully submerged position, and had been impressed by some of the advantages which could accrue from such an installation. Naturally, this led to the consideration of such an installation during the re-examination of the Sparrow 2 installation.

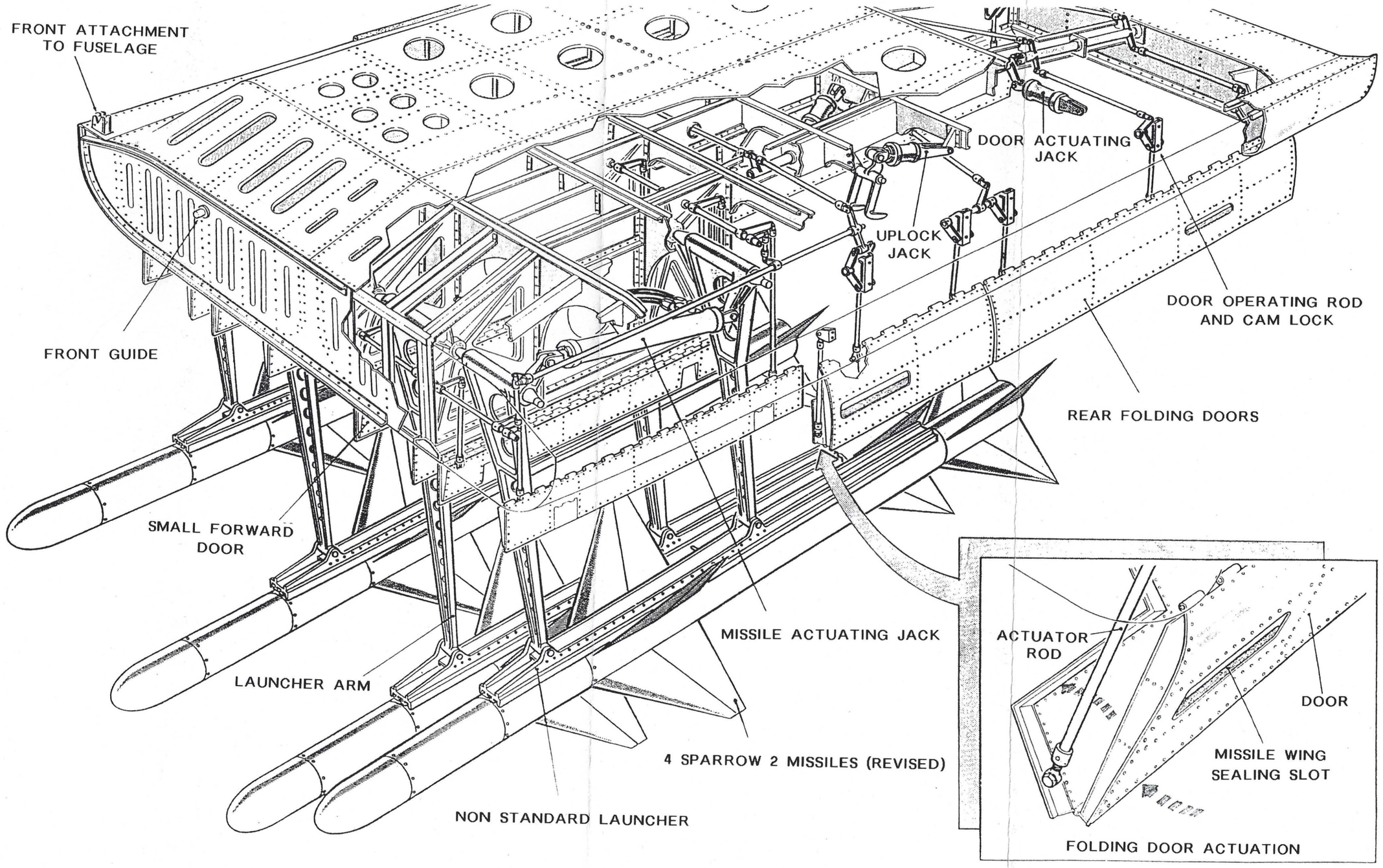
By lowering the missiles until their centre lines were on the aircraft skin line, it was found possible to obtain a good top structure which did away with the necessity for a keel member. The missiles could be thus spaced further apart without encroaching on the size of the side beams and adequate clearances could be obtained. This resulted was considerably more efficient and resulted in a weight saving of about 500 lbs.

DOORS.

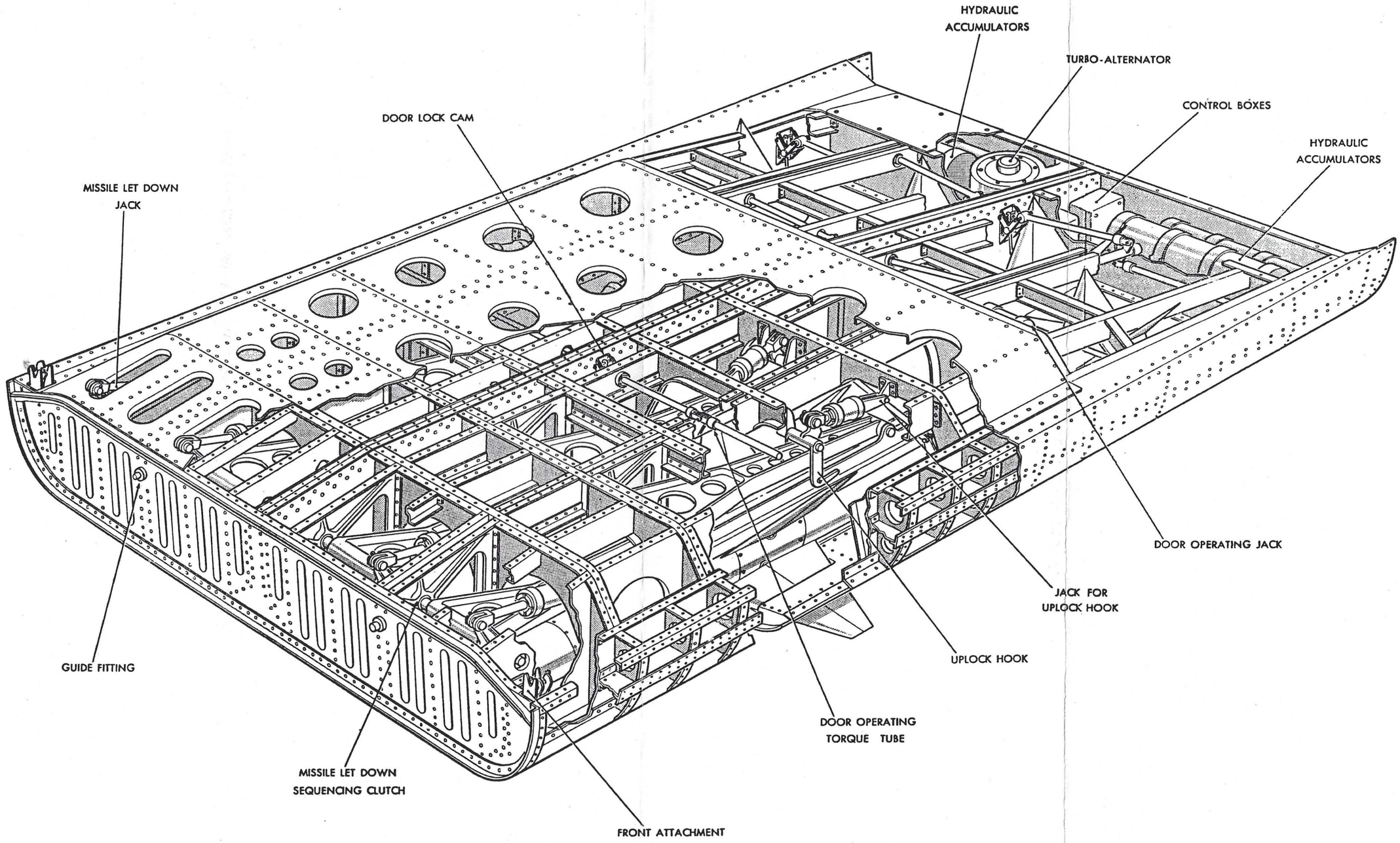
Perhaps the major uncertainty of the original installation was with regard to the integrity of the doors, which opened outwards to permit missile extension. These doors were large and, because of space limitations, very thin. By installing the missiles with their centre lines at the aircraft skin line, it was no longer necessary to have doors to permit the missile body to be extended for firing. Doors were still required however, in the region of the wings and fins to permit them to pass through the skin line on extension. As a result of the reshuffle in missile positioning these doors were no longer needed to be outward opening. It was however, still necessary to seal the hole left by the missile after firing. For this purpose, small chord flap doors were considered. These doors opened inwards and only come into operation after the retraction of an empty launcher, and it was not intended to close these doors during launch, as this would again added to the complexity of an already complex system. Because of the position of the empty launcher it was not possible to seal the slot with a simple hinged door, instead, hydraulically actuated doors of the roller type were chosen.

WING DOORS.

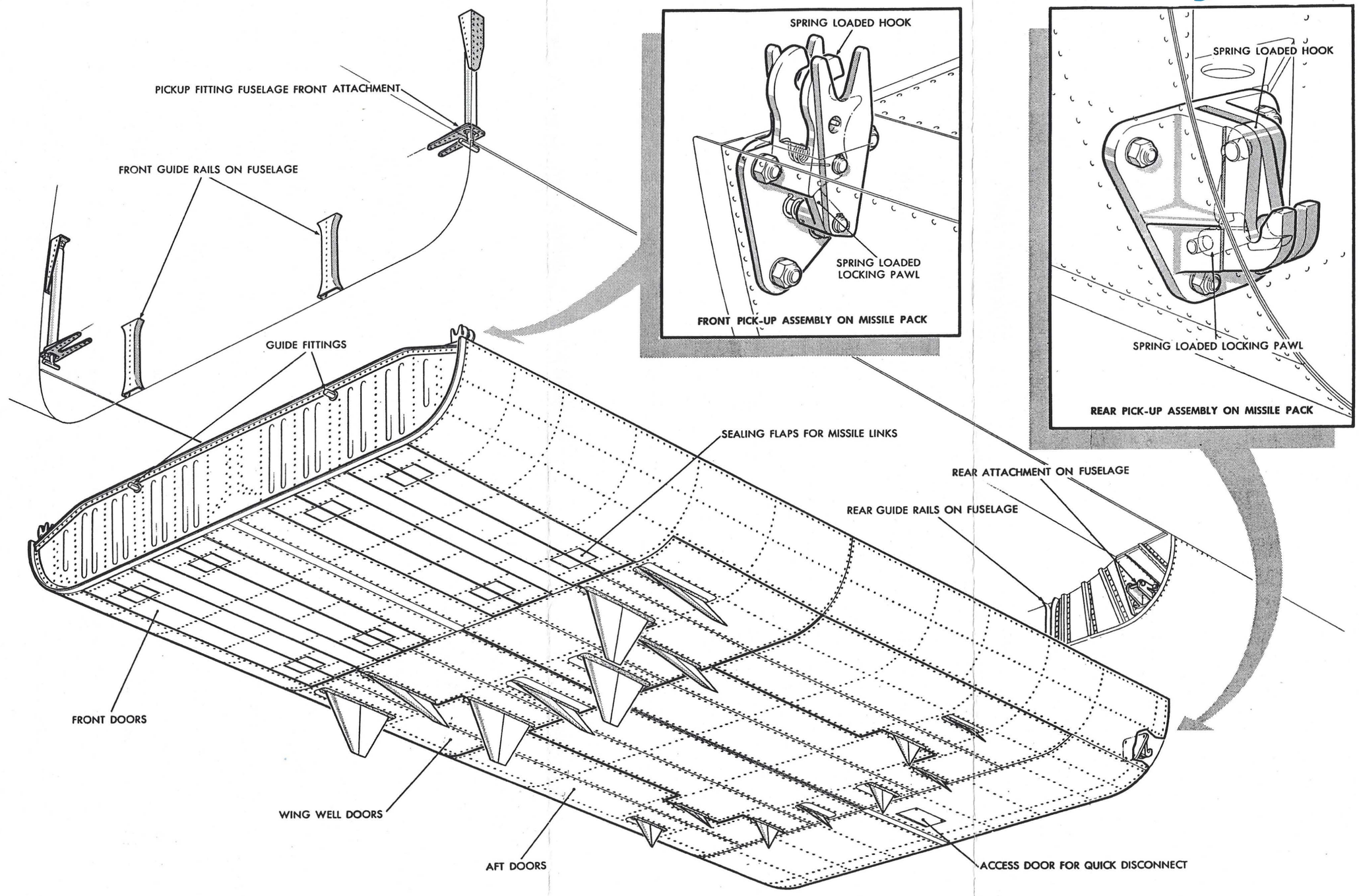
In order to extend the missile for launch it was necessary to first open doors to allow the missile wings and fins to pass through the skin line. Several types of doors were investigated in detail and the multi-element sliding door proved to be the most suitable. There were rollers at each end of the door which ran in tracks. The exposed part of the missile body still required the protection which was previously provided by internal carriage. Douglas was proceeding with the development of the Sparrow 2 which would have been suitable for exposed carriage throughout the flight envelope of the CF-105, but as this would not be ready until a later date, it was



INSTALLATION OF FOUR SPARROW MISSILES. FEBRUARY 1955.



CF-105 SPARROW 2 MISSILE PACK. 1955



CF-105 SPARROW 2 MISSILE PACK. 1955

proposed to cover the exposed portions of the missile with a light fairing which could be jettisoned prior to firing. Cooling air was to be passed through the annulus between the missile and the fairing and exhausted to the atmosphere at the rear of the fairing, which was to be jettisoned by releasing the forward end and, allowing it to rotate through a fixed angle, and then releasing the rear end. (Subsequent wind tunnel tests showed that this did not have the greatest success as at least one of the fairings hung-up in the wing notch after jettisoning). Even with the improved version of the missile a fairing over the radome would be required to prevent damage from mud, stones etc. A small fairing was then envisaged that would fit over the radome but would not be jettisonable, instead, it would be a part of the installation and used to hold the forward end of the large fairing in position (when fitted).

EXTENSION LINKAGE.

The original installation imposed severe restrictions on the type of extension mechanism which could be used, because of the small space above the missile in the retracted position. When the missiles were lowered to the semi-submerged position considerably more space was available for the retracted linkage, and it became possible to consider other types of extension mechanism. Several alternatives were fully investigated and one showed up head and shoulders above all the others. This was the 'two jack with drag link' scheme. As will readily be seen from the diagram, this scheme only begins to score when adequate room is available in the retracted position.

DEVELOPMENT PROGRAM.

The timing of the various phases of the development program was based on two key dates:

(a) The availability of a weapons test CF-105 in Dec./57.)

(b) The requirement to have a Weapons Installation available for evaluation in conjunction with a Fire Control System in, about March, 1959.

The development program was, therefore aimed at providing a Sparrow 2 installation for flight work by the end of 1957, and at completing flight development in the following fifteen months. Before this could happen however, several test rigs had to be built:

1. Extension mechanism test rig.
2. Door test rig.
3. Hydraulics test rig.
4. Wind tunnel tests.
5. Mock-up.

6. Dummy missiles for ground and air testing.
7. Launcher test rig.

In order to have had the pre-flight development program complete before the end of 1957, it was essential to have a complete airworthy Sparrow package installation ready by May 1957. This meant that the design must be complete and the drawings issued by Sept./56.

Work progressed on the armament pack through 1956 and in June 1957, Avro issued a report entitled "ARROW 2 ARMAMENT SYSTEM" No.72/Systems 26/8. The results were based on the initial designs of Nov./55, refined, tested and a tentative production design schedule set up. Two notable features emerged from this work. First, the fibre glass fairing for the missile was dropped and second, a pneumatic power operated dolly was designed for the raising and lowering of the pack. This had been perfected to the point that a pack could be changed in 3 1/2 minutes.

There follows in two sets, illustrations from both these reports:

1. Sketches from the initial schemes.
2. The refined design drawings in report form.

On 23 September 1958, the Canadian Government canceled the ASTRA 1 electronic system and the Sparrow 2D missile programs.

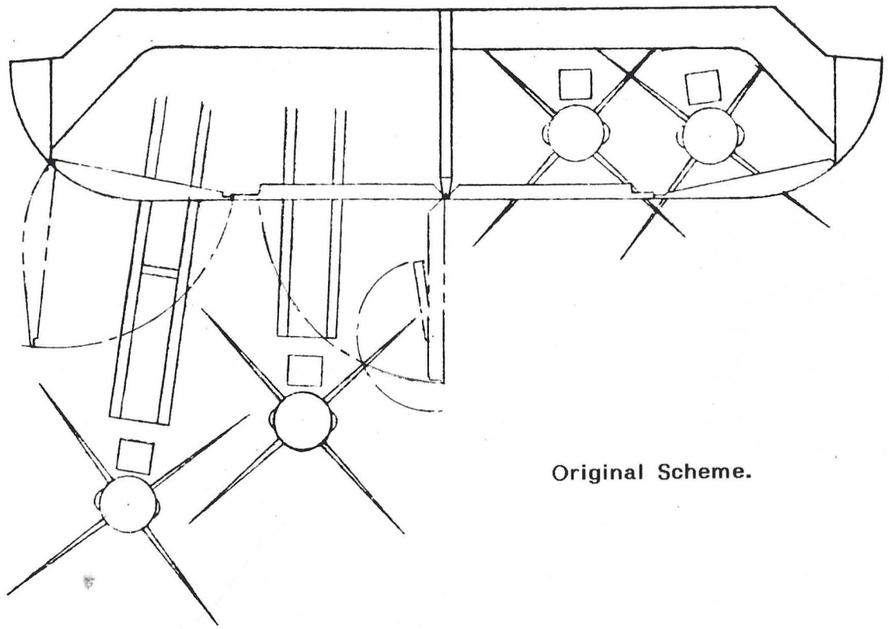
To replace them, the Cabinet decided to install a developed FCS/Missile system in the Arrow, namely the MA-1C/Falcon 3A, 4A and the MB-1. It was stated that the MA-1C/Missile installation in the Arrow would compare satisfactorily with the installation in the USAF F-106.

Thus the Canadian Government was reduced to doing what Avro had advocated all along - to install a proven system that would be updated progressively during its service life. If this had been carried out in the beginning, many millions of dollars of the taxpayers' money would have been saved instead of being thrown away.

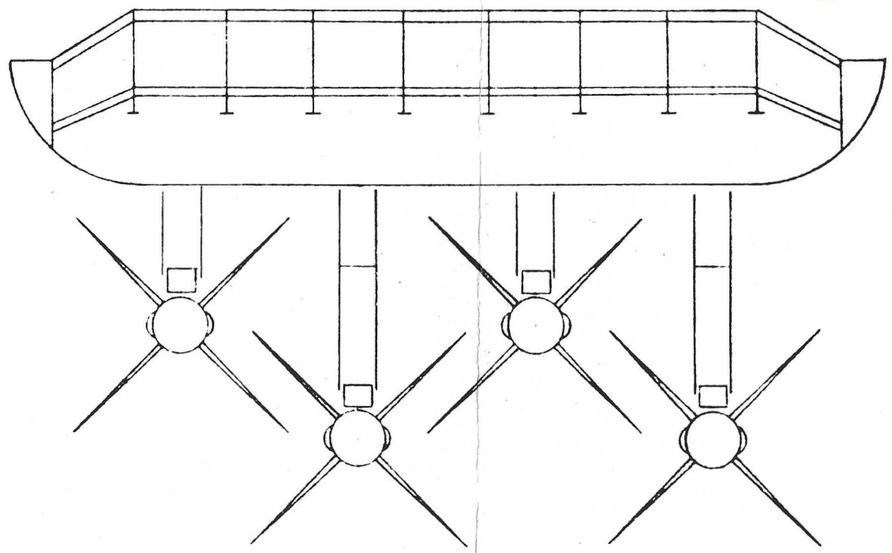
Author's Note:-

The "Red Dean" AAM as designed by Vickers, was too massive both in size and weight, hence too aerodynamically dirty to be seriously considered and it was soon abandoned in favor of the "Red Hebe" AAM, though not before the RCAF had expressed a desire for it to be adopted for the Arrow. This illustrated a complete lack of understanding of the issues and reality. The "Red Dean" was 23.9ft long!.

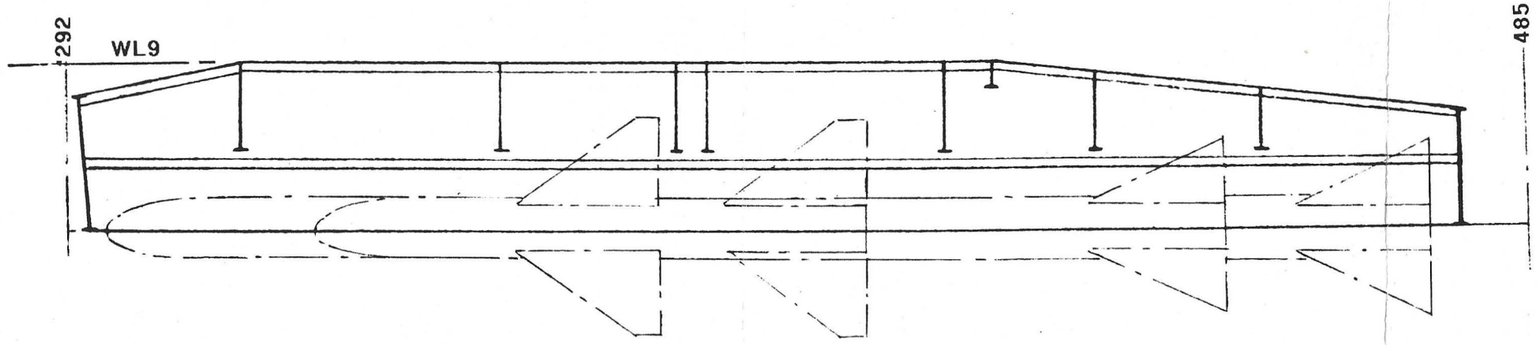
The "Red Hebe" was developed to OR 1131 and was to be coupled with an advanced radar (AI 18) which was capable of long range and wide coverage, but it



Original Scheme.



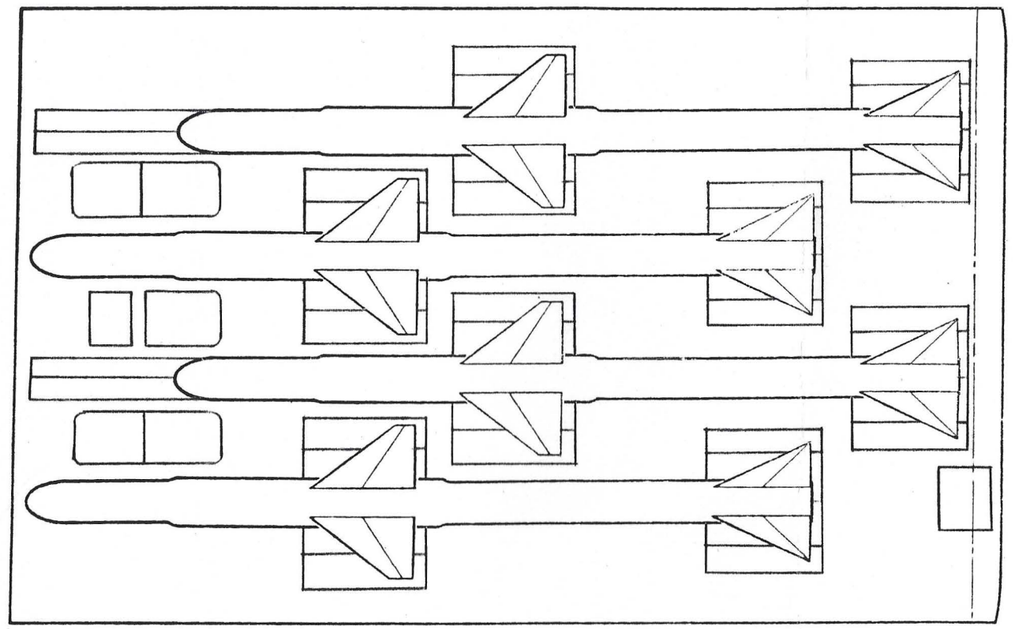
Modified Scheme.



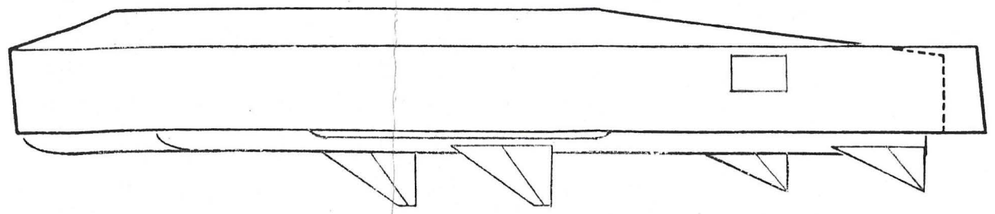
Semi-submerged Missile Stowage.

1957

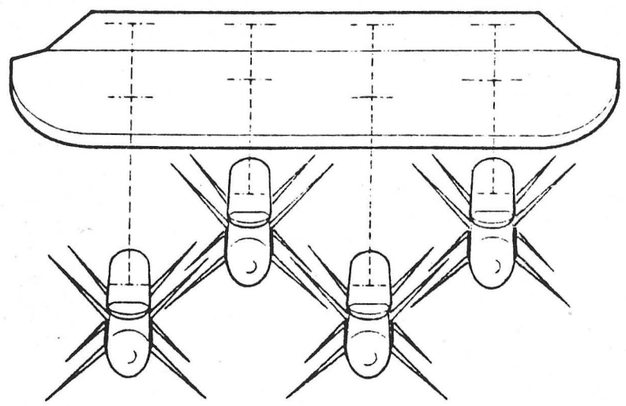
SCHEME FOR SPARROW MISSILE INSTALLATION



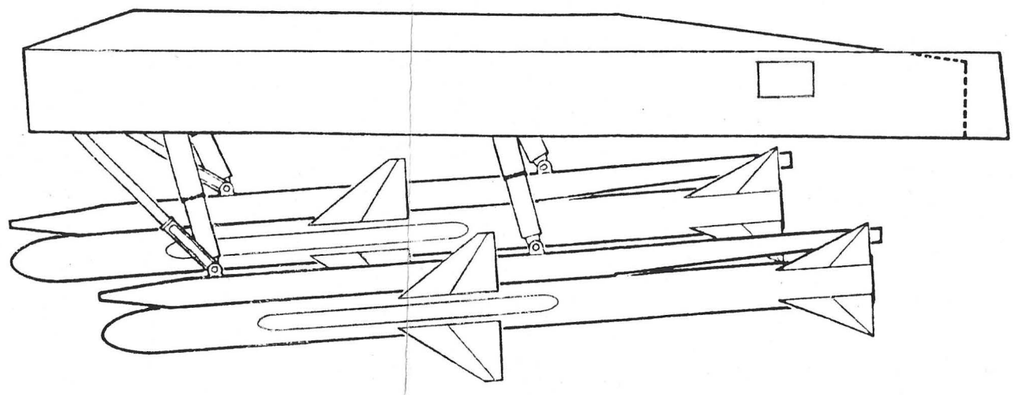
PLAN VIEW-MISSILES STOWED



SIDE VIEW-MISSILES STOWED

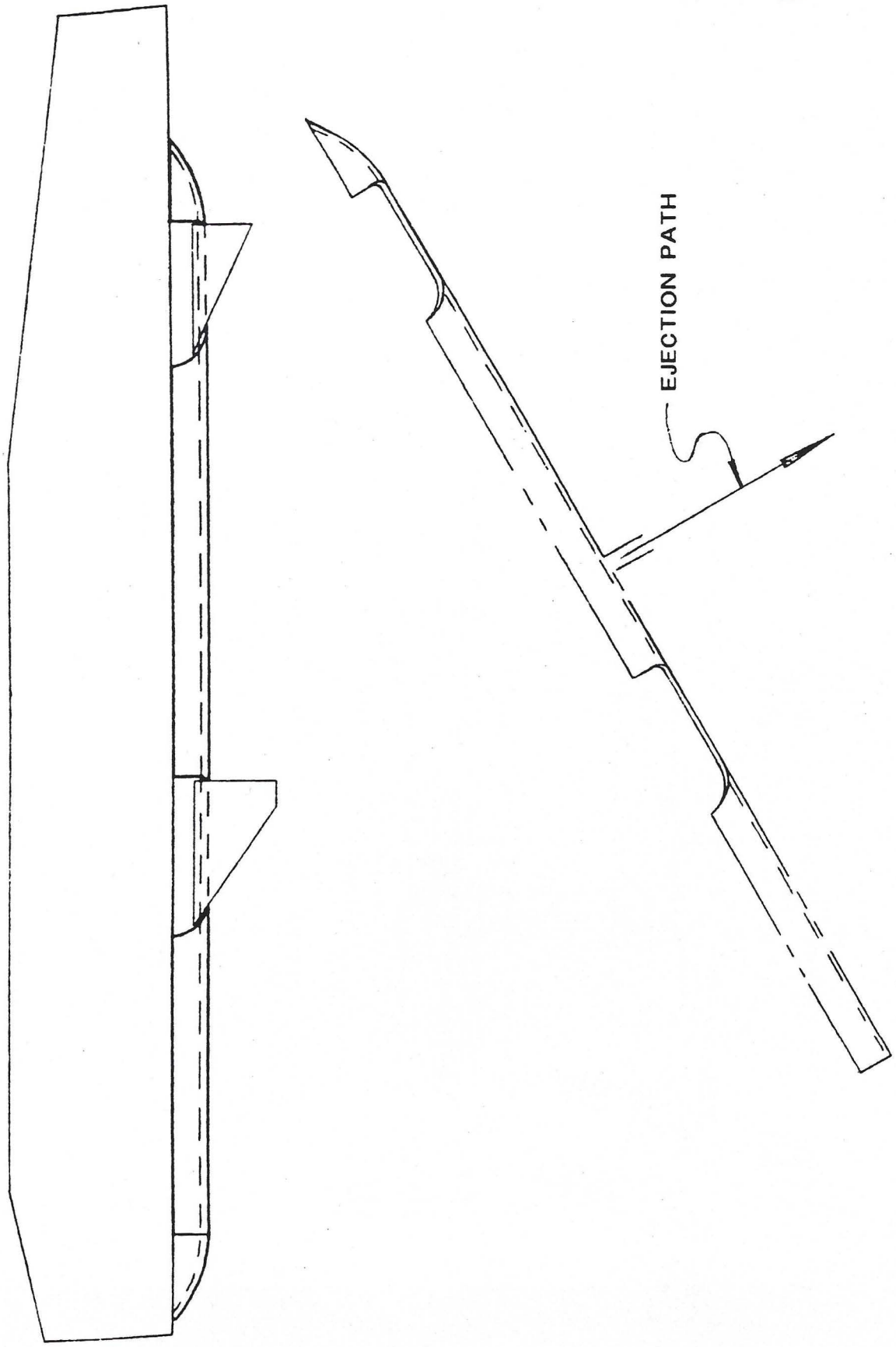


FRONT ELEVATION-MISSILES EXTENDED



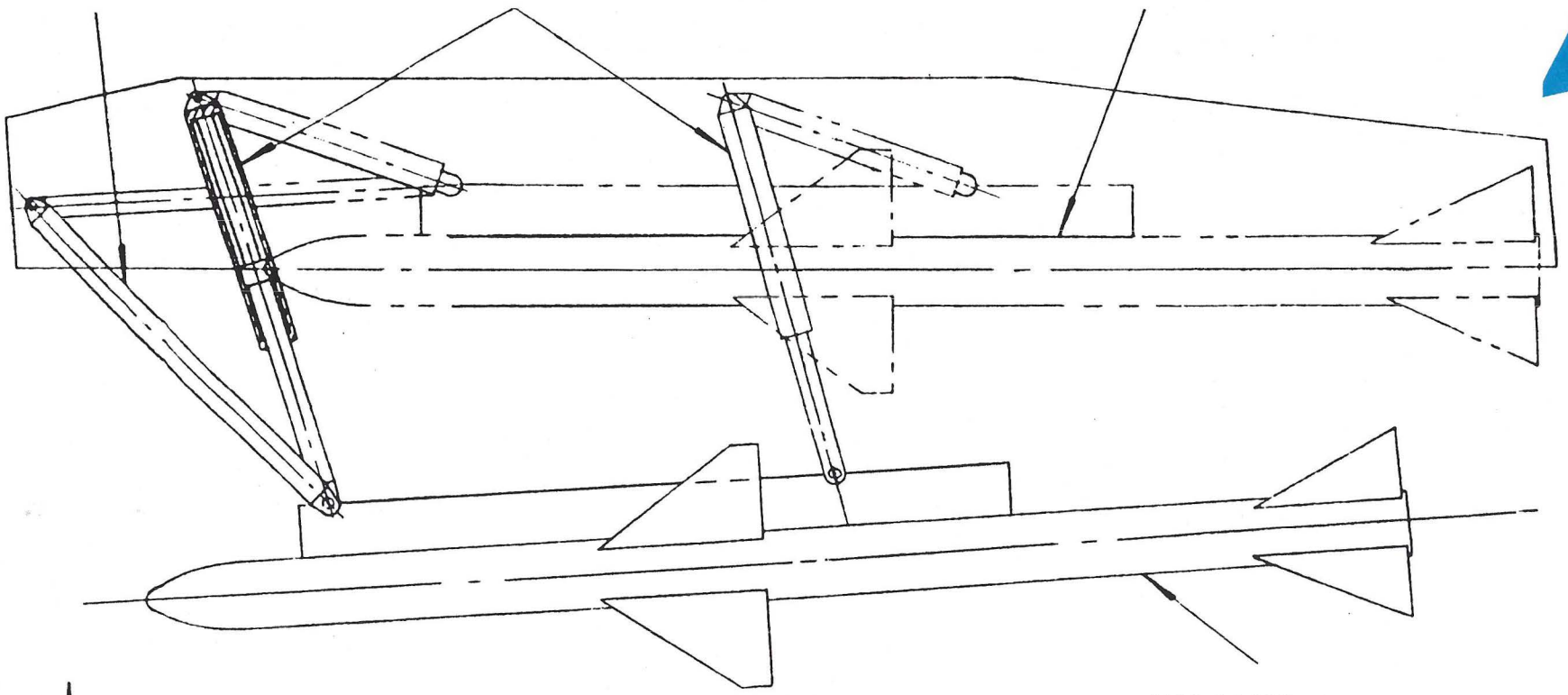
SIDE VIEW-MISSILES EXTENDED

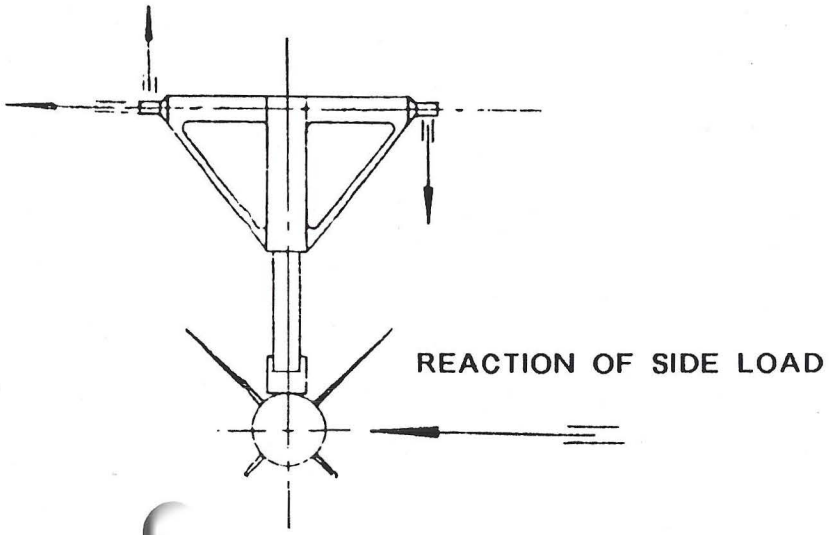
JUNE 1957 INSTALLATION SCHEME FOR FOUR SPARROW MISSILES



SPARROW MISSILE FAIRING

1957

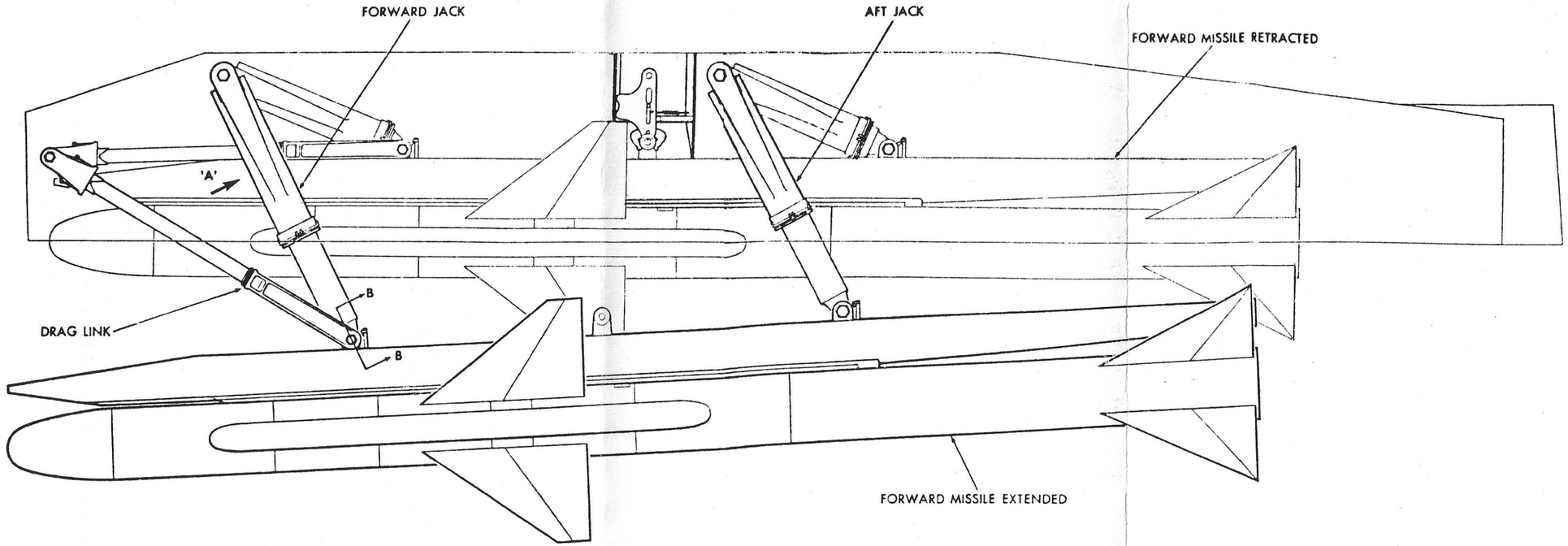


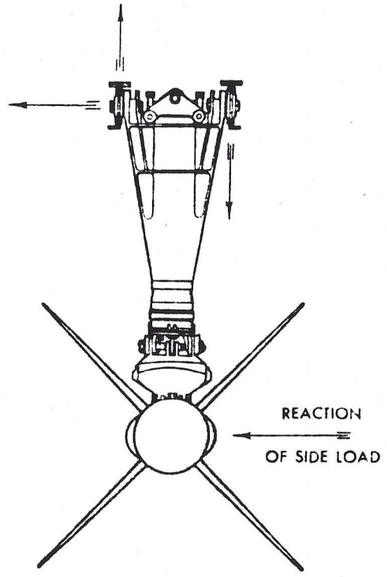


TWIN JACK EXTENSION LINKAGE

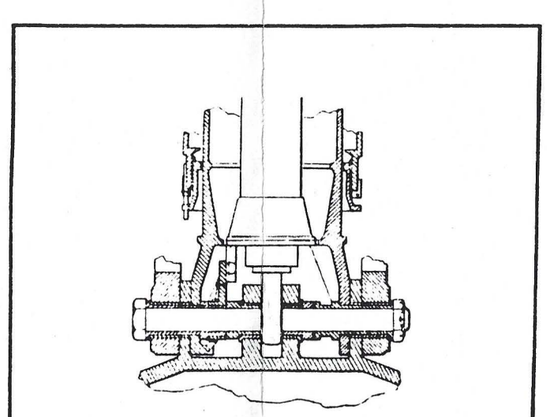
SPARROW HYDRAULIC JACK ARRANGEMENT

1957





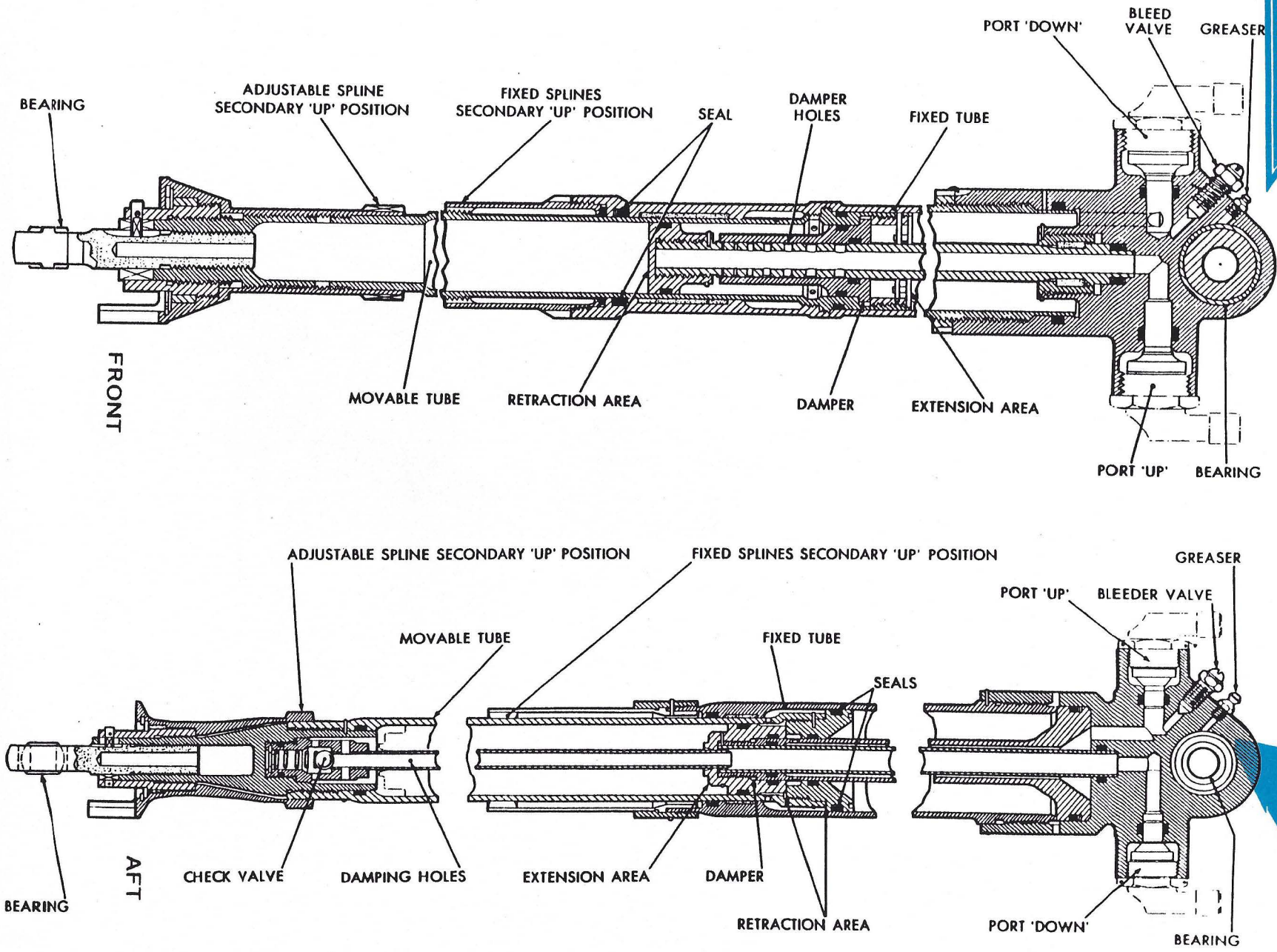
VIEW ON ARROW 'A'

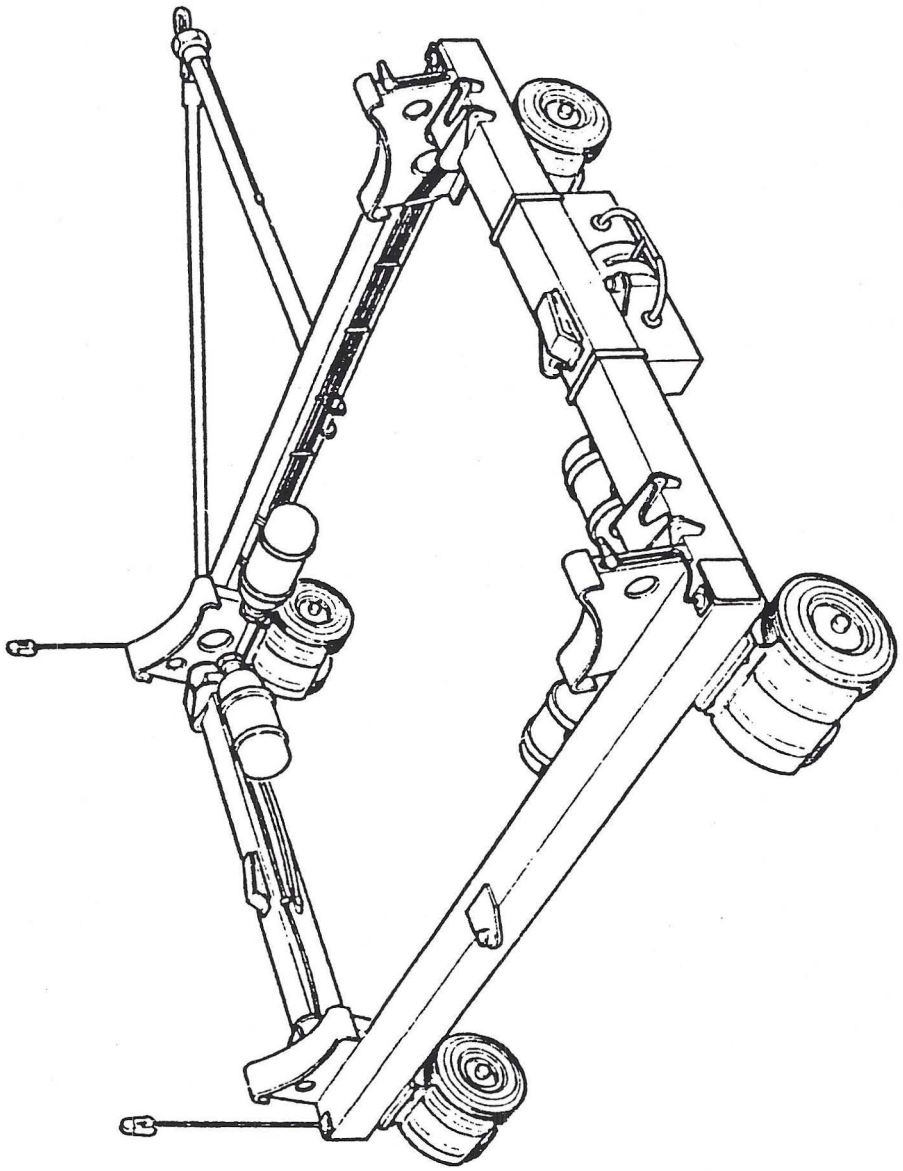


SECTION B-B

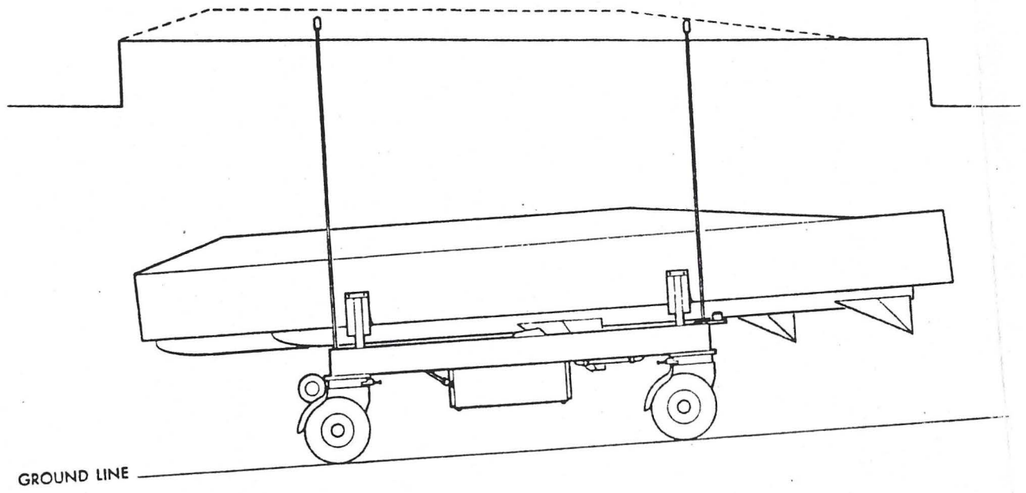
JUNE 1957 INSTALLATION SCHEME FOR FOUR SPARROW MISSILES

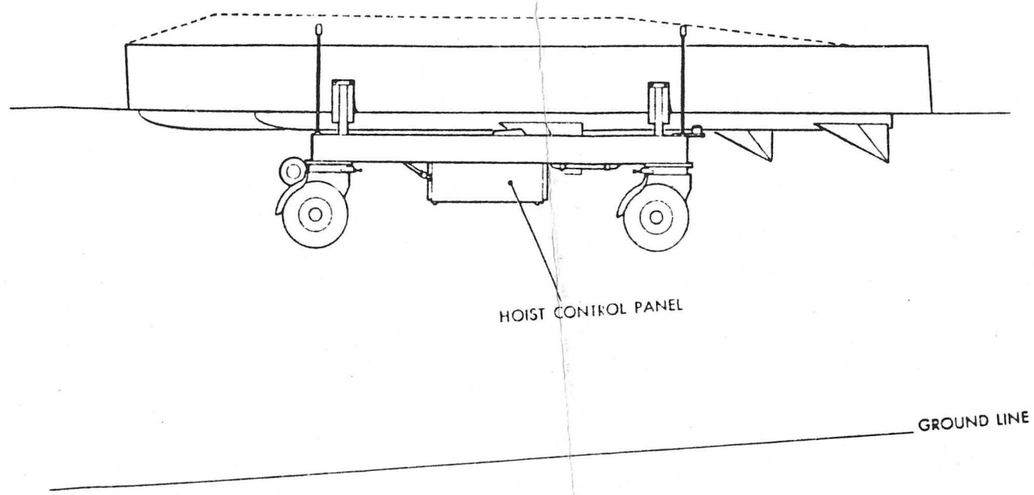
SINGLE MISSILE INSTALLATION SHOWN

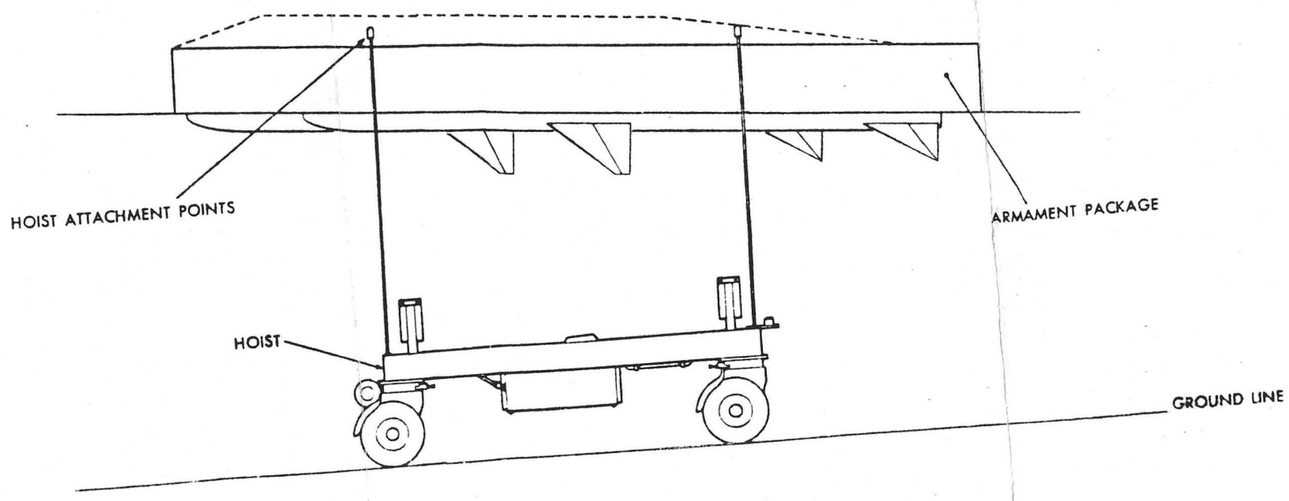

BEARING
ADJUSTABLE SPLINE SECONDARY 'UP' POSITION
FIXED SPLINES SECONDARY 'UP' POSITION
SEAL
DAMPER HOLES
FIXED TUBE
PORT 'DOWN'
BLEED VALVE
GREASER
FRONT
MOVABLE TUBE
RETRACTION AREA
DAMPER
EXTENSION AREA
PORT 'UP'
BEARING
ADJUSTABLE SPLINE SECONDARY 'UP' POSITION
FIXED SPLINES SECONDARY 'UP' POSITION
GREASER
PORT 'UP'
BLEEDER VALVE
MOVABLE TUBE
FIXED TUBE
SEALS
AFT
CHECK VALVE
DAMPING HOLES
EXTENSION AREA
DAMPER
RETRACTION AREA
PORT 'DOWN'
BEARING
BEARING



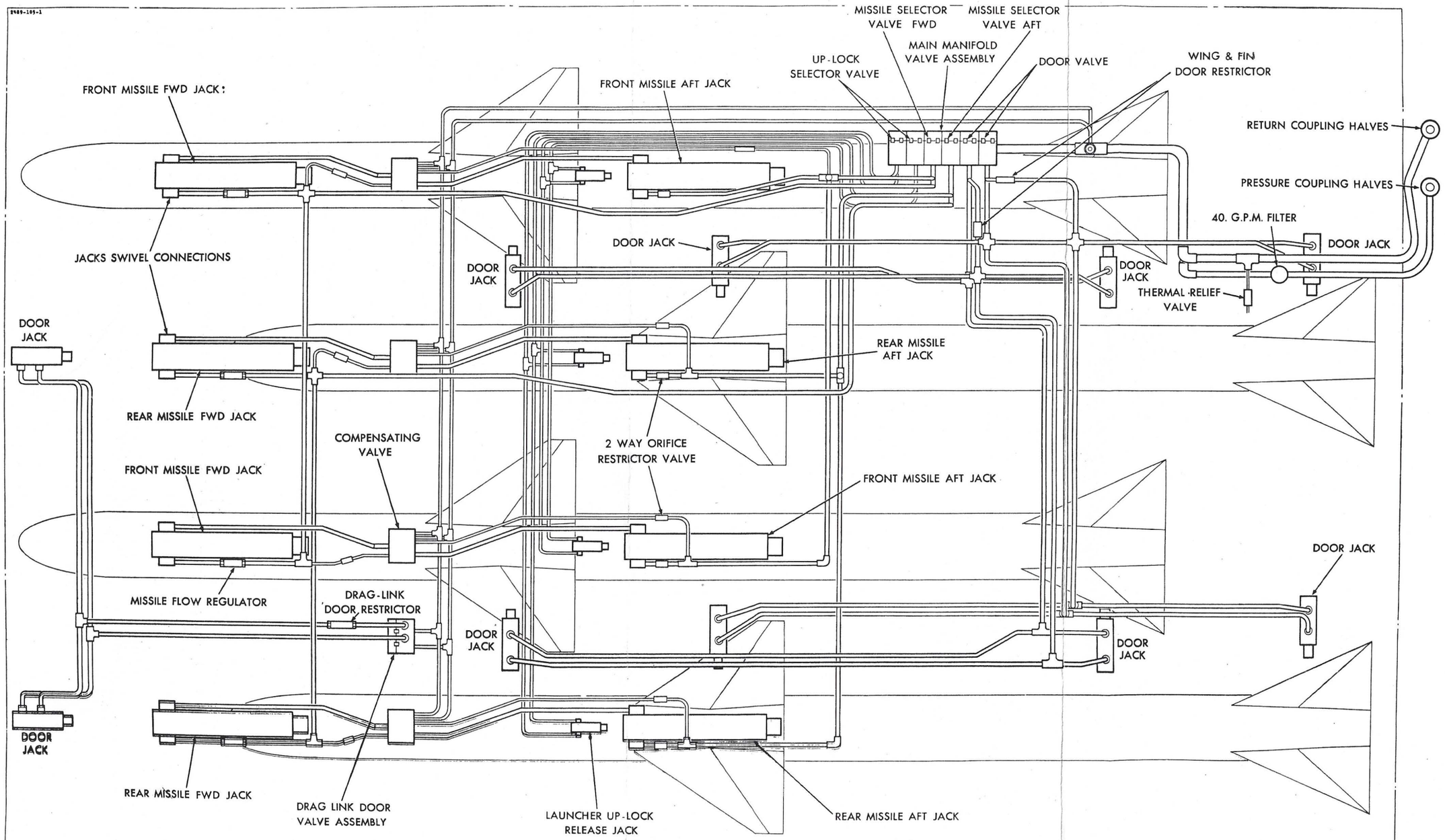
THE ARMAMENT PACK HOIST



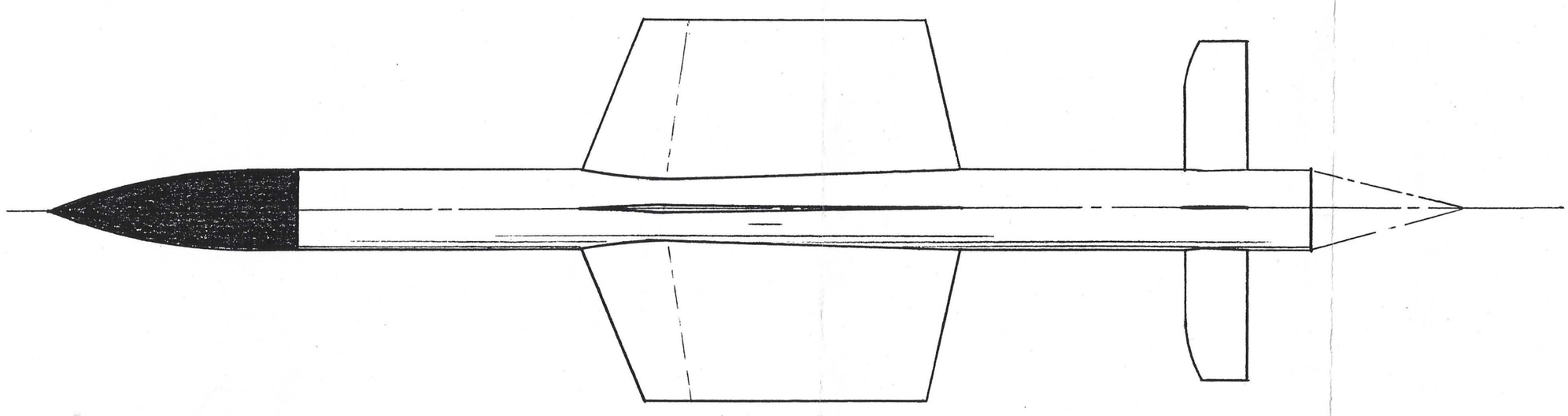




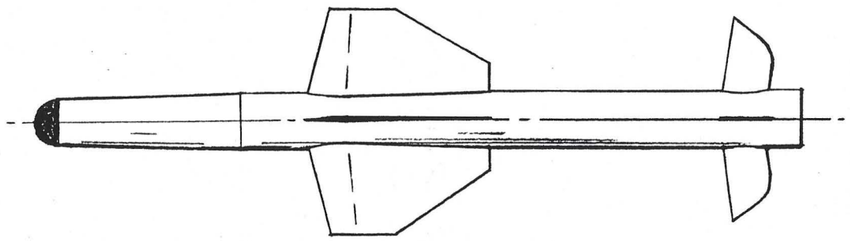
ARMAMENT PACKAGE AND HOIST



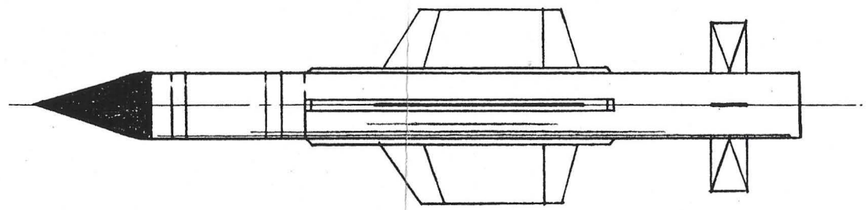
SPARROW MISSILE HYDRAULICS



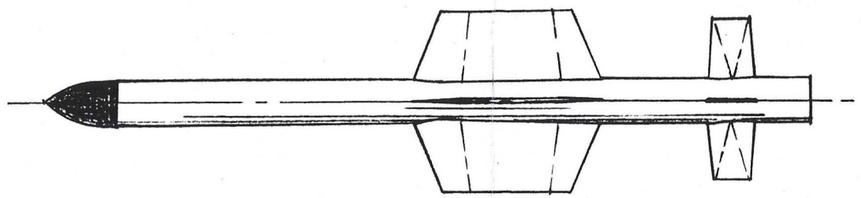
Vickers "Red Dean" AAM



DeHavilland "Blue Jay" AAM



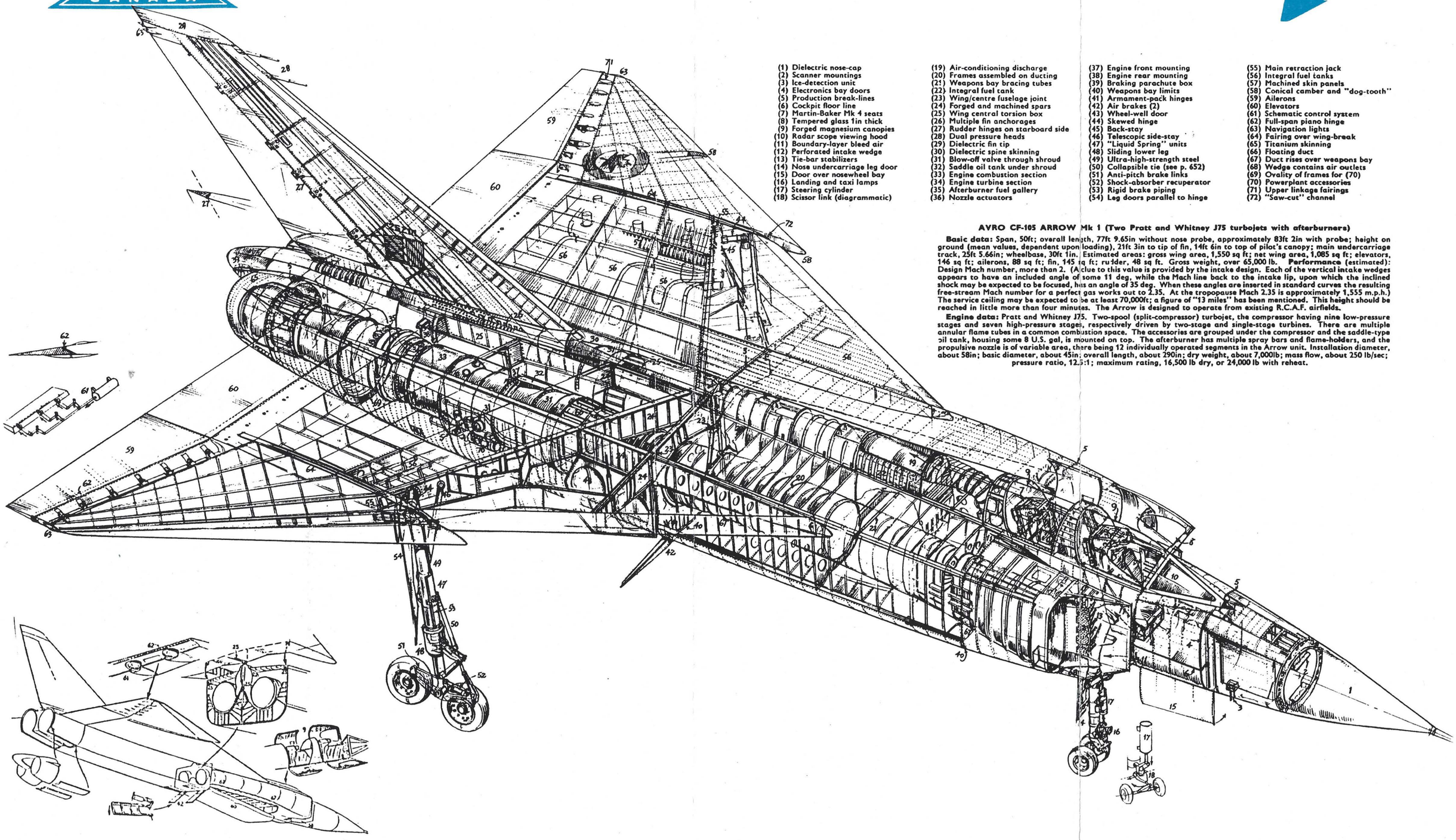
DeHavilland "Firestreak Mk4" AAM



Vickers "Red Hebe" AAM

BRITISH AAM MISSILES. 1950 TO 1960 PERIOD. SCALE 1/24

AVRO CANADA



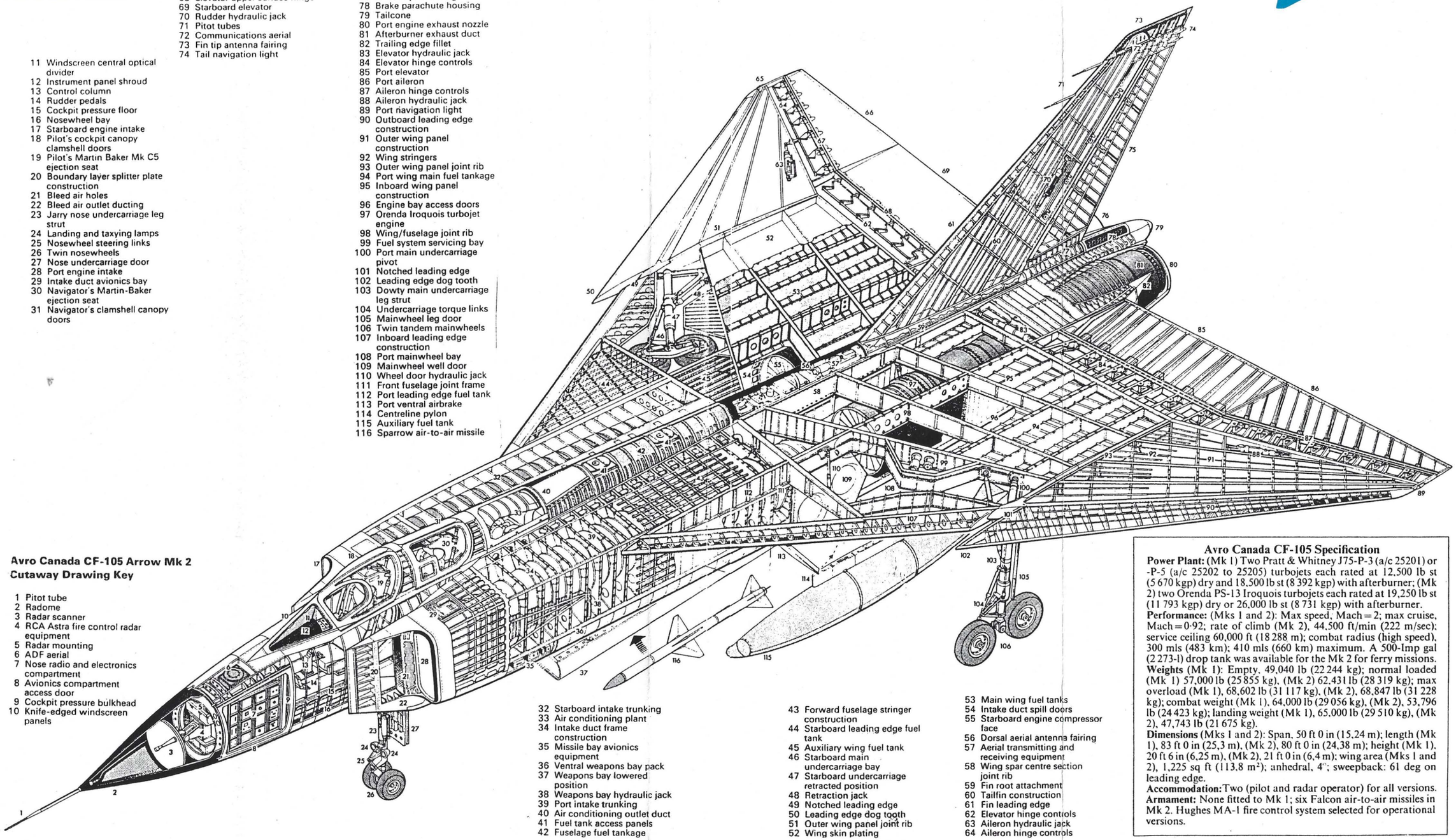
(1) Dielectric nose-cap
(2) Scanner mountings
(3) Ice-detection unit
(4) Electronics bay doors
(5) Production break-lines
(6) Cockpit floor line
(7) Martin-Baker Mk 4 seats
(8) Tempered glass 1in thick
(9) Forged magnesium canopies
(10) Radar scope viewing hood
(11) Boundary-layer bleed air
(12) Perforated intake wedge
(13) Tie-bar stabilizers
(14) Nose undercarriage leg door
(15) Door over nosewheel bay
(16) Landing and taxi lamps
(17) Steering cylinder
(18) Scissor link (diagrammatic)
(19) Air-conditioning discharge
(20) Frames assembled on ducting
(21) Weapons bay bracing tubes
(22) Integral fuel tank
(23) Wing/centre fuselage joint
(24) Forged and machined spars
(25) Wing central torsion box
(26) Multiple fin anchorages
(27) Rudder hinges on starboard side
(28) Dual pressure heads
(29) Dielectric fin tip
(30) Dielectric spine skinning
(31) Blow-off valve through shroud
(32) Saddle oil tank under shroud
(33) Engine combustion section
(34) Engine turbine section
(35) Afterburner fuel gallery
(36) Nozzle actuators
(37) Engine front mounting
(38) Engine rear mounting
(39) Braking parachute box
(40) Weapons bay limits
(41) Armament-pack hinges
(42) Air brakes (2)
(43) Wheel-well door
(44) Skewed hinge
(45) Back-stay
(46) Telescopic side-stay
(47) "Liquid Spring" units
(48) Sliding lower leg
(49) Ultra-high-strength steel
(50) Collapsible tie (see p. 652)
(51) Anti-pitch brake links
(52) Shock-absorber recuperator
(53) Rigid brake piping
(54) Leg doors parallel to hinge
(55) Main retraction jack
(56) Integral fuel tanks
(57) Machined skin panels
(58) Conical camber and "dog-tooth"
(59) Ailerons
(60) Elevators
(61) Schematic control system
(62) Full-span piano hinge
(63) Navigation lights
(64) Fairing over wing-break
(65) Titanium skinning
(66) Floating duct
(67) Duct rises over weapons bay
(68) Wedge contains air outlets
(69) Ovality of frames for (70)
(70) Powerplant accessories
(71) Upper linkage fairings
(72) "Saw-cut" channel

AVRO CF-105 ARROW Mk 1 (Two Pratt and Whitney J75 turbojets with afterburners)

Basic data: Span, 50ft; overall length, 77ft 9.65in without nose probe, approximately 83ft 2in with probe; height on ground (mean values, dependent upon loading), 21ft 3in to tip of fin, 14ft 6in to top of pilot's canopy; main undercarriage track, 25ft 5.66in; wheelbase, 30ft 1in. Estimated areas: gross wing area, 1,550 sq ft; net wing area, 1,085 sq ft; elevators, 146 sq ft; ailerons, 88 sq ft; fin, 145 sq ft; rudder, 48 sq ft. Gross weight, over 65,000 lb. **Performance** (estimated): Design Mach number, more than 2. (A clue to this value is provided by the intake design. Each of the vertical intake wedges appears to have an included angle of some 11 deg, while the Mach line back to the intake lip, upon which the inclined shock may be expected to be focused, has an angle of 35 deg. When these angles are inserted in standard curves the resulting free-stream Mach number for a perfect gas works out to 2.35. At the tropopause Mach 2.35 is approximately 1,555 m.p.h.) The service ceiling may be expected to be at least 70,000ft; a figure of "13 miles" has been mentioned. This height should be reached in little more than four minutes. The Arrow is designed to operate from existing R.C.A.F. airfields.

Engine data: Pratt and Whitney J75. Two-spool (split-compressor) turbojet, the compressor having nine low-pressure stages and seven high-pressure stages, respectively driven by two-stage and single-stage turbines. There are multiple annular flame tubes in a common combustion space. The accessories are grouped under the compressor and the saddle-type oil tank, housing some 8 U.S. gal, is mounted on top. The afterburner has multiple spray bars and flame-holders, and the propulsive nozzle is of variable area, there being 12 individually operated segments in the Arrow unit. Installation diameter, about 58in; basic diameter, about 45in; overall length, about 290in; dry weight, about 7,000lb; mass flow, about 250 lb/sec; pressure ratio, 12.5:1; maximum rating, 16,500 lb dry, or 24,000 lb with reheat.

ILLUSTRATION FROM FLIGHT MAGAZINE. OCTOBER 25 1957.



Avro Canada CF-105 Arrow Mk 2 Cutaway Drawing Key

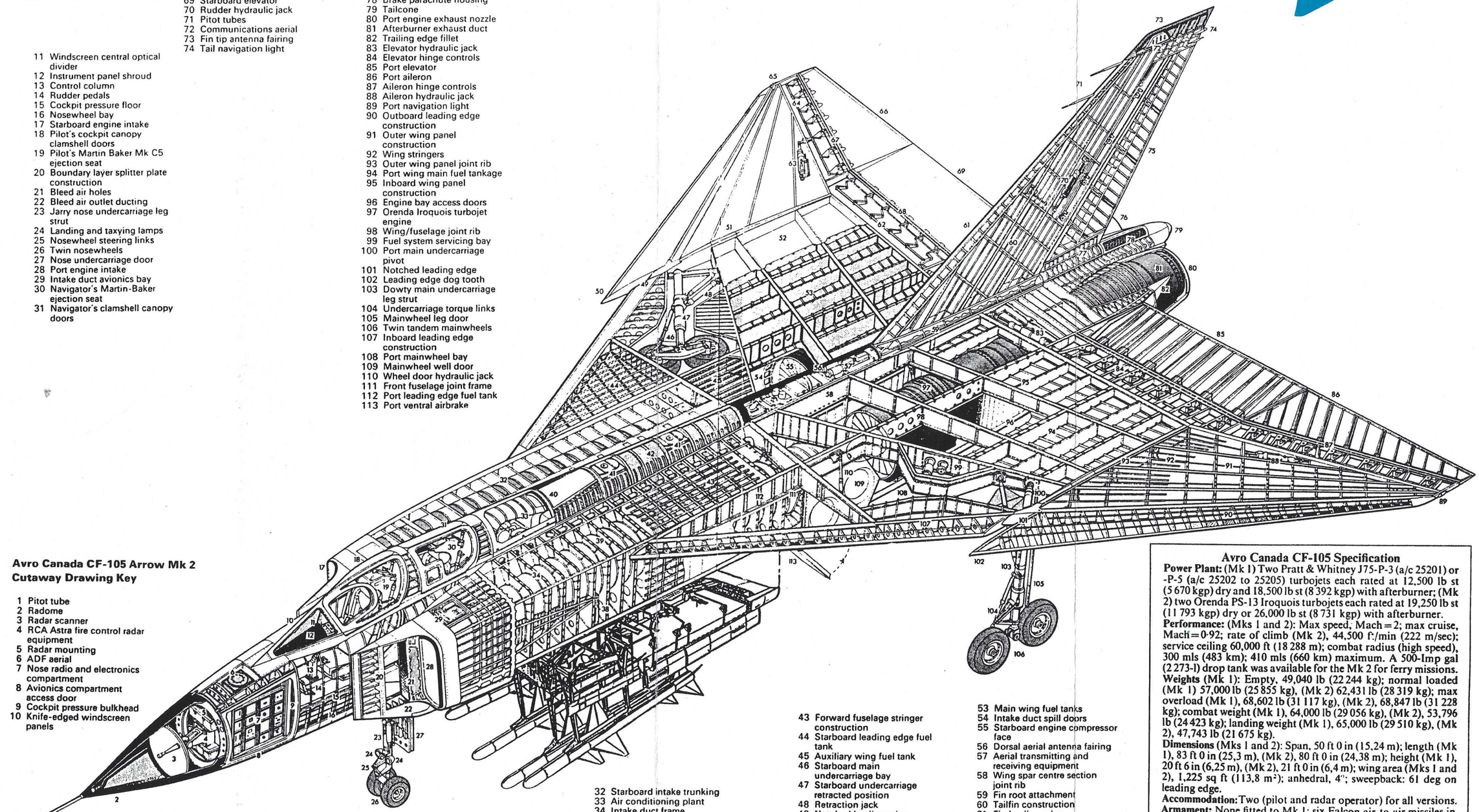
1 Pitot tube
2 Radome
3 Radar scanner
4 RCA Astra fire control radar equipment
5 Radar mounting
6 ADF aerial
7 Nose radio and electronics compartment
8 Avionics compartment access door
9 Cockpit pressure bulkhead
10 Knife-edged windscreen panels
11 Windscreen central optical divider
12 Instrument panel shroud
13 Control column
14 Rudder pedals
15 Cockpit pressure floor
16 Nosewheel bay
17 Starboard engine intake
18 Pilot's cockpit canopy clamshell doors
19 Pilot's Martin Baker Mk C5 ejection seat
20 Boundary layer splitter plate construction
21 Bleed air holes
22 Bleed air outlet ducting
23 Jarry nose undercarriage leg strut
24 Landing and taxying lamps
25 Nosewheel steering links
26 Twin nosewheels
27 Nose undercarriage door
28 Port engine intake
29 Intake duct avionics bay
30 Navigator's Martin-Baker ejection seat
31 Navigator's clamshell canopy doors
32 Starboard intake trunking
33 Air conditioning plant
34 Intake duct frame construction
35 Missile bay avionics equipment
36 Ventral weapons bay pack
37 Weapons bay lowered position
38 Weapons bay hydraulic jack
39 Port intake trunking
40 Air conditioning outlet duct
41 Fuel tank access panels
42 Fuselage fuel tankage
43 Forward fuselage stringer construction
44 Starboard leading edge fuel tank
45 Auxiliary wing fuel tank
46 Starboard main undercarriage bay
47 Starboard undercarriage retracted position
48 Retraction jack
49 Notched leading edge
50 Leading edge dog tooth
51 Outer wing panel joint rib
52 Wing skin plating
53 Main wing fuel tanks
54 Intake duct spill doors
55 Starboard engine compressor face
56 Dorsal aerial antenna fairing
57 Aerial transmitting and receiving equipment
58 Wing spar centre section joint rib
59 Fin root attachment
60 Tailfin construction
61 Fin leading edge
62 Elevator hinge controls
63 Aileron hydraulic jack
64 Aileron hinge controls
65 Starboard navigation light
66 Starboard aileron
67 Aileron upper surface hinge
68 Elevator upper surface hinge
69 Starboard elevator
70 Rudder hydraulic jack
71 Pitot tubes
72 Communications aerial
73 Fin tip antenna fairing
74 Tail navigation light
75 Rudder construction
76 Starboard engine exhaust nozzle
77 Dorsal spine fairing
78 Brake parachute housing
79 Tailcone
80 Port engine exhaust nozzle
81 Afterburner exhaust duct
82 Trailing edge fillet
83 Elevator hydraulic jack
84 Elevator hinge controls
85 Port elevator
86 Port aileron
87 Aileron hinge controls
88 Aileron hydraulic jack
89 Port navigation light
90 Outboard leading edge construction
91 Outer wing panel construction
92 Wing stringers
93 Outer wing panel joint rib
94 Port wing main fuel tankage
95 Inboard wing panel construction
96 Engine bay access doors
97 Orenda Iroquois turbojet engine
98 Wing/fuselage joint rib
99 Fuel system servicing bay
100 Port main undercarriage pivot
101 Notched leading edge
102 Leading edge dog tooth
103 Dowty main undercarriage leg strut
104 Undercarriage torque links
105 Mainwheel leg door
106 Twin tandem mainwheels
107 Inboard leading edge construction
108 Port mainwheel bay
109 Mainwheel well door
110 Wheel door hydraulic jack
111 Front fuselage joint frame
112 Port leading edge fuel tank
113 Port ventral airbrake
114 Centreline pylon
115 Auxiliary fuel tank
116 Sparrow air-to-air missile

Avro Canada CF-105 Specification

Power Plant: (Mk 1) Two Pratt & Whitney J75-P-3 (a/c 25201) or -P-5 (a/c 25202 to 25205) turbojets each rated at 12,500 lb st (5 670 kgp) dry and 18,500 lb st (8 392 kgp) with afterburner; (Mk 2) two Orenda PS-13 Iroquois turbojets each rated at 19,250 lb st (11 793 kgp) dry or 26,000 lb st (8 731 kgp) with afterburner.
Performance: (Mks 1 and 2): Max speed, Mach = 2; max cruise, Mach = 0·92; rate of climb (Mk 2), 44,500 ft/min (222 m/sec); service ceiling 60,000 ft (18 288 m); combat radius (high speed), 300 mls (483 km); 410 mls (660 km) maximum. A 500-Imp gal (2 273-l) drop tank was available for the Mk 2 for ferry missions.
Weights (Mk 1): Empty, 49,040 lb (22 244 kg); normal loaded (Mk 1) 57,000 lb (25 855 kg), (Mk 2) 62,431 lb (28 319 kg); max overload (Mk 1), 68,602 lb (31 117 kg), (Mk 2), 68,847 lb (31 228 kg); combat weight (Mk 1), 64,000 lb (29 056 kg), (Mk 2), 53,796 lb (24 423 kg); landing weight (Mk 1), 65,000 lb (29 510 kg), (Mk 2), 47,743 lb (21 675 kg).
Dimensions (Mks 1 and 2): Span, 50 ft 0 in (15,24 m); length (Mk 1), 83 ft 0 in (25,3 m), (Mk 2), 80 ft 0 in (24,38 m); height (Mk 1), 20 ft 6 in (6,25 m), (Mk 2), 21 ft 0 in (6,4 m); wing area (Mks 1 and 2), 1,225 sq ft (113,8 m²); anhedral, 4°; sweepback: 61 deg on leading edge.
Accommodation: Two (pilot and radar operator) for all versions.
Armament: None fitted to Mk 1; six Falcon air-to-air missiles in Mk 2. Hughes MA-1 fire control system selected for operational versions.

ILLUSTRATION FROM AIR ENTHUSIAST NUMBER 8.

AVRO CANADA



Avro Canada CF-105 Arrow Mk 2 Cutaway Drawing Key

1 Pitot tube
2 Radome
3 Radar scanner
4 RCA Astra fire control radar equipment
5 Radar mounting
6 ADF aerial
7 Nose radio and electronics compartment
8 Avionics compartment access door
9 Cockpit pressure bulkhead
10 Knife-edged windscreen panels
11 Windscreen central optical divider
12 Instrument panel shroud
13 Control column
14 Rudder pedals
15 Cockpit pressure floor
16 Nosewheel bay
17 Starboard engine intake
18 Pilot's cockpit canopy clamshell doors
19 Pilot's Martin Baker Mk C5 ejection seat
20 Boundary layer splitter plate construction
21 Bleed air holes
22 Bleed air outlet ducting
23 Jarry nose undercarriage leg strut
24 Landing and taxying lamps
25 Nosewheel steering links
26 Twin nosewheels
27 Nose undercarriage door
28 Port engine intake
29 Intake duct avionics bay
30 Navigator's Martin-Baker ejection seat
31 Navigator's clamshell canopy doors
32 Starboard intake trunking
33 Air conditioning plant
34 Intake duct frame construction
35 Missile bay avionics equipment
36 Ventral weapons bay pack
37 Weapons bay lowered position
38 Weapons bay hydraulic jack
39 Port intake trunking
40 Air conditioning outlet duct
41 Fuel tank access panels
42 Fuselage fuel tankage
43 Forward fuselage stringer construction
44 Starboard leading edge fuel tank
45 Auxiliary wing fuel tank
46 Starboard main undercarriage bay
47 Starboard undercarriage retracted position
48 Retraction jack
49 Notched leading edge
50 Leading edge dog tooth
51 Outer wing panel joint rib
52 Wing skin plating
53 Main wing fuel tanks
54 Intake duct spill doors
55 Starboard engine compressor face
56 Dorsal aerial antenna fairing
57 Aerial transmitting and receiving equipment
58 Wing spar centre section joint rib
59 Fin root attachment
60 Tailfin construction
61 Fin leading edge
62 Elevator hinge controls
63 Aileron hydraulic jack
64 Aileron hinge controls
65 Starboard navigation light
66 Starboard aileron
67 Aileron upper surface hinge
68 Elevator upper surface hinge
69 Starboard elevator
70 Rudder hydraulic jack
71 Pitot tubes
72 Communications aerial
73 Fin tip antenna fairing
74 Tail navigation light
75 Rudder construction
76 Starboard engine exhaust nozzle
77 Dorsal spine fairing
78 Brake parachute housing
79 Tailcone
80 Port engine exhaust nozzle
81 Afterburner exhaust duct
82 Trailing edge fillet
83 Elevator hydraulic jack
84 Elevator hinge controls
85 Port elevator
86 Port aileron
87 Aileron hinge controls
88 Aileron hydraulic jack
89 Port navigation light
90 Outboard leading edge construction
91 Outer wing panel construction
92 Wing stringers
93 Outer wing panel joint rib
94 Port wing main fuel tankage
95 Inboard wing panel construction
96 Engine bay access doors
97 Orenda Iroquois turbojet engine
98 Wing/fuselage joint rib
99 Fuel system servicing bay
100 Port main undercarriage pivot
101 Notched leading edge
102 Leading edge dog tooth
103 Dowty main undercarriage leg strut
104 Undercarriage torque links
105 Mainwheel leg door
106 Twin tandem mainwheels
107 Inboard leading edge construction
108 Port mainwheel bay
109 Mainwheel well door
110 Wheel door hydraulic jack
111 Front fuselage joint frame
112 Port leading edge fuel tank
113 Port ventral airbrake

Note that the armament pack and the Sparrow missiles are shown in the detracted position. The armament pack could be serviced either on or off the aircraft.

Avro Canada CF-105 Specification

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Accommodation: Two (pilot and radar operator) for all versions.
Armament: None fitted to Mk 1; six Falcon air-to-air missiles in Mk 2. Hughes MA-1 fire control system selected for operational versions.

ILLUSTRATION FROM AIR ENTHUSIAST NUMBER 8.

was also recognized that improvements would have to be made in ground radar in order to make best use of the aircraft. Eventually, the "Red Hebe" AAM gave way to the DeHavilland "Red Top" AAM, an outgrowth of the "Blue Jay" and "Firestreak Mk4" AAM's. None of these types were considered for the Arrow.

Scale sketches of the British missiles of the period are included for comparison purposes on page 182.

MEDIA ILLUSTRATIONS OF THE ARROW.

One of the illustrations published by the Media and shown on page 184 that led to the mistaken impression that the missile pack was hinged down or lowered in order to fire the missiles. This one was published in Flight Magazine for October 25, 1957, page 652 and quotes;

> "No details of the weapon carried may be published, but the space available is quite remarkable, not the least impressive dimension being the width of some 10 ft. The armament pack occupies the lower part of the centre fuselage and the missile must clearly be lowered beneath the aircraft before launching. Inspection shows that the pack itself is arranged to hinge downwards about a transverse axis at its rear end immediately before the missiles are fired. It will also be noted that a detachable pack makes the Arrow inherently versatile."

The sketch on the left is also from the same article, illustrating the above 'incorrect' information and even identifies item 38 as the Weapons Bay Hydraulic Jack and item 37 as the Weapons Pack Lowered Position.

Another illustration published by the Media and shown on page 185 that led to the mistaken impression that the Weapons Pack was hinged down in order to fire the missiles. This one was taken from Air Enthusiast Number 8, page 63 and identifies item 38 as the Weapons Bay Hydraulic Jack. (This was later corrected on Air Enthusiast Number 54.)

The Author has provided a re-worked illustration of Mike Badrocke's on page 185, in that the external long-range fuel tank, which bore no relation to the actual one, has been eliminated and the missile pack installation has been corrected to show that it could be lowered and removed from the aircraft as well as being serviced whilst still on the aircraft. The missiles are shown in the lowered position ready for firing.

This illustration appears on page 185.