THE AVRO ARROW

AVRO CANADA

TO DOUG & DONETTE
WITH MY BEST
REGARDS

A BOOK BY

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CHAPTER 7

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ARROW Mk 2 MOCK-UP.

As a result of the Arrow 2 mock-up conference held in September, 1957, a total of 252 change requests required investigation. The effect of these changes involved the determination of Avro, RCA, Martin-Baker and the RCAF.

STATUS OF MOCK-UP CHANGE REQUESTS.				
Subject	Change Requests	Under Initial Investigation	Undergoing Corrective Action	Complete
Cockpit	62	11	11	40
Structure	51	5	3	43
Engine Installation	17	-	-	17
Electrical	22	2	4	16
Air Cond.	7	-	2	5
Low Press. Pneumatics	1	-	-	1
Fire Exting. System.	3	-	-	3
De-Icing	2	-	-	2
Fuel system	11	2	1	8
Hydraulics	15	-	2	13
Oxygen system.	5	-	1	4
Instruments	7	2	-	5
ASTRA 1	34	4	3	27
Armament	15	2	4	9
Totals	252	28	31	193

In addition, ten (10) items required demonstration. These changes led to many items being changed in production.

ARROW Mk 2. - THE FIRST Mk 2, RL25206.

The Mk2 ARROW was a virtual redesign of the Mk1. This was necessitated by modifications due to flight testing of the Mk1 aircraft, new parts and assemblies due to the installation of the IROQUOIS engine, a new radar nose plus new profile lines in these areas. These were the changes that were to be encountered on RL25206, but the final production Mk2 would be as different again. For one thing, the ramp air bleed dump ducts on the underside of the Mk1 aircraft would be eliminated and this area reverted to a similar arrangement as first envisioned on the C-105 and CF-105 designs. The air from the ramp bleed would have been diverted to either engine cooling or dumped overboard through top surface louvres. It will be noted that the Mk3 ARROW eliminated this feature as well, albeit the intakes were completely redesigned.

A partial list of new parts, machined parts and assembly changes are noted below. Again, these apply only to RL25206.

Component Assembly	New Parts	Machined Parts	Assembly Changes
Final Assembly	2766	547	1785
Radar Nose	-	-	-
Front Fuselage	1404	360	380
Centre Fuselage	1887	313	169
Duct Bay	-	-	-
Engine Bay	4020	314	337
Rear Fuselage	3112	200	306
Inner Wing	366	100	62
Wing/Fin T/E	-	-	-
Armament Pack	1109	427	118
Drop Tank			

Many of the parts of course were changed many times due to RCAF and RCA requirements not to mention the Hughes and Douglas connections.

It will be understood however that the above was only the beginning. The flight tests of the Mk 2 in its development, would undoubtedly have led to as many if not more changes as they continued. The armament package together with its fire control (in whatever configuration that would have finally been decided upon) would have accounted for an indeterminate number by itself, not to mention those that would have been created by the further Marks of the aircraft, had they been adopted. Naturally, a great amount of the Arrow Mk 1 tooling, in modified form, was used for the Mk 2, and new tooling was manufactured only as necessitated.

The following describes the work in an overall sense for the entire Arrow program, with emphasis on the Arrow Mk 2, up to the end of November 1958.

THE ARROW Mk 2 PROGRAM. - INTRODUCTION.

This Statement of Work covers four important phases of the development of the Avro Arrow.

1. The design, development, tooling and production of the Arrow Mk1, RL 25201 to RL 25205.

2. The design, development, tooling and production of the Arrow Mk2 No. RL 25206.

3. The design, development, tooling and production of the Arrow Mk2 aircraft from RL 25207 to RL 25237.

4. The design, development, tooling and production of the Arrow Mk2 production aircraft (projected).

Parts 13 and 14 respectively contain the Phase 1 and Phase 2 program for engineering the MA-1 type electronic system, Falcon missiles, and the Genie (MB-1) rocket into the Arrow.

Work on the Astra and Sparrow installations is shown as "work terminated", in accordance with DDP's stop-work telegram dated September 29, 1958.

Except where otherwise noted, all items of the product improvement and flight-test program would have ended on or before September 30, 1960, the delivery date of the last of the 20 Arrow development aircraft. Engineering support to production would have ended on July 31, 1961, the delivery date of the last of the 37 aircraft manufacturing program.

PART ONE. SPECIFICATIONS AND PRELIMINARY WORK.

1.1 PRELIMINARY ENGINEERING OF THE ARROW AIRCRAFT.

-Design study and submission of a preliminary design. (Work completed).

-Definition of and fiscal investigations preparatory to or as a result of, major revisions of the program.

-Additional studies at the request of the RCAF necessary to complement the design of the aircraft and associated GSE.

1.2 Preparation and revision of model specifications for :-

-The Arrow Weapon System. (Work terminated).

-The Arrow 1 aircraft.

-Arrow 2 aircraft 25206.

-Arrow 2 operational version.

1.3 Assistance to the RCAF in the preparation and revision of Requirement Specification WSC 1-2 - Requirements for the Air- frame and GSM Installations for the Arrow aircraft.

1.4 Evaluation of model specifications of sub-systems of Arrow Weapon System (Work terminated).

2.1. - PART TWO - ARROW Mk 1 - ARROW 1 ENGINEERING.

-Arrow 1 basic airframe design comprising and/or specification of structure and systems, contractor-furnished equipment and installation of CFE and GFE, including J75 engines and interim electronic system. (Work completed).

-Engineering work beyond basic design through December 1959, including ground testing of engineering changes; installation of these changes in development aircraft to permit their continuing participation in the Arrow 2 program.

-Investigation of change requests and incorporation into the aircraft design, specification, and/or mock-ups of agreed changes resulting from the mock-up conference.

2.2 ARROW 1 TOOLING.

-Process planning, design, development and manufacture or acquisition of such tooling, master models, jigs, dies, interchangeability media, fixtures and gauges as may be required for the airframe production and assembly of five Arrow 1 aircraft. (Work completed).

-Process planning, design and manufacture or acquisition of such production tooling as may be required for the manufacture and/or incorporation of modification kits for the Arrow 1 aircraft.

-Maintenance, process planning, repair and replacement of tooling acquired above. Funds provided for tool maintenance until March 31, 1958.

2.3 MANUFACTURE OF FIVE ARROW 1 AIRCRAFT.

(Note:- This section includes costs accumulated on terminated work in connection with Astra and Sparrow installations.)

-The manufacture of airframes for, and the assembly of, five Arrow 1 aircraft. including the procurement of related contractor-furnished equipment and airframe sensing instrumentation for them, and the procurement of airborne data recording instrumentation for Arrow 1 aircraft allocated to airframe development.

-Manufacturing costs include all those required to progress these aircraft through first flight. On completion of the first flight, these aircraft were accepted by the RCAF and transferred back to Avro Aircraft Ltd to carry out the various phases of the flight test development program.

-Manufacture and/or acquisition of spare parts and assemblies proposed by Avro as being required for the maintenance of Arrow 1 airframes, and approved by the RCAF, including packaging and storage as necessary.

-Manufacture and/or acquisition of modification kits for Arrow 1 airframes and the incorporation of such modifications prior to RCAF acceptance, including packaging and storage as necessary.

3.1. PART THREE - ARROW 2 ENGINEERING.

-Arrow 2 basic airframe design through December 1958 comprising design and/or specification of structure and systems, external fuel tank, Sparrow 2 Mk 1 weapon pack and launchers, contractor-furnished equipment, and installation of CFE and GFE as defined in the Model Specification for the Arrow 2 airframe and installed GSM, including Iroquois engine, Astra 1 electronic system and Sparrow missiles.

-Continued engineering of Arrow 2 airframe beyond basic design, through date of delivery of the first Squadron aircraft, to achieve operational standard.

Note:- This paragraph includes costs accumulated on terminated work in connection with Astra and Sparrow installations.

-Investigation of change requests and incorporation into the airframe design and/or mock-ups of agreed changes resulting from the mock-up conference.

-Deletion of Astra and Sparrow from the Arrow program and associated drawing records.

-Liaison with the technical assistance to Associate Contractors and major Sub-Contractors.

Note:- Engineering of the MA-1/Genie/Falcon installation is covered in parts 13 and 14.

3.2 ARROW 2 TOOLING.

Note:- This section includes costs accumulated with terminated work on Astra and Sparrow installation.

-Process planning, design, development and manufacture or acquisition of such tooling, master models, jigs, dies, interchangeability media, fixtures and gauges as may be required for the production of thirty-two Arrow 2 aircraft and the continued production of Arrow 2 aircraft at the rate of four aircraft per month thereafter, including the MA-1 radar nose, Genie/Falcon weapon pack, long range fuel tank, and changes necessary for the incorporation of the MA-1 electronic system in Arrow 2 aircraft.

-Process planning, design and manufacture or acquisition of such tooling as may be required for the manufacture and/or incorporation of modification kits for the Arrow 2 aircraft.

-Maintenance, process planning, repair and replacement of tooling acquired above, was started on April 1 1958.

-Process planning, design, modification and incorporation, with DDP approval, of such tool improvements as were recommended by Avro Aircraft Ltd as essential to reduce Arrow 2 airframe manufacturing costs were compatible with the cost supplement to the statement of this work.

3.3 ARROW 2 MANUFACTURE.

Note:- this section includes costs accumulated in connection with terminated work on Astra and Sparrow installations.

-The manufacture of airframes for, and the assembly of, Arrow 2 aircraft, including the procurement of related contractor-furnished equipment and airframe sensing instrumentation for them, and the procurement of airborne data recording equipment for Arrow 2 aircraft through 25220 allocated to the contractor and RCAF test programs, except for MA-1 instrumentation procured in Part 13. Instrumentation was to have been simplified as much as possible.

-Manufacturing costs include all those required to progress aircraft through RCAF acceptance. (Manufacture of production-type long-range fuel tanks is not included in this paragraph. These tanks are considered special order items).

3.4 THREE ARROW 2 AIRCRAFT.

-Manufacture of three Arrow 2 aircraft (25206, 25207 and 25208). These aircraft were to be accepted upon completion of first flight. They were to have had the original Astra-type Arrow 2 radar nose. 25206 and 25208 were to have been equipped with standard instrument packs and instrumentation for airframe development. 25207 would have been similar to 25206 and 25208 except that it was to have been fitted with instrumentation for Iroquois engine development.

3.5 TWENTY NINE ARROW 2 AIRCRAFT.

-Manufacture of twenty-nine Arrow 2 aircraft (25209 through 25237). Aircraft 25209 through 25220 would have been accepted upon completion of first flight, while aircraft 25221 through 25237 would have been accepted after completion of a full production flight test program.

3.6 AIRCRAFT 25209.

-This aircraft was to have been fitted with the original Astra-type Arrow 2 radar nose, a standard instrument pack and instrumentation for the Iroquois engine development program. No MA-1/Genie/Falcon provisions were included.

3.7 AIRCRAFT 25210 THROUGH 25220.

-These aircraft were to have been completed on the production line without a radar nose, weapon pack or other MA-1/Genie/Falcon provisions. They would then have proceeded through normal pre-flight functions prior to entering into an out-of-sequence program for the embodiment of the MA-1 electronic system at which time the MA-1 radar nose would have been available, but with initial flights being made with the temporary weapon or instrument packs. Aircraft 25215 and subsequent were to have been fitted with production Genie/Falcon weapon packs prior to delivery to the RCAF.

3.8 AIRCRAFT 25221 THROUGH 25237.

-These aircraft were to have had the MA-1 electronic systems and the Genie/Falcon pack incorporated during production.

-Manufacture and/or acquisition of spare parts and assemblies proposed by Avro as being required for the maintenance of Arrow 2 airframes and approved by the RCAF, including storage and packing as necessary.

-Manufacture and/or acquisition of modification kits for Arrow 2 airframes and the incorporation of such modification into the aircraft prior to aircraft acceptance.

-Manufacture of six production-type long-range fuel tanks which were required for ferrying purposes.

-Support to production electronic system activities and flight testing.

-Provision of power and cooling facilities for testing MA-1 electronic systems in Arrow aircraft in production floor positions.

-Provision of power and cooling facilities for use in conjunction with Government-furnished MA-1 support equipment.

4.1. PART FOUR. TEST PROGRAMS LABORATORY PROGRAMS.

-Design and construction of wind tunnel models and conduct of wind tunnel tests. (See also part 13 for additional wind tunnel work for the Genie/Falcon program).

-Design and construction of free-flight models and of required test rigs, and performance of tests. (Work completed).

-Design, specification and operation of systems analysis and flight simulation aids, including analog computer, for use in stability, control, autopilot and airframe systems problems. Operation of cockpit simulator and flying control test rig in conjunction with analog computer were to be included.

-Conducting of a telecommunication antenna development and model test program.

4.2 STRUCTURAL AND SYSTEM TEST PROGRAMS.

-Manufacture of test components. Note:- This includes costs accumulated on terminated work in connection with Astra and Sparrow installations.

-Manufacture of fifteen pre-production launchers for Sparrow 2 missiles. (Work terminated).

-Conduct of ground testing, including firing, of the Sparrow 2 weapon pack, excluding provision of missiles and simulated air vehicles. (Work terminated).

-Structural and systems ground testing for the Arrow aircraft, including the design and specification of test specimens, design and construction of test rigs and facilities, conduct of tests, analysis of data and preparation of reports.

a. Air conditioning systems.

b. Fuel systems.

c. Flying controls.

d. Landing gear.

e. Static test aircraft.

f. Minor testing of escape system.

(See 3.1 and 9.1 for continued structural and systems ground testing to achieve the Arrow 2 operational standard).

-Sled testing and associated work on Arrow crew escape system. (Work terminated).

-Supply of items of contractor-furnished aircraft equipment required for test purposes.

4.3 TEST PROVISIONS AND INSTRUMENTS.

-Sparrow weapon pack test provisions in aircraft 25203. (Work terminated).

-Instrumentation for Arrow flight test program.

a. Design and specification of airframe sensing and airborne data recording instrumentation.

b. Design of instrumentation installation; manufacture of special parts for mounting; installation of recording instrumentation; check-out and calibration of instrumentation.

c. Design, provision and installation of changes to airborne instrumentation.

d. Maintenance of airborne instrumentation through aircraft 25214.

-Design and/or specification, and fabrication of Arrow airframe system developmental installations on CF-100 test vehicles, including flying control, instrumentation, and telecommunication antenna work. (Completed). Reconversion of aircraft if required would have been done under CF-100 repair and overhaul arrangements.

-Design and/or specification, and provision of ground telecommunication facilities required for the Arrow flight test program at Malton. (Work completed).

-Instrumentation for Orenda Engines Ltd flight test program:

a. Design of the installation of airborne data recording instrumentation.

b. Installation, check-out and calibration of instrumentation.

c. Assistance with the maintenance of and changes to instrumentation.

-Instrumentation for joint RCAF/Avro flight test program on aircraft 25215 through 25220;

a. Design and specification of airframe sensing and air- borne data recording instrumentation.

b. Design of instrumentation installation including the manufacture of special parts for mounting, installation, check-out and calibration of instrumentation.

-Design, tooling, and manufacture of ten instrument packs, including terminated work on Sparrow combination weapon/instrument packs.

4.4 ENGINEERING FLIGHT TESTING.

-Planning and conduct of the Avro flight test program.

-Basic Arrow 2 Aircraft;

a. Detail planning of test programs.

b. Specification of required instrumentation for specific flights.

c. Recording and reduction of flight test data.

d. Pre-flight testing.

e. Provision of flight crews.

f. Briefing and debriefing of flight crews.

g. Supply of flight test data to Orenda Engines Ltd.

h. Analysis of test data and preparation of test reports.

-Continued Arrow 2 flight testing to achieve Arrow 2 operational standard.

-Maintenance and operation at Malton by Avro of aircraft 25201 through 25214 with two Sabre 6 and one CF-100 Mk 5 chase aircraft. This would have included:

a. Supply of fuel and oil.

b. Procurement of maintenance assistance from sub-contractors other than Hughes Aircraft Company.

c. Support to RCAF Phase 2 program on one Arrow 1 aircraft

d. Incorporation of Government-furnished kits for 6A modifications in chase aircraft.

(For procurement of HAC technical assistance see 13.1).

-Necessary alterations to three RCAF-supplied chase aircraft (Namely one CF-100 and two Sabre 6's) to enable their use for this purpose. (Completed). Reconversion of these aircraft, if required would have been covered by the repair and overhaul arrangements for the individual aircraft.

-Planning in conjunction with the other Associate Contractors of an integrated weapon system flight test program. (Work terminated).

-Training of two Orenda pilots and on-the-job training of Orenda ground crews.

4.5 AIRCRAFT/FCS/WEAPON COMPATIBILITY PROGRAM.

Note:- Base facilities were assumed to have been provided and/or contracted for by the RCAF. No provision was made for chase aircraft other than the Arrow aircraft directly involved in this program.

-Conduct of Genie and Falcon separation test program at a base to have been designated by the RCAF, on Arrow 1 aircraft equipped with interim Genie and Genie/Falcon weapon packs including:

a. Maintenance and operation.

b. Provision of personnel to support the flight test program. (For HAC support see 13.1).

c. Provision of technical assistance from major sub- contractors.

d. Provision of necessary GSE acquired as per 10.1.

-Conduct of an aircraft/FCS/weapon compatibility test program at a base to have been designated by the RCAF on three Arrow 2 aircraft equipped with Genie/Falcon weapon packs including:

a. Maintenance and operation of three Arrow 2 aircraft.

b. Provision of personnel to support the flight test program.

c. Provision of technical assistance from major sub-contractors.

d. Provision of necessary GSE acquired as per 10.3.

e. Provision of modifications to enable each of these aircraft to be used as targets when necessary.

f. Provision of personnel to make necessary changes to these aircraft during the program.

-Support of RCAF/Avro joint test programs at a base to have been designated by the RCAF on six Arrow 2 aircraft fitted with Genie/Falcon weapon packs including:

a. Provision of personnel to assist the test program.

b. Provision of technical assistance from major sub-contractors.

c. Provision of maintenance for airborne instrumentation.

d. Minimum essential planning and analysis.

Note 1:- Aircraft allocation to this program were to have been four to six aircraft depending on need for attrition replacements.

Note 2:- For provision of mobile repair and maintenance parties, service representatives and modification kits to support this operation, see 3, 11 and 12.

5.1. PART 5. MOCK-UP AND EVALUATION.

-Design and construction of the following developmental and demonstration mock-ups:-

a. Arrow 1 aircraft, including interim electronic system. (Work completed).

b. Arrow 2 aircraft, including the installation of ASTRA 1 system and Iroquois engine. (Work completed).

c. Weapon pack for Sparrow 2 missiles. (Work completed).

d. Ground support equipment. (Work completed).

e. Special cockpit mock-up for evaluation of take-off and landing conditions.

f. Continuing aircraft mock-up work as required during the development program.

-Construction of a full scale Arrow 1 airframe metal mock-up. (Work completed).

-Provision of facilities and services for RCAF mock-up conferences relevant to the mock-ups above. (Work completed).

-Provision of facilities and services for RCAF Engineering Evaluation Conference for Arrow 2 GSE (Reference RCAF document DDA-24). (Work completed).

6.1. PART 6. DATA AND PUBLICATIONS.

-One microfilm copy of requested Avro sub-assembly and assembly drawings for the Arrow 1 and Arrow 2 aircraft, in accordance with a version of PROC 100-11 to have been agreed between Avro and the RCAF.

-One reproducible copy of GSE drawings in accordance with PROC 100-2.

-Supply of drawings to other contractors as necessary to ensure compatibility of equipment installation in the airframe.

-Provision and publication of data and support for RCAF evaluation of Arrow 2 GSE. (Work completed).

-Provision of services and materials for maintenance appraisal and the collection and preparation of maintenance and logistics data on the airframe and associated GSE.

-Preparation and publication of a Program Planning Report. (Work terminated).

-Preparation and publication of periodic Arrow program reports, as follows;-

a. Quarterly physical report.

b. Quarterly financial report.

c. Monthly letter report.

d. Quarterly technical report. (Work terminated).

-Provision of Engineering data and reports on request from the RCAF including;-

a. Performance and weights reports.

b. Ground and flight test reports.

c. Wind tunnel, strength and system reports.

ARROW 1 SERVICE DATA, COMPRISING:-

a. Preparation and publication of Arrow 1 Service Data to November 30, 1958 describing and illustrating each aircraft system including component removal and installation, maintenance and trouble shooting procedures.

b. Preparation and publication of interim Arrow 1 Aircraft Operating Instructions to November 30, 1958 to support the aircraft in the absence of normal Engineering Orders.

c. Preparation and publication of special Weapon System Co-ordination reports.

d. Preparation and maintenance of Arrow 2 systems brochures. (Work to have continued on minimum essential brochures).

-Preparation and publication of the following Arrow 2 aircraft series Engineering Orders and revisions to such generally in accordance with PROC 100-8 but with reduced cost format to be agreed between AMC and Avro.

a. Aircraft Operating Instructions.

b. Description and Maintenance Instructions.

c. Structural Repair Manual.

d. Illustrated Parts List.

e. Maintenance Schedules. (Primary).

f. Maintenance Schedules. (Periodical).

-Preparation and publication of Arrow 2 equipment series Engineering Orders with reduced cost format, and revision of such as follows:-

a. Selected Items of Proprietary Equipment.

b. Selected Items of Ground Support Equipment. (GSE).

-EO control forms to have been submitted in accordance with a version of PROC 100-15 to be agreed between AMC and Avro.
Note:- These EO's would have been prepared only for equipment for which existing publications were not available.

-Preparation, publication and maintenance of aircraft service and modification bulletins.

-Preparation and publication, using minimum cost presentation, of program proposals, special program reports, slides, transparencies, film scripts, and similar material for essential information purposes of the Arrow program.

7.1. PART SEVEN. STUDIES.

-Design study of an aircraft systems trainer for the airframe contractor-furnished systems, including construction of a model for design investigation. (Work completed).

-Design study for a ground equipment trainer. (Work completed).

-Measurement of in-flight thrust of engines. (Preliminary investigation only.) (Work completed).

-Studies relative to Astra 1 installation. (Work completed).

-Improvements to the crew escape system. (Work completed).

-Installation of arrester hook on the Arrow. (Work completed).

-Requirements for achieving compatibility between the Arrow and the RCAF specified runway barrier. (Work completed).

-Physical installation of Genie rockets in the Arrow. (Work completed).

-Weapon System mathematical model program. (Work terminated).

-Mathematical model extension re growth potential and tactics. (Work terminated).

-Studies of Arrow Weapon System air base requirements as follows:-

a. Study of operational air base requirements. (Work terminated).

b. Study of Cold Lake air base requirements. (Work terminated)

-Weapon System support studies:-

a. PRD study and co-ordination. (Work terminated).

-Analysis of Associate Contractor technical progress reports. (Work terminated).

-Study and analysis of technical problems with respect to GSM on request from the RCAF, and recommendations of solutions to these technical problems.

-Study re:- flight and tactical trainer. (Work terminated).

-Study of semi-submerged carriage of Sparrow 2 missiles. (Work terminated).

8.1. PART 8. WEAPON SYSTEM DEMONSTRATION.

-Support to RCA. (Work terminated).

-Modification to aircraft 25202, 25204 and 25205. (Work terminated).

-Instrumentation of RCA Arrow aircraft. (Work terminated).

-Manufacture of instrument packs for RCA Arrow aircraft. (Work terminated).

-Support of RCA flight test program at Malton. (Work terminated).

-Support to Orenda Engines Ltd. (See 4.1)

-Support to Canadair Ltd. (Work terminated).

-Instrumentation of Canadair Arrow aircraft. (Work terminated).

-Manufacture of weapon/instrument packs for Canadair Arrow aircraft. (Work terminated).

-Support to RCAF testing and evaluation. (See 4.1)
-Support to the Weapon System Demonstration.

a. Planning of Integrated Weapon System demonstration. (Work terminated).

b. Manufacture of weapon/instrument packs for weapon system demonstration aircraft. (Work terminated).

9.1. PART NINE. - ENGINEERING SUPPORT TO PRODUCTION.

-Investigations into, and design and specification of, and testing of, changes, salvage schemes and/or material substitutions to aid production and/or servicing of the Arrow airframe and associated GSE.

-Engineering work necessary to rectify problems resulting from the RCAF/Avro joint test program and from service flying, including the implementation of remedial action to improve the reliability of defective items and installation into Avro and Orenda flight test aircraft, after RCAF aircraft acceptance of:-

a. Mandatory items.

b. Approved modifications necessary for the flight test program.

c. Work necessary to attain completion to a standard to permit the commencement of the flight test program.

d. Preliminary modifications to permit the development program to proceed.

-Manufacture of parts when required prior to production availability is included.

-Sustaining engineering on airframe equipment, including appraisal of vendors' proposals and monitoring of vendor qualification testing and type approval of CFE.

9.2. DEFECT REPORTING.

-Collection and reporting of field and in-plant defects on the Arrow airframe and associated GSE; statistical and technical analysis of these reports; recommendation of remedial action to improve the reliability of defective items; monitoring of the implementation of these recommendations.

-Analysis of statistical summaries of field and in-plant defects from Associate Contractors and major sub-contractors; remedial action to improve reliability of defective items; monitoring of the implementation of these recommendations.

10.1. PART TEN. - GROUND SUPPORT EQUIPMENT AND TRAINERS.

-Design and/or specification of an aircraft systems trainer (AST) and of modifications thereto, for the instruction of RCAF personnel in maintenance aspects of the airframe systems and airframe ground support equipment.

-Design and/or specification, after RCAF scheme approval, of contractor-furnished

Ground Support Equipment for Arrow 1 and Arrow 2, as defined in Avro Report 70/GEQ/2-3, and of modifications to this GSE.

-Provision of RCAF approved Ground Support Equipment.

a. The manufacture and/or provision of Avro-furnished ground support equipment for support of aircraft 25201 through 25220 as defined in Avro Report 70/GEQ/2-3.

b. The manufacture and/or provision of additional GSE of the types covered in 10.3. for support of aircraft 25221 through 25237.

-Investigation of change requests and incorporation into GSE design specifications and/or mock-ups of agreed changes resulting from the evaluation conference.

-Manufacture and installation of minor modifications for Avro-furnished Ground Support Equipment specified above, such modifications to be approved by the RCAF and contractually authorized. All major modifications would have required separate authorization.

-Supply of spare parts and assemblies recommended by Avro as being required for the maintenance and/or repair and overhaul of Avro-furnished GSE specified above, and authorized by the RCAF, including packing and storage as necessary.

-Procurement, manufacture, assembly and supply (including necessary publications and panel illustrations) of one Aircraft System Trainer.

-Supply to the RCAF of one reproducible copy of all drawings to PROC 100-2 of Aircraft Systems Trainer.

11.1. PART ELEVEN. - REPAIR AND OVERHAUL.

-Investigation and design of standard and specific repair schemes for Arrow air-frame and for related spares, after acceptance by the RCAF, including accident investigation.

-Repair and overhaul of thirty seven Arrow airframes and related spares, and Avro-furnished GSE, after acceptance by RCAF.

-Acquisition and/or manufacture of repair and overhaul spares for Arrow airframes.

-Provision of maintenance parties and mobile repair parties at one RCAF-designated proving base and one RCAF operational station.

-Repair and overhaul of flight test instrumentation used for Avro flight test vehicles.

12.1. PART TWELVE. TRAINING, TECHNICAL SUPPORT AND CO-ORDINATION.

-Training of Avro personnel on sub-systems supplied by Associate Contractors and major Sub-contractors and Co-ordination of Associate Contractors' statements of work. (Work terminated).

-Compilation and maintenance of a master phasing schedule for the Arrow program, including analysis and monitoring of program schedules of Associate Contractors and major Sub-contractors.

-Analysis of plans of Associate Contractors and major Sub-contractors for Arrow program support, including such items as ancillary equipment, training, services, supporting personnel and facilities. Combination of above into unified support plan and monitoring of its progress.

-Analysis of data control systems of Associate Contractors. (Work terminated).

-Provision of representation at AAWS. (Covered by a separate contract).

-Continuous co-ordination and liaison with AAWS, Associate Contractors and major sub-contractors regarding schedule, progress, technical and responsibility aspects of the Arrow and its sub-systems.

-Management of Arrow Weapon System training for RCAF personnel, including management of airframe, engine, electronic system and weapon training.

-Preparation and presentation of airframe and engine training courses for RCAF.

-Co-ordination of:-

a. Avro and Orenda personnel training, including provision of airframe courses for Orenda.

b. Airframe and engine systems trainers.

-Provision of assistance at Avro to support service representatives in the field.

-Provision of field service representatives to support Arrow airframe activities at one RCAF designated proving base and at one RCAF operational station.

13.1. PART 13. MA-1/GENIE/FALCON PROGRAM. - PHASE 1.

DEFINITION.

-Phase 1 was Avro's program for the engineering of a modified MA-1 electronic system, designated the MA-1C system, and a Genie (MB-1)/Falcon weapon pack into the Arrow 2 aircraft. with support by Hughes Aircraft Company (HAC). Phase 1 included a trial installation of the XMA-1C/Genie system in one Arrow aircraft.

SERVICES AND MATERIALS SUPPLIED BY HAC.

-Engineering and modification of the MA-1 system for installation in the Arrow 1 including:-

a. Provision of a definition of the XMA-1C system, including instrumentation, as modified for the Arrow 1, resulting in a master index and a system specification.

b. Engineering and fabrication of modifications to the MA-1 system and incorporation into two Government- supplied MA-1 systems including:-

1. Modifications to operate with 400 cycle aircraft power supply where appropriate.

2. Construction of 1600 cycle motor generator sets.

3. Construction of static converter units.

4. Provision of attack presentation in front cockpit and converters as necessary.

5. Revision of units for radar operating function in rear cockpit.

6. Study and incorporation of revisions to the values of the weapon parameters used in the computer, which were affected by the particular MA-1 installation.

c. Provision at Malton of spares for items peculiar to the XMA-1C system and modification of Government-supplied spares as appropriate.

d. Provision at Malton of a modified factory-type test position to support the XMA-1C system.

e. (1) Provision at Malton of support equipment (with spares) peculiar to the XMA-1C system.

(2) Provision at Malton of modification to Government-supplied MA-1 support equipment and spares for same, as appropriate.

-Assistance with the engineering of the XMA-1C system into aircraft 25203, including:-

a. Design and technical assistance at Malton.

b. Provision of one instrumentation system packaged in a Genie configuration for the XMA-1C system, including recording oscillograph(s), instrumentation spares and strike cameras.

c. Installation, check-out and flight test support at Malton through March 31, 1960.

-Application engineering and the supply of data to Avro for the YMA-1C and MA-1C systems for Arrow 2, including:-

a. Definitions of the systems, including master indices and system specifications.

b. Definition of the instrumentation for the systems.

c. Definition of the support equipment for the systems.

d. Outline and mounting drawings, wiring books, and other installation data.

-Technical assistance to the Arrow 2 MA-1C engineering program comprising:-

a. Support to Arrow 2 MA-1C installation design at Malton through March 31, 1960.

b. Installation and check-out assistance at Malton to support four systems referred to above.

c. Flight test support at Malton and at one RCAF designated base through July 1961, including flight test data analysis and assistance in flight test planning.

-Engineering and modification of four Government-furnished YMA-1C systems (less AFCS) and spares for installation in Arrow 2 aircraft, and of one set of Government-furnished MA-1 field-type special test equipment.

-Provision of three sets of instrumentation recording systems including spares and strike cameras, in addition to above.

-Studies, jointly with Avro, to determine the operational capability of the MA-1C system with Arrow 2 aircraft parameters and with the operational requirement of the RCAF defence mission.

a. Provision of engineering services and materials for the modification, testing and support of a Government-furnished AFCS system (and spares) for Arrow 1.

b. Provision of engineering services and materials for the modification, testing and support for four Government-furnished AFCS systems (and spares) for Arrow 2.

13.2. SERVICES AND MATERIALS SUPPLIED BY AVRO.

-Engineering and incorporation of the XMA-1C system into aircraft 25203, including:-

a. Detail design of changes to, and modification of, the airframe structure and systems to accommodate the XMA- 1C system.

b. Installation of one instrumentation system packaged in Genie configuration.

c. Modified Arrow radome.

d. Minimum mock-up work to assist installation engineering.

e. Liaison with HAC including provisions to HAC of all necessary technical data and drawings.

-Engineering of YMA-1C and MA-1C systems into the Arrow 2 including:-

a. Modifications to the radar nose structure.

b. Wiring changes.

c. Power supply changes.

d. Air conditioning and miscellaneous aircraft system changes.

e. Miscellaneous aircraft structural revision to accommodate the system.

d. Studies of control and utilization of Falcon and Genie weapons with the Arrow equipped with

-Engineering and manufacture of seven interim weapon packs for testing, including

a. Pack design and manufacture.

b. Provision of Genie launchers.

c. Aircraft changes associated with the installation of the interim packs on Arrow aircraft.

-Engineering of a weapon pack to accommodate Genie and Falcon weapons, and fuel, together with associated aircraft changes resulting from the introduction of this pack on Arrow 2 aircraft.

-Ground testing of the weapon packs, including ground firing trials and the design and manufacture of required rigs.

-Design, construction and/or modification of wind tunnel models and conduct of wind tunnel tests for the Genie/Falcon program.

14.1. PART FOURTEEN. MA-1/GENIE/FALCON - PHASE 2.

Definition.

The basic Arrow program (Parts 1 through 12) and Phase 1 program (Part 13) provide complete engineering of the Basic Arrow/MA-1/Genie/Falcon weapon system. The Phase 2 program details the application engineering required to introduce proposed electronic system modifications listed herein into the Arrow 2 aircraft. It was assumed that each item to have been incorporated would have been fully developed under USAF contracts prior to introduction into the Arrow program.

-Application engineering for introduction of the following proposed electronic system improvements:-

a. A larger, hydraulically driven antenna (approximately 36" diameter).

b. Master oscillator power amplifier (MOPA).

c. Counter-countermeasures.

1. Electronic system.

2. Chaff system.

d. Provision for IR scanner tie-in (Excluding scanning system).

e. Time division data link.

f. Complete conversion of the MA-1 system to 400 cycle power with the exception of the supply to the Falcon missiles.

g. Appropriate modifications to system support equipment.

EXCLUSIONS.

The following items were excluded from the preceding Statement of Work:-

1. Extra work resulting from changes to Specification WSC 1-2 Issue 1 other than that associated with the introduction of MA-1/Genie/Falcon.
2. Missile development or evaluation, and/or the supply of tow targets, tugs, target drones, missiles and simulated air vehicles for ground and flight tests.
3. Design and development of antennas forming part of servo loops of Government-furnished sub-systems, and of multiplexing for antennas.
4. Repair and overhaul of any aircraft participating in the Arrow program other than Arrow aircraft, or of Government-furnished sub-systems or components thereof.
5. Measurement of in-flight thrust, including studies beyond preliminary investigation of methods of accomplishing it.
6. Work entailed by the failure of GSM to meet required schedules or standards.
7. Major re-engineering of any work within RCAF Specification WSC1-2 Issue 1.
8. Provision of facilities for conducting training programs for RCAF personnel.
9. Any work involving aircraft other than Arrow aircraft, one CF- 100 and two Sabre chase/target aircraft.
10. Manufacture of production-type long range fuel tanks other than those covered in 3.1 and 4.1.
11. All changes to this program introduced after November 7, 1958.
12. Supply of any spares other than those covered in 2.1, 3.1, 10.1 and 11.1.
13. Replacement of airborne instrumentation destroyed as a result of aircraft accidents.
14. Costs for design and incorporation of items included in Part 14 of this Statement of Work.

15. Provision for accident investigation telemetry in aircraft subsequent to 25206.

SUPPORT FROM CANADIAN GOVERNMENT AGENCIES.

The following items of support were assumed to have been provided by the Canadian Government:-

1. Provision of the following at bases to be designated by the RCAF; data reduction facilities, fuel, oil, ground support equipment, laboratory and special test equipment, chase, ECM and target aircraft, drones, miss distance instrumentation, and facilities for repair and overhaul.

2. Provision of engines, electronic systems, and other GSM, including:-

   a. Spare MA-1 systems for permanent allocation to test benches at Avro, additional to installation systems called out in GSM delivery schedule in Part13.

   b. Technical assistance, spares, repair and overhaul of GSM engines and components.

3. Provision of Government-furnished special test equipment. This included one set of MA-1 field type special test equipment, modified for Arrow use, additional to the sets of support and/or test equipment called out in Part 13.

4. Provision of modification kits for chase and target aircraft used during Arrow test programs at Malton and at bases designated by the RCAF.

5. Provision of office space, laboratory space and living quarters for personnel supplied by Avro in support of test programs at bases designated by the RCAF.

6. Supply of telecommunication equipment for ground telecommunication facilities to support the Arrow flight test program at Malton.

7. Provision of chase aircraft.

8. Provision of firing ranges and facilities.

9. Provision of flight crews, and instruments for photo panels for RCAF Phase 2 testing.

10. Provision for shuttle service between Malton and Culver City, California, to support The MA-1C program at Malton.

11. Hughes Aircraft Company field service representatives and technicians to assist

Avro with installation, testing, calibration, flight acceptance, repair and mainten-ance of production installations of MA-1C electronic systems installed in aircraft 25215 and subsequent.

SUPPORT FROM ORENDA ENGINES LIMITED.

The following support was presumed to have been supplied by Orenda Engines Limited:-

a. Suitably instrumented Government-furnished Iroquois engines for instal-lation in aircraft 25207 and 25209.

b. Provision of, maintenance of (with Avro installation and removal assistance), and changes to airborne engine data telemetering adaption equipment and special airborne instrumentation)other than airframe sensing instrumentation) in aircraft 25207 and 25209.

c. Provision of agreed Iroquois GSE for programs conducted at Malton.

d. Provision and operation at Malton, and operation at bases designated by the RCAF, of Iroquois maintenance facilities, for aircraft engaged in contractor flight test programs.

e. Provision of facilities and services to train Avro personnel on the Iroquois engine.

f. Technical assistance to Avro in obtaining RCAF acceptance of Arrow 2 aircraft.

g. Provision to Avro of available defect data and reliability data on components of the Iroquois engine.

h. Provision and operation of Iroquois engine run-up and check-out facilities at Malton.

i. Provision of flight crews for aircraft 25207 and 25209.

j. Supply of available data required for co-ordination of the Arrow program and for preparation of Arrow program reports.

APPENDIX 1. ARROW TEST COMPONENTS.

COMPONENT	QUANTITY (A/C SETS)
Front fuselage.	1 Including canopy and canopy actuating mechanism.
Canopy.	5 Including one (1) canopy mounted on the front fuselage.
Centre fuselage.	1
Air Intake	1
Duct bay.	1
Engine bay.	1
Rear fuselage.	1
Inner wing complete.	1
Outer wing.	1
Dive brakes.	1 Brake, left hand component only.
Aileron.	2 Standard 1 Modified.
Elevator.	2 Standard. 1 Modified.
Fin.	1
Rudder.	2 Standard. 1 Modified.
Main and nose landing gear.	1
Main landing gear pivot door.	1 Door, right hand component only.
Main landing gear fairings.	1 Fairing, right hand component only.

Fin trailing edge for rudder tests.	1 Complete with control linkage and mountings.
Outer wing trailing edge for aileron tests.	1 Complete with control linkage and mountings.
Air conditioning duct.	1
Engine intake duct, forward portion.	1
Engine intake duct, aft portion.	1 Duct, left hand component only.
Inner wing posted box tanks.	5
Windshield for canopy testing.	2
Power panel for electrical system.	1
Ram and fan exhaust duct.	1 (Part No. 7-2254-884).
Fan exhaust duct.	1 (Part No. 7-2254-1171).
Transmission duct assembly.	1 (Part No. 7-2254 663).
Dorsal fairing (Fibreglass).	1 Part No. 7-1000 473).
Engine mount (Worm and gear).	6
Elevator drive links.	3
Radar nose.	1 Part only, unassembled details of Arrow 2 Astra nose.
Engine intake transition duct (Arrow 2).	1
Dive brake (Arrow 2).	1 Brake, right hand complete. (Part No. 7-1072-2).
Dive brake hydraulic jack.	1 (Part No. 7-1956-7).
Hydraulic components required to complete right hand dive brake assembly to drawing	1 Set. right hand only.

7-1956-42.

Long range tanks.	5
Former 469, Arrow 2.	1 (Part No. 7-1054-15031).
Seat for linkage test.	1

Miscellaneous items as required to supply production parts for interim Genie/Falcon packs, and for future tests.

Work on the following items, which were previously required, has been terminated:-

Weapon pack, Sparrow.	3
Single missile extension linkage.	1
Radar nose.	2

Production parts for combination Sparrow/instrument packs.

INTRODUCTION OF PRATT AND WHITNEY J75-P6 ENGINES IN ARROW 2 AIRCRAFT.

INTRODUCTION.

In a request letter date June 25, 1958, the RCAF and DDP requested Avro to do a design study of the above mentioned engines as alternatives to the Iroquois 2. The Company did so and issued a report, Brochure SS120 in August of 1958. The summary is as follows;-

> "The installation of two Pratt and Whitney J75-P6, JT4B-23 engines into an Arrow 2 airframe involves an estimated weight penalty of approximately 2,600 lbs. to the aircraft basic weight. The comparison with the Iroquois series 2 powered Arrow 2 from a performance standpoint shows both versions to be comparable when operating subs-sonic with afterburners unlit, but at supersonic speeds with afterburner lit it is evident that the JT4B-23 engine has a much greater fuel consumption than the Iroquois.
>
> The JT4B-23 engine installation would require modifications to the air intakes, the inner wing, duct bay, engine bay, rear fuselage, tail-cones and stinger structures together with the closely associated engine systems. A number of these modifications could be implemented by using Arrow 1 components, however, a complete reversion to the Arrow 1 configuration

is not possible due to the J75-P6 engine requiring increased intake capacity and having a larger afterburner than the J75-P5 currently installed in the Arrow 1. The engine power outputs would also require matching with the Arrow 2 systems and installations."

In addition, the performance in typical missions was practically identical therefore there would have been little, if any advantage of such a conversion. Drawings of the proposed engine installation are provided.

INCREASED COMBAT RADIUS FOR ARROW 2.

INTRODUCTION.

Also in early 1958, the RCAF and DDP requested that Avro conduct a design study into the increase of the combat radius of the Arrow 2. Avro did so and published their findings in Brochure SS119 dated July 1958. The summary is as follows;-

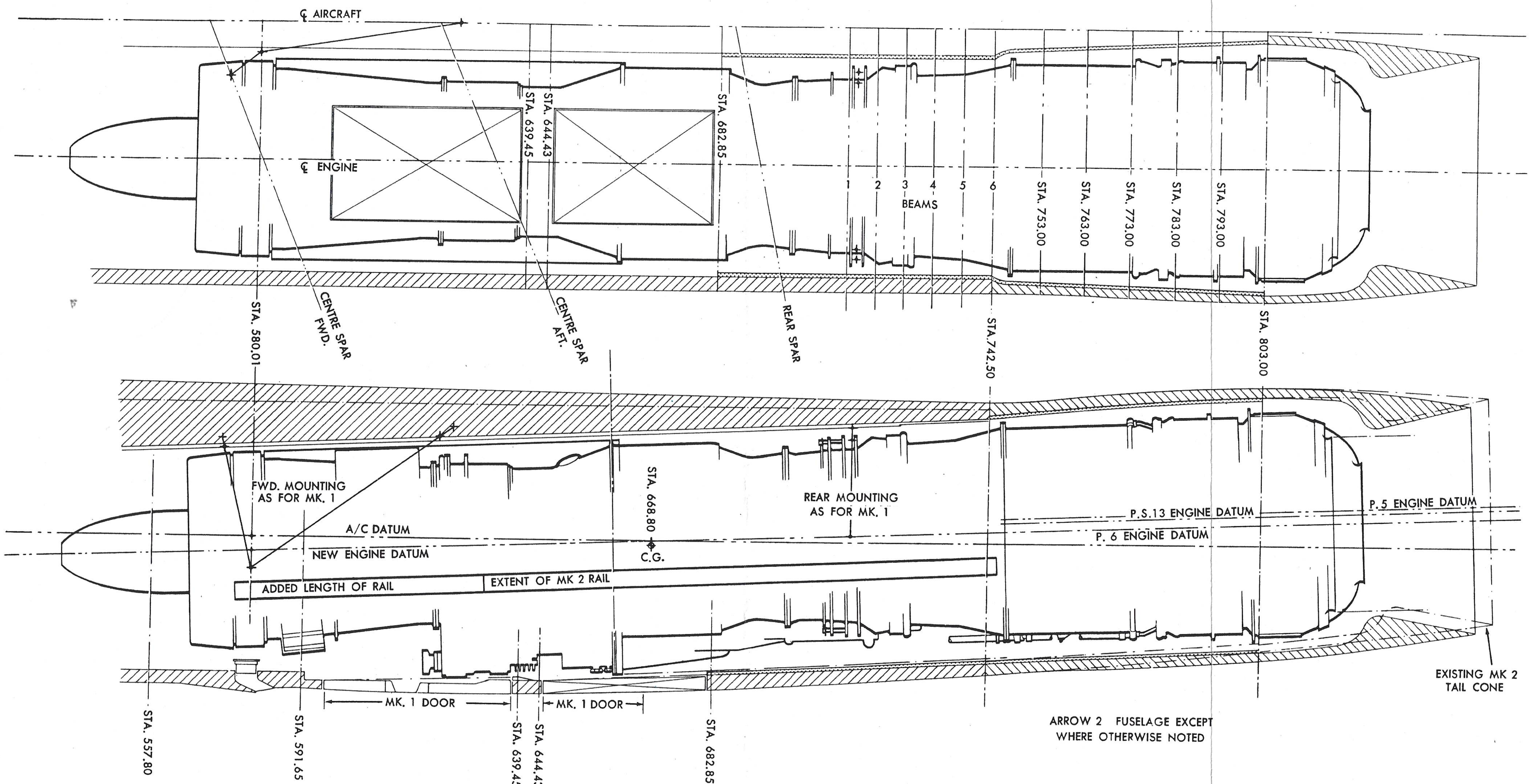
"The addition of about 9,300 lbs. of fuel internally, as shown in the attached drawings, shows an increase in the combat radius of up to approximately 90% over that of the basic Arrow 2. The incorporation of necessary modifications can be accomplished without major system or equipment changes, and the necessary structural redesign would utilize existing engineering and manufacturing techniques. This capability could be made available during 1961 provided authority to proceed with the design and set up is granted by December 1 and September 1 1958 respectively.

Further extensions to the Arrow 2 combat radius may be obtained by the introduction of variable ejectors and a moveable wing leading edge. However further study and development testing will be required to determine the degree of improvement achievable. The portions of the aircraft where changes are proposed are illustrated on the following pages."

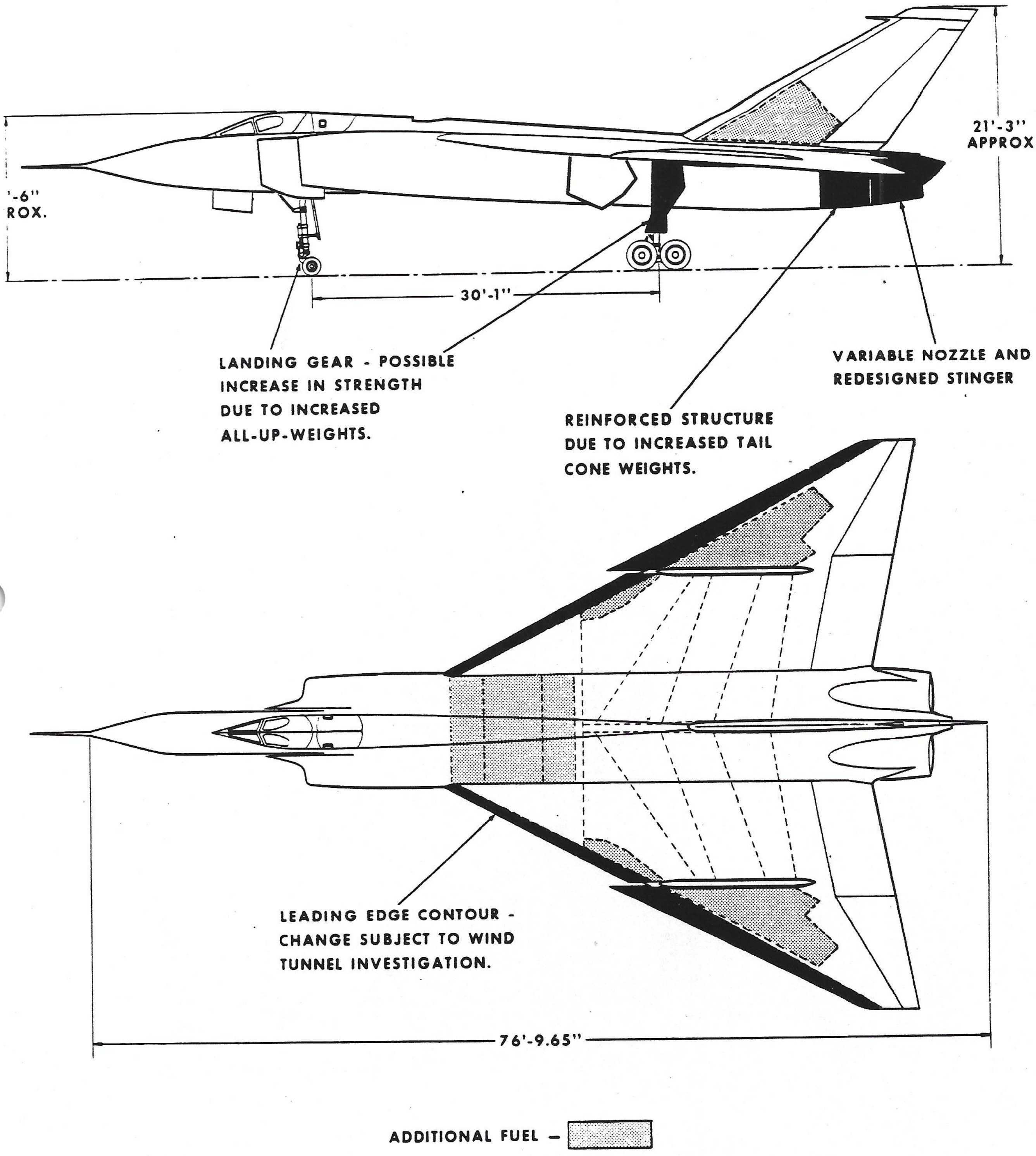
Compared to the basic Arrow 2, the operational weight empty was increased by 1,569 lbs. and combined with the extra usable fuel of 9,300 lbs, this represented a gross weight increase of some 10,869 lbs. The major changes to the basic Arrow 2, were to have been as follows;-

1. Change to solid machined skins for the outer wing with a solid machined rib at the outboard end of the new tank area.

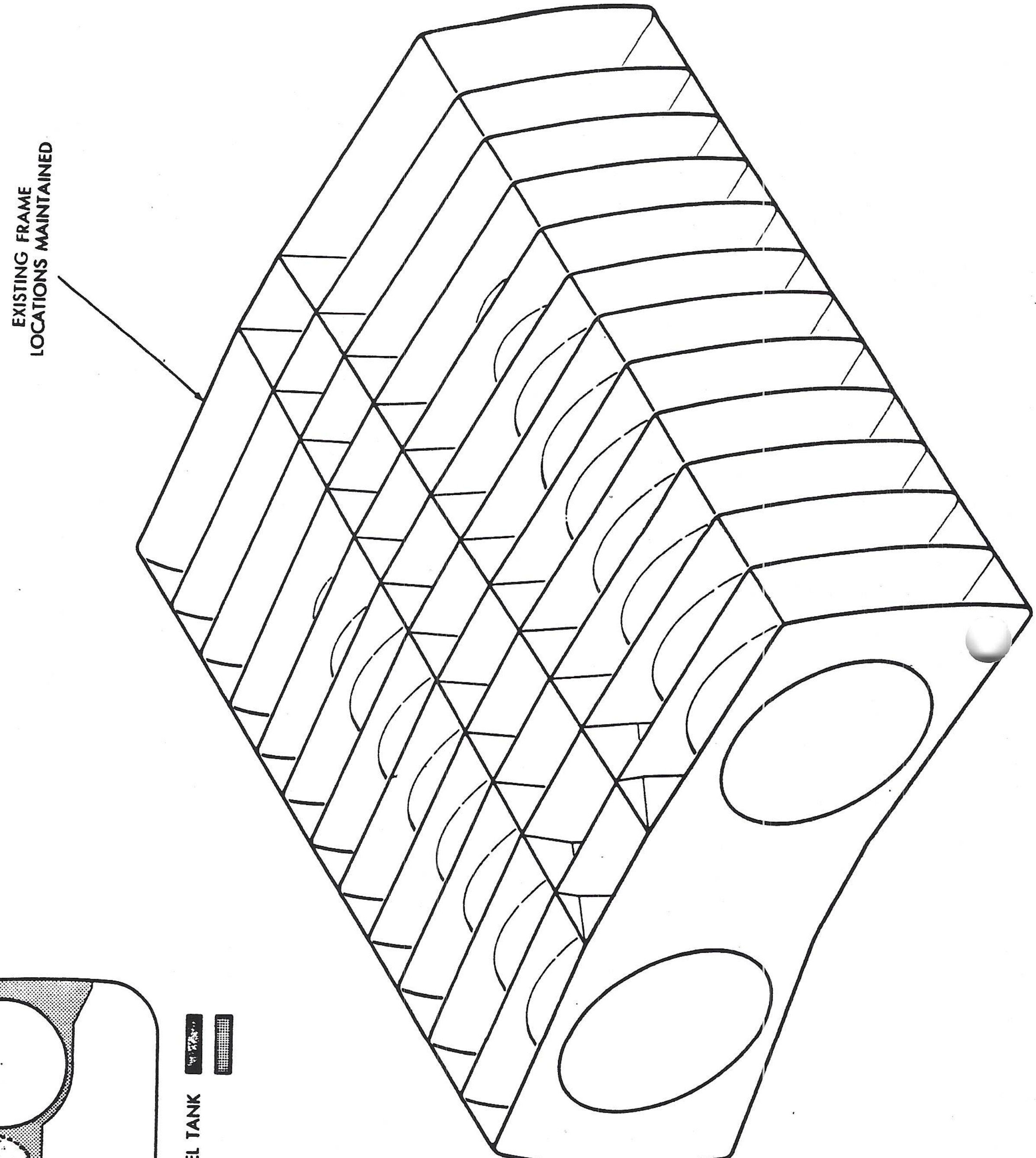
2. The changes here would have been as for the new outer wing, with the addition of a machined root rib and front and rear spars in place of the riveted ones.

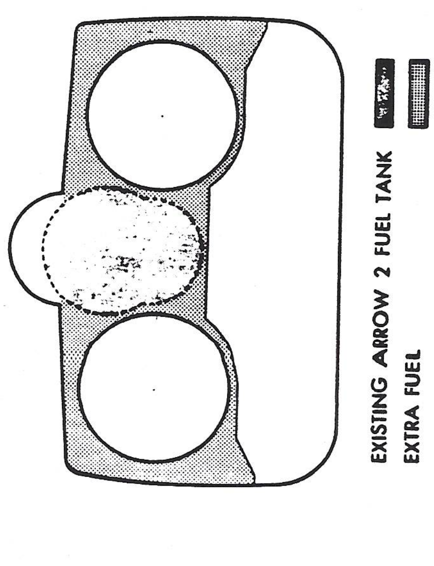


J75-P6 ENGINE INSTALLATION IN ARROW 2 FUSELAGE

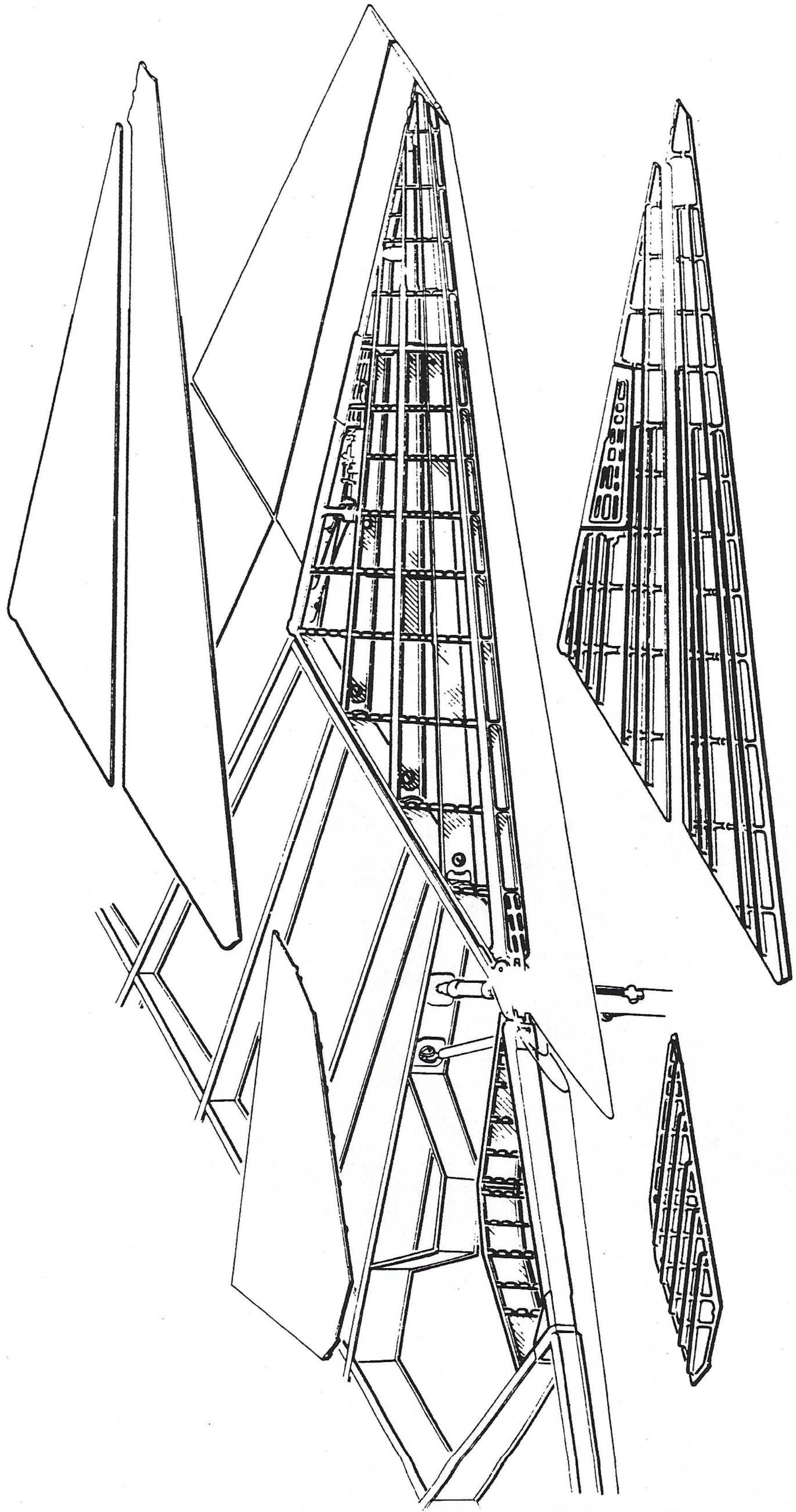


CHANGES TO ARROW 2

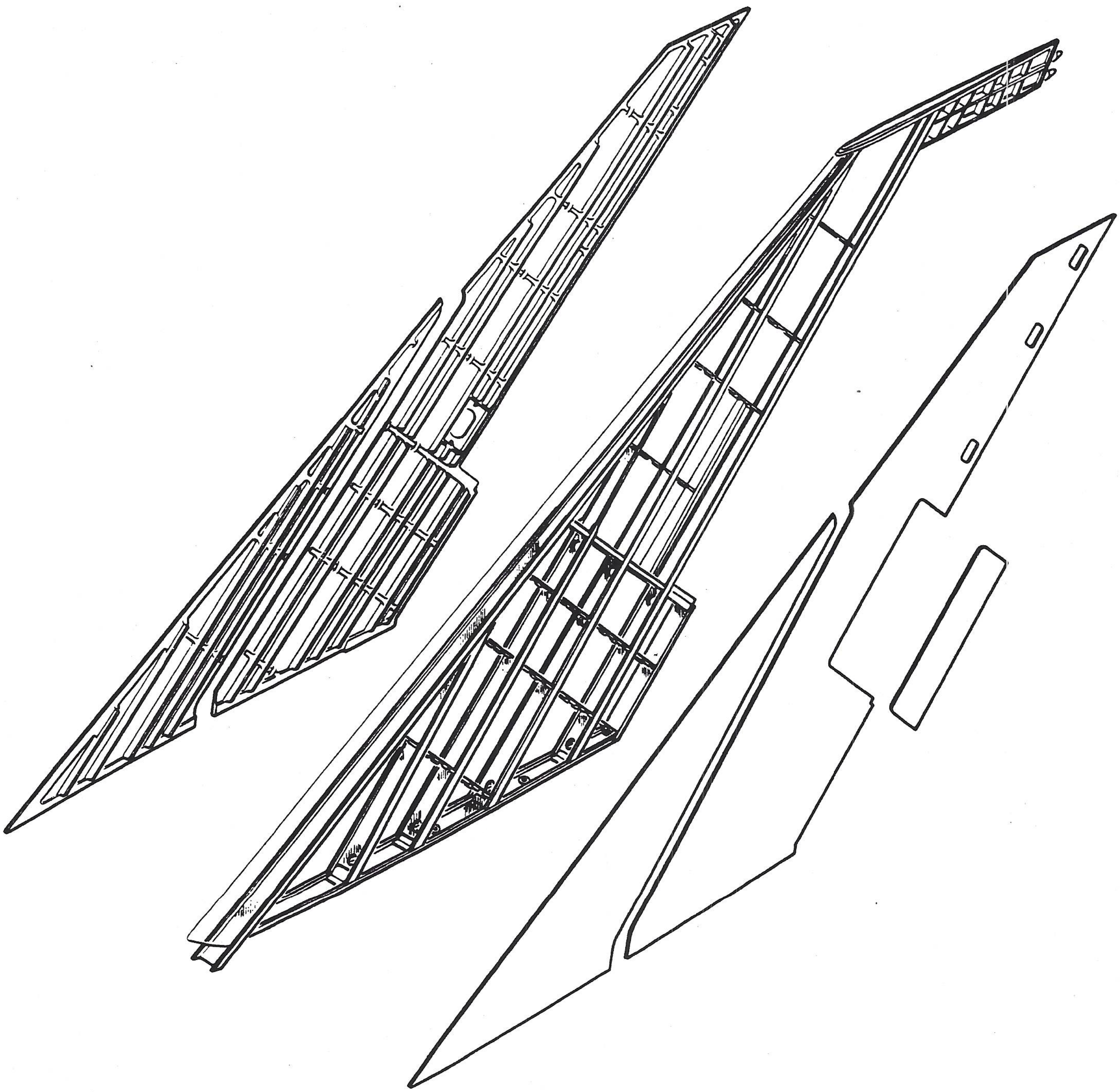




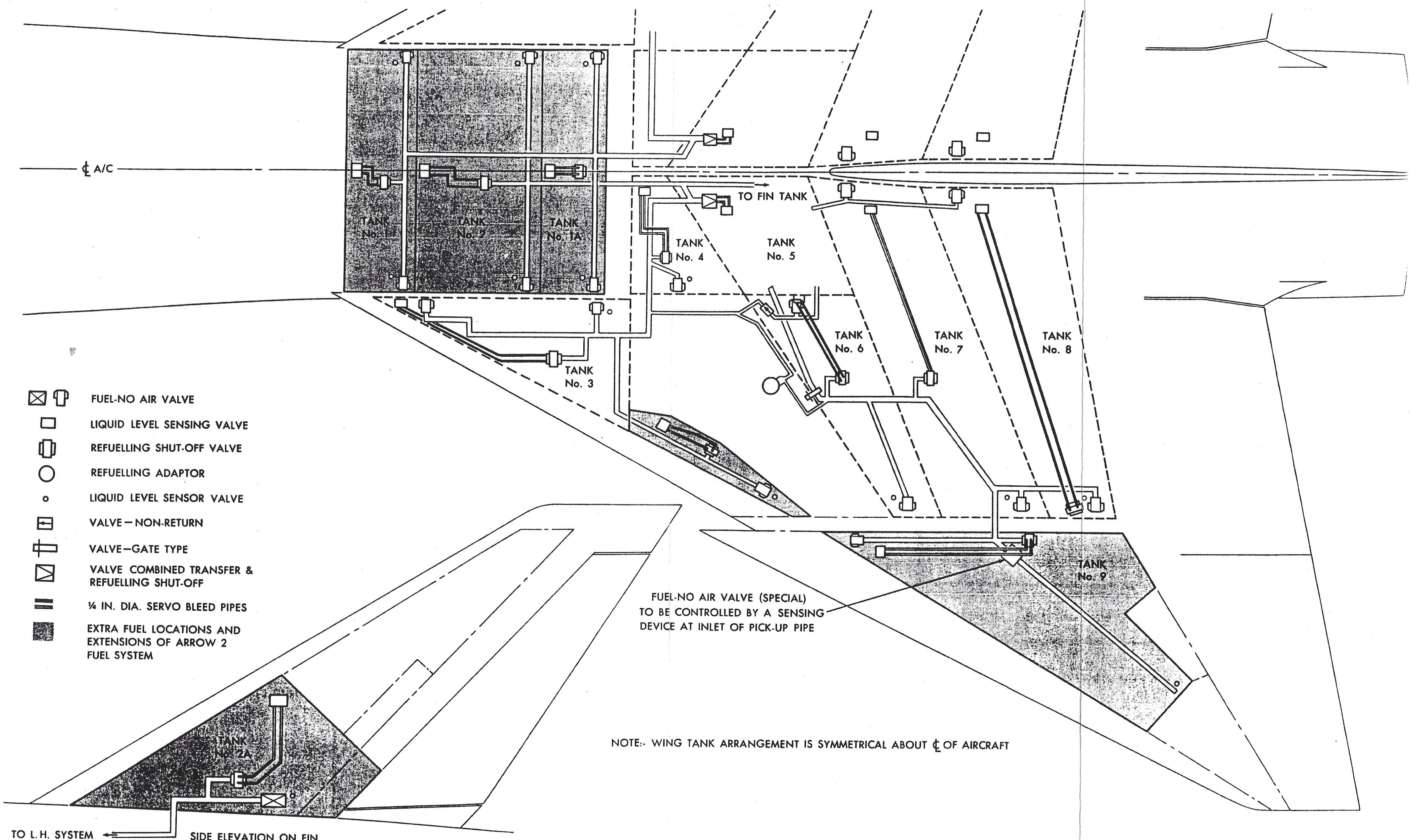
CENTRE FUSELAGE FUEL TANK



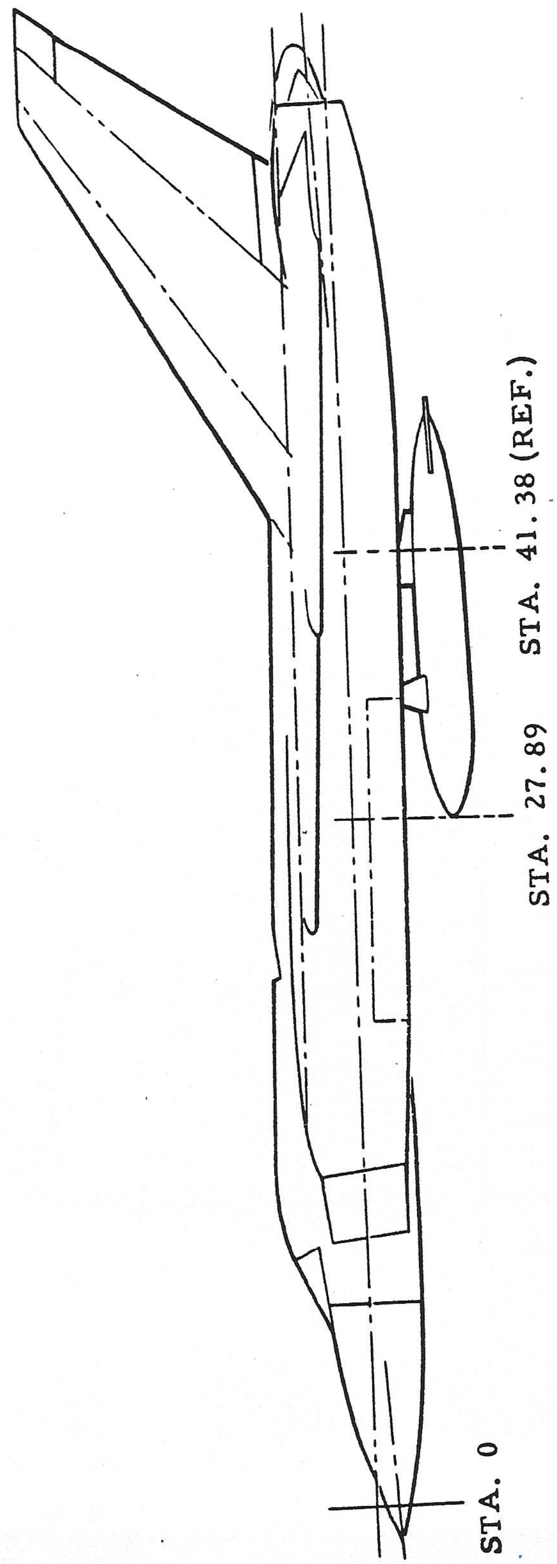
MODIFIED STRUCTURE TO USE WING SPACE FOR EXTRA FUEL



MODIFIED STRUCTURE TO USE FIN SPACE FOR EXTRA FUEL



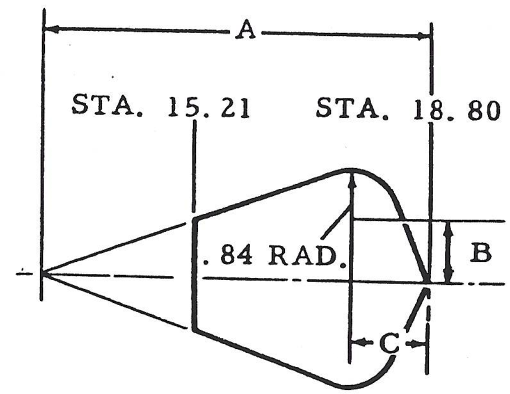
FUEL TRANSFER AND REFUELLING SYSTEM



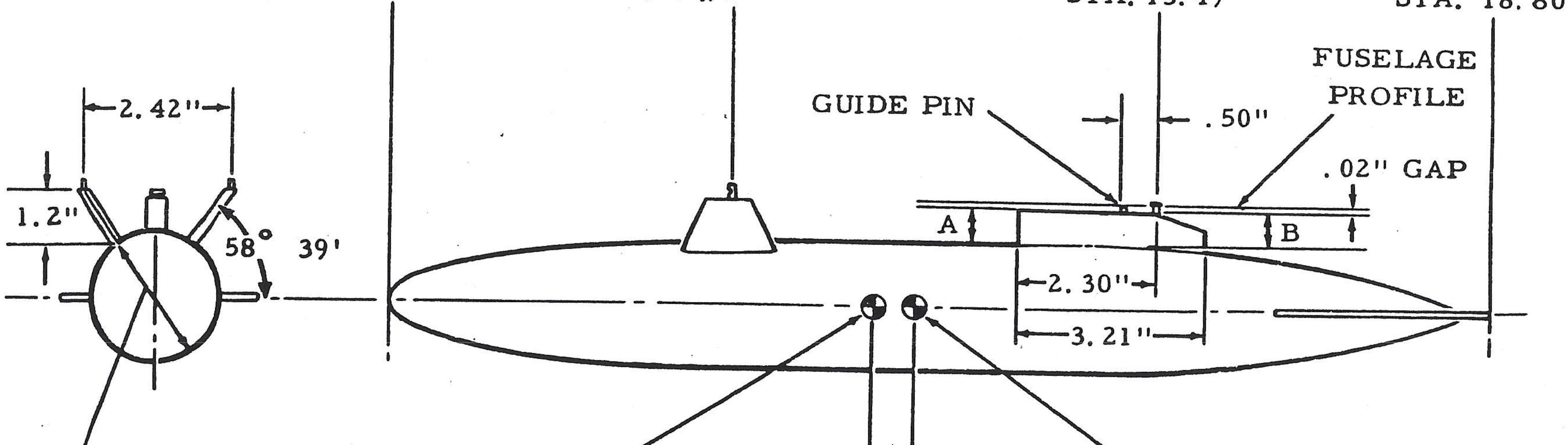
SIDE VIEW OF DROP TANK INSTALLED ON THE AIRCRAFT

3010-105-1

FIN GEOMETRY			AFT PYLON			GUIDE PIN HEIGHT
	SMALL	LARGE	TANK INCIDENCE			5° DROP ANGLE .051
A	5.50	4.82		-2°	-3°	
B	.88	1.21	A	.638	.493	$7\frac{1}{2}$° DROP ANGLE .065
C	1.28	1.40	B	.617	.504	



TAIL FIN



.07 SCALE DROP TANK USED IN WIND TUNNEL TESTS

3. In the centre fuselage, the entire component would have had to be redesigned to remove the existing bladder tanks and to increase the fuel capacity. This would have involved converting the area between Stations 337 and 469 into an integral fuel tank.

4. In the inner wing, a small fuel cell would have been added to the area formed by the front spar and the wheel well.

5. The increase in the all-up weight of the aircraft could possibly have resulted in the strengthening of the undercarriage legs, bogies and associated wing and fuselage structure depending on wheel, brake and tire weights and also the minimum sinking speeds allowable. The front nose wheel assembly would also have required modifications.

LONG RANGE PROVISION.

To meet the requirements of the long range ferry mission, a single tank of five-hundred gallons capacity was to be installed on the under-side of the fuselage. Fuel transfer was to be effected by means of an extension of the aircraft pressurization system, of 19 psi (absolute) nominal pressure, and the Series Sequencing System.

The drop tank was the first tank in the sequence and thus the first to drain; the addition of the drop tank meant that all tanks in the aircraft internal fuel system were connected, through their fuel-no-air valve solenoid coils, to the Sequence Control Units. Dry disconnect valves and spring loaded couplings, broke transfer and pressurization lines automatically when the tank was dropped. Non-return valves fitted inside the aircraft also ensured that no air or fuel could escape. Filling was accomplished by hand through the top of the drop tank.

NAE LOW SPEED WIND TUNNEL TESTS.

In keeping with all other aspects of the design of the Avro Arrow, models were built in .07 scale of the drop tank so that it could be tested in the tunnel, along with the .07 scale model of the aircraft itself.

This was done in order to check the optimum angle, altitude and speed at which the tank was to be released. Many attitudes, speeds and angles of release were tried, and in the high-speed movie films that were taken of the tests, there were several occasions when the tank was seen to apparently touch the fuselage after release. This was never confirmed positively, and before an actual drop could be attempted, the whole program was canceled.

Two sizes of tail were tried and satisfactory jettison characteristics were obtained for a tank configuration with the small tail, -2 degrees incidence to the fuselage datum, and a 5 degree release angle. Illustrations of both the full size tank and the .07 scale model are provided.

LONG RANGE ARROW PROPOSAL.

INTRODUCTION.

The potentiality of an airplane lies in its flexibility, that is, being capable of fulfilling a variety of mission profiles. If the Avro Arrow were to be developed to its fullest extent, the following would have had to have been done:

1. Arrange for more power to increase Mach number and altitude.

2. Arrange for an increased fuel load for increased range.

3. Arrange for a higher take-off weight to accommodate 1 and 2.

In fulfilment of the above conditions, a carefully proposed configuration is shown. The changes are more than minor modifications, but it was felt that the increased potential of such an Arrow would have been well worth the effort.

EVOLUTION.

Prior to exposing the Long Range Arrow features, a brief summary on the evolution of studies is presented:

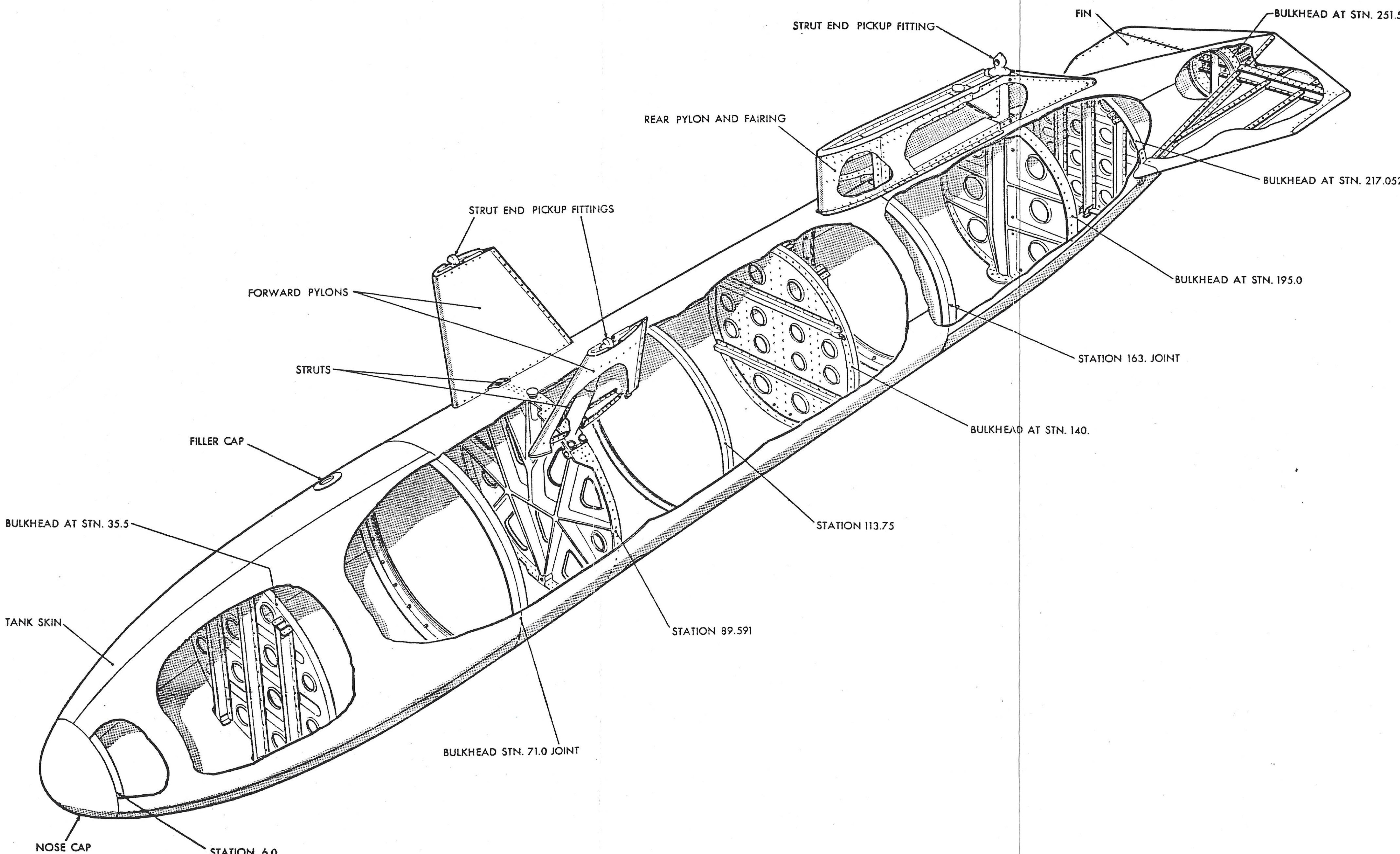
STUDY 1.

The placement of the ramjet wing tip pods and additional wing area created an adverse CG-CP-U/C combination. This necessitated relocating the main undercarriage. Further, it was felt (by the stress office) that the then present design could never cope with a take-off weight in excess of 75,000 - 80,000 lbs.

Careful consideration of the above and other problems prompted an evolution to Study 2, which represents the Long Range Arrow proposal.

STUDY 2.

The placement of the ramjet pods and additional wing area maintained the static margin the same, and the relocation and combination of the main undercarriage with the ramjet pylons resulted in the removal of the main disadvantages of Study 1. Thus we now have the same relative CG-CP-U/C placements as on the Arrow 2.



LONG RANGE DROP TANK STRUCTURE

BASIC MODIFICATIONS FOR THE LONG RANGE ARROW.

UNDERCARRIAGE.

It was established that the take-off weight of a Long Range Arrow was in the order of 105,000 lbs, and it was very unlikely that the main undercarriage scheme as it then existed, could have been developed to cope with these loads. Further, the redesign would have had to have been capable of a potential take-off weight of much more than the immediate 105,000 lb. requirement.

A plausible solution would have been to:

1. Remove the existing undercarriage and utilize the space for fuel storage.

2. Integrate the main undercarriage with the pylons which support twin ramjets and are located at the transport joints of the inner and outer wing. The bulk of the increased weight would be concentrated at the undercarriage thus keeping the other structural changes to a minimum.

MIXED POWER.

A high supersonic performance may be achieved without sacrifice of subsonic capability by the utilization of mixed power plants. This principle when applied to the Avro Arrow results in increased performance at altitude. It was therefore recommended that:

1. A pair of 36" diameter ramjets straddle each pylon undercarriage structure.

INCREASED FUEL.

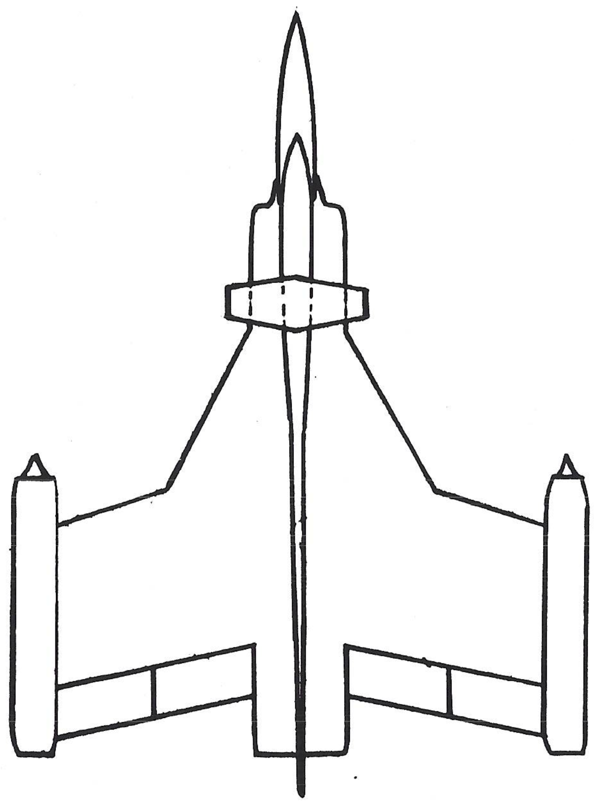
Additional fuel could be carried in:

1. Ramjet pods...........29,200 lbs.

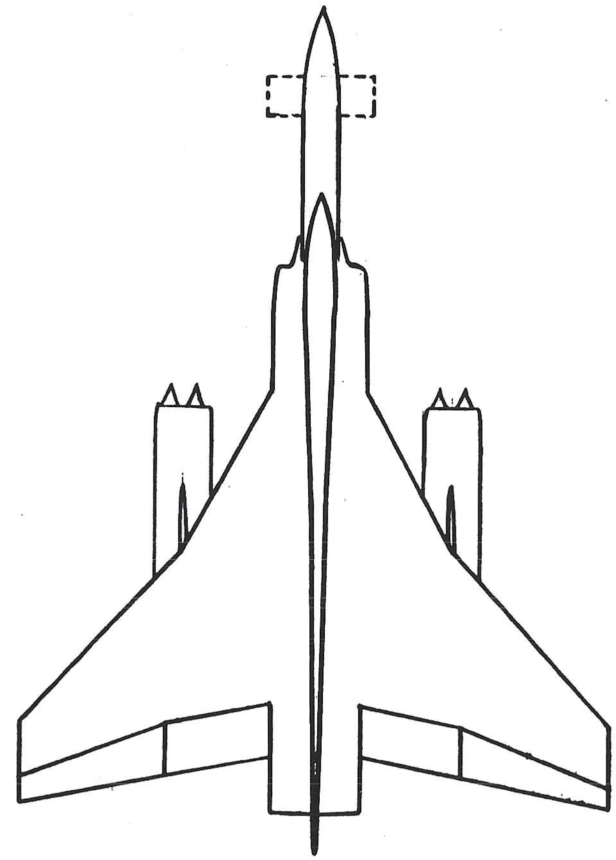
2. Outer wings............6,000 lbs.

3. Former wheel well......2,000 lbs.

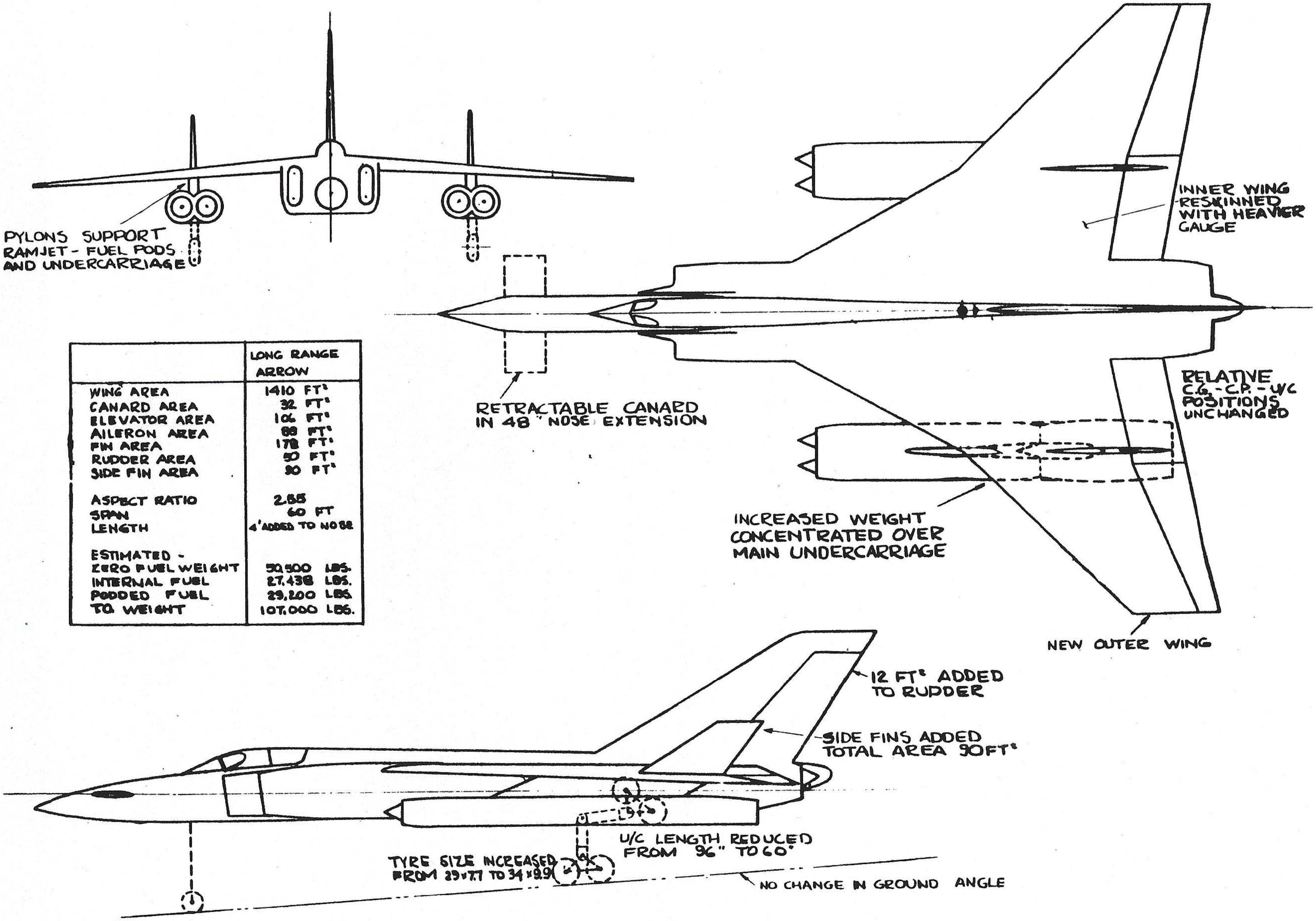
This would have increased the fuel load to at least 19,438 + 37,200 = 56,638 lbs. It is noteworthy that the Long Range Arrow mission profiles to be shown later are based upon a 56,200 lb. fuel load and a 105,000 lb. take-off weight.



Study 1. Adverse CG-CP-Main U/C Conditions.

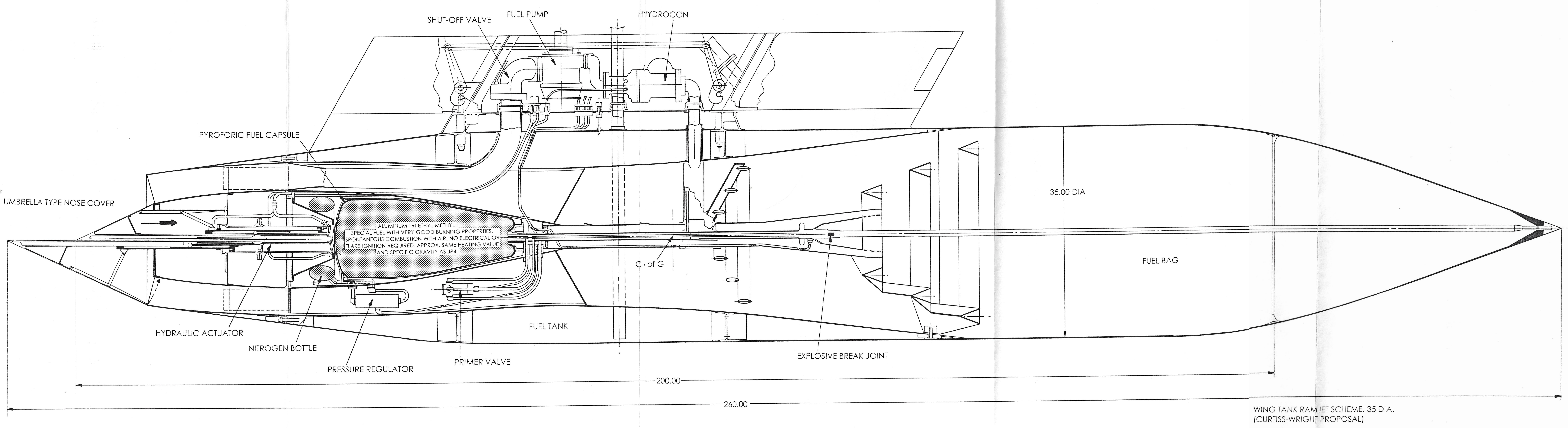


Study 2. Static Margin Maintained and Main U/C Accomodating.



	LONG RANGE ARROW
WING AREA	1410 FT²
CANARD AREA	32 FT²
ELEVATOR AREA	106 FT²
AILERON AREA	88 FT²
FIN AREA	178 FT²
RUDDER AREA	50 FT²
SIDE FIN AREA	90 FT²
ASPECT RATIO	2.55
SPAN	60 FT
LENGTH	4' ADDED TO NOSE
ESTIMATED -	
ZERO FUEL WEIGHT	50,500 LBS.
INTERNAL FUEL	27,438 LBS.
PODDED FUEL	29,200 LBS.
TO. WEIGHT	107,000 LBS.

LONG RANGE ARROW PROPOSAL



WING TANK RAMJET SCHEME. 35 DIA.
(CURTISS-WRIGHT PROPOSAL)

DRAG REDUCTION.

A drag estimate of the Avro Arrow 2 showed that at M= 2.5, 90,000 ft. altitude and W/P=250,000 sq.in. the drag components to be:

Profile drag..............4,080 lb.

Induced drag..........11,080 lb.

Trim drag.................6,960 lb. - totaling 22,120 lbs.

Profile drag is relatively a 'fixed item' and any large improvement of it was unlikely. Therefore the reduction is more probable in the induced and trim drags. Consequently it is recommended that:

1. A canard be added to provide supersonic trim, 32 sq.ft. LE at Station 0.

2. The wing area be increased from 1,225 to 1,410 sq.ft.(outer wing increased).

3. The aspect ratio be increased from 2.04 to 2.55.

The preceding three basic modifications would in effect reduce the drag at M 2.5, 90,000 ft. altitude to:

Profile drag.............4,900 lb.

Induced drag...........6,950 lb.

Trim drag................1,230 lb., totaling 13,080 lbs. and a reduction of over 9,000 lbs.

It should be noted however that the subsonic drag at M=.92, 40,000 ft. altitude and W/P = 22,000, increases approximately from 6,660 to 7,000 lbs., a small subsonic penalty to pay for attainment of a 90,000 ft. ceiling.

1. CANARD.

It was intended that the canard be used as an additional trim control at supersonic speeds only. At subsonic speeds it would be retracted into a four foot nose extension. The aircraft controls in all other aspects could function essentially the same. It was felt that the additional canard air loads induced into the fuselage could be adequately catered for by increasing the skin thickness.

2. WING AREA.

The increased wing area would have been obtained by utilizing an entirely new outer wing of a lesser sweep back angle. The resulting increased tip chord (from 52.085 to 102 in.) also would provide for a much stiffer wing. It was however anticipated that some re-vamping of the aileron and aileron control may have been necessary.

3. INCREASED SPAN.

. The addition of 10 ft. to the existing span increases the aspect ratio from 2.04 to 2.55 therefore resulting in a substantial reduction in induced drag.

LONG RANGE AVRO ARROW PROPOSAL.
TABLE 1

	ARROW 2	LONG RANGE ARROW
Wing area	1,225 sq.ft.	1,410 sq.ft
Canard area	Nil	32 sq.ft.
Elevator area	106 sq.ft.	106 sq.ft.
Aileron area	66 sq.ft.	88 sq.ft.
Fin area	170 sq.ft.	172 sq.ft.
Side fin area	Nil	90 sq.ft.
Rudder area	38 sq.ft.	50 sq.ft.
Aspect ratio	2.04	2.55
Span	50 ft.	60 ft.
Length Estimated.		4 ft. added to nose.
Zero fuel weight	44,516 lbs.	50,500 lbs.
Internal fuel	19,438 lbs.	27,500 lbs.
Podded fuel		29,200 lbs.
Take-off weight		107,000 lbs.

LONG RANGE AVRO ARROW

PRELIMINARY PERFORMANCE ESTIMATES

TABLE 2

1. CLIMB DATA

Altitude	Weight	Mc	R/C ft/min.	Power	Xn=LB
41,000	78,520	1.5	20,000	TJ+AB+RJ	17,450
50,000	77,650	1.5	10,000	"	8,770
60,000	79,650	1.5	7,300	"	6,670
41,000	80,000	2.5	130,500	"	70,400
50,000	79,000	2.5	105,300	"	56,400
60,000	79,000	2.5	42,500	"	22,800
70,000	79,000	2.5	27,300	"	14,600
80,000	79,000	2.5	6,400	"	3,430

2. CRUISE DATA.

Altitude	Weight	M	G	Note
70,000	79,000	2.5	1	
70,000	70,000	2.5	1.5	Sustained
80,000	80,000	2.5	1	
80,000	70,000	3.0	1.5	Sustained
90,000	60,000	3.0	1	

LONG RANGE ARROW.

The Long Range Arrow lends itself to a variety of roles:-

a. Long Range Supersonic Interceptor - could have been a threat to the Mach 2 high altitude bomber.

b. Reconnaissance Arrow - which with greatly improved performance would have provided a very useful Mach 2.5, 90,000 ft altitude dash for evading potential enemies and positioning prior to the observance and photographing of target areas.

c. Tactical bomber should the need have arisen.

A variety of missions demonstrating the flexibility of the Long Range Arrow are shown in the Long Range Arrow Missions 1 to 7, following.

MISSION No 1. - LONG RANGE INTERCEPTION.

Internal fuel 25,400 lbs., plus 29,200 lbs. in ramjet pods.

This constitutes a subsonic cruise-out followed by 5 minutes combat at Mach 2, 50,000 ft. altitude, and sustained 2.5g manoeuvre at full power. The return radius consists of a Mach 0.92 climb cruise, 15 minutes loiter at 50,000 ft. altitude and a landing with reserve fuel for 5 minutes loiter at sea level. The operational radius of this mission is 900 nautical miles.

MISSION No 2. - LONG RANGE INTERCEPTION.

Internal fuel 25,400 lbs., plus 29,200 lbs. in ramjet pods.

This mission constitutes a subsonic cruise-out, followed by 5 minutes combat at Mach 2, 60,000 ft. altitude and 1.5g sustained manoeuvre at full power. The return radius consists of a Mach 0.92 climb cruise, 15 minutes loiter at 50,000 ft. altitude and a landing with reserve fuel for 5 minutes loiter at sea level. The operational radius of this mission is 950 nautical miles - somewhat more than on Mission No 1, because of 5 minutes combat at higher a altitude.

MISSION No 3. - LOW ALTITUDE TOSS BOMB.

Internal fuel 25,400 lbs., plus 29,200 lbs. in ramjet pods.

This mission consists of a 640 nautical mile climb cruise at Mach 0.92 followed by a descent to 500 ft. altitude and a cruise for 280 nautical miles immediately after which the bomb is tossed. The return radius consists of a climb to economical altitude, a Mach 0.92 climb cruise, 15 minutes loiter at 50,000 ft. and a landing with fuel reserves fo 5 minutes loiter at sea level. The operational radius of this mission is 920 nautical miles.

MISSION No 4. - HIGH ALTITUDE TOSS BOMB.

Internal fuel 25,400 lbs., plus 29,200 lbs. in ramjet pods.

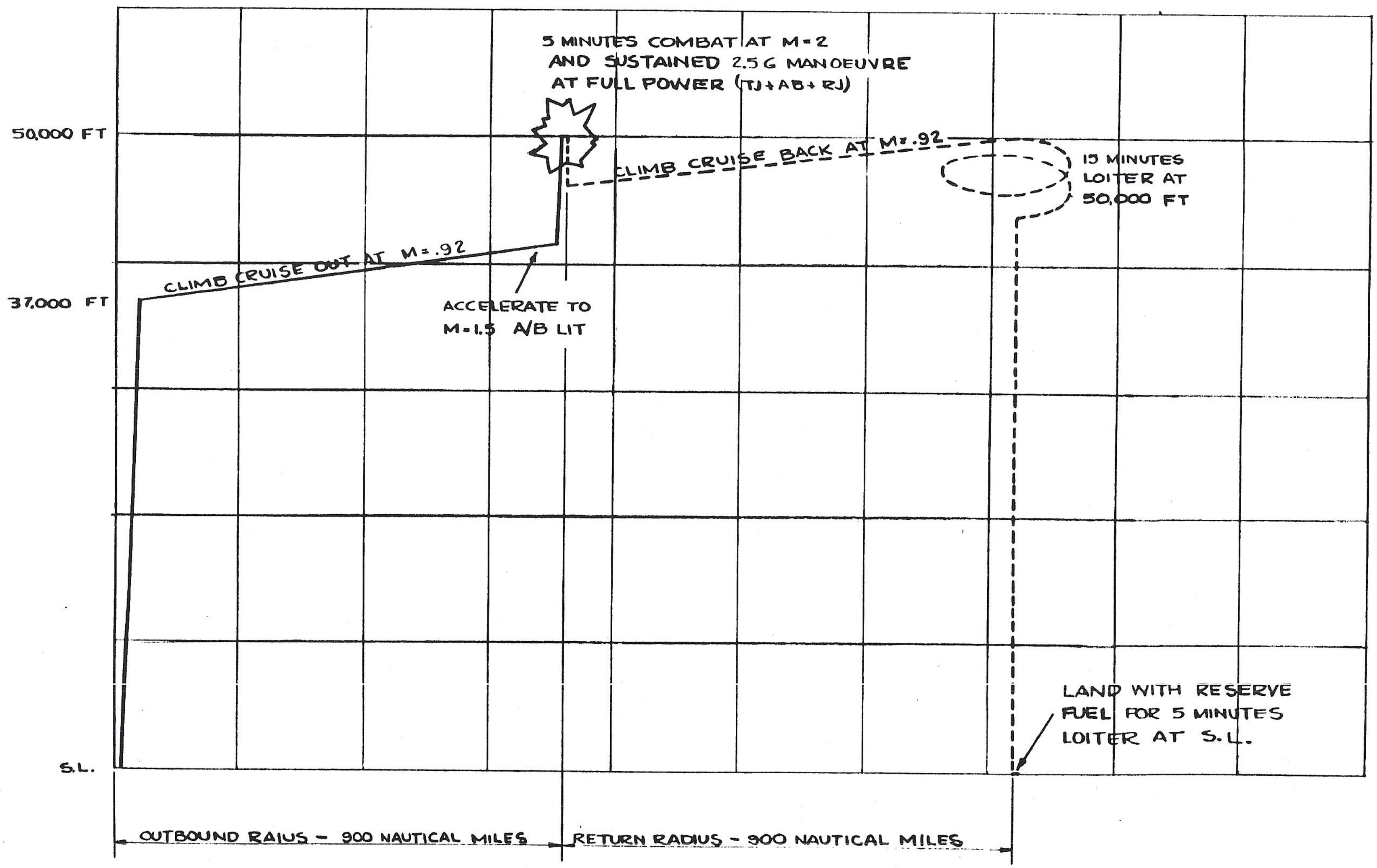
This mission consists of a 690 nautical mile climb cruise at Mach 0.92 followed by a descent to 5000 ft. altitude and a cruise for 280 nautical miles, immediately after which the bomb is tossed.

The return radius consists of a climb to economical altitude, a Mach 0.92 climb cruise, 15 minutes loiter at 50,000 ft. and a landing with fuel reserves for 5 minutes at sea level. The operational radius of this mission is 970 nautical miles.

LONG RANGE ARROW MISSION - 1

SUBSONIC CRUISE OUT

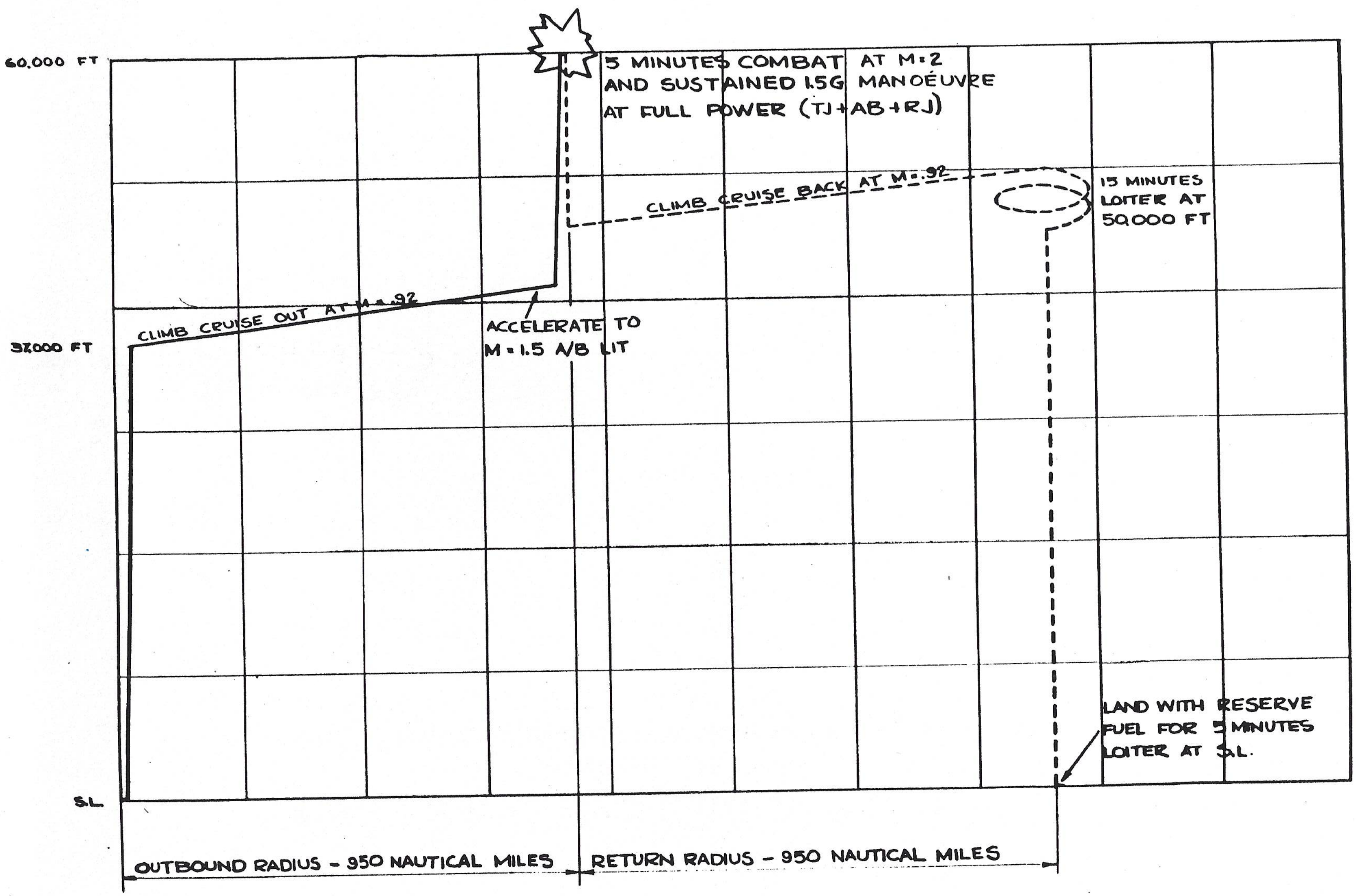
INTERNAL FUEL 25,400 LBS, PLUS 29,200 LBS IN RAMJET PODS.



LONG RANGE ARROW MISSION - 2

SUBSONIC CRUISE OUT

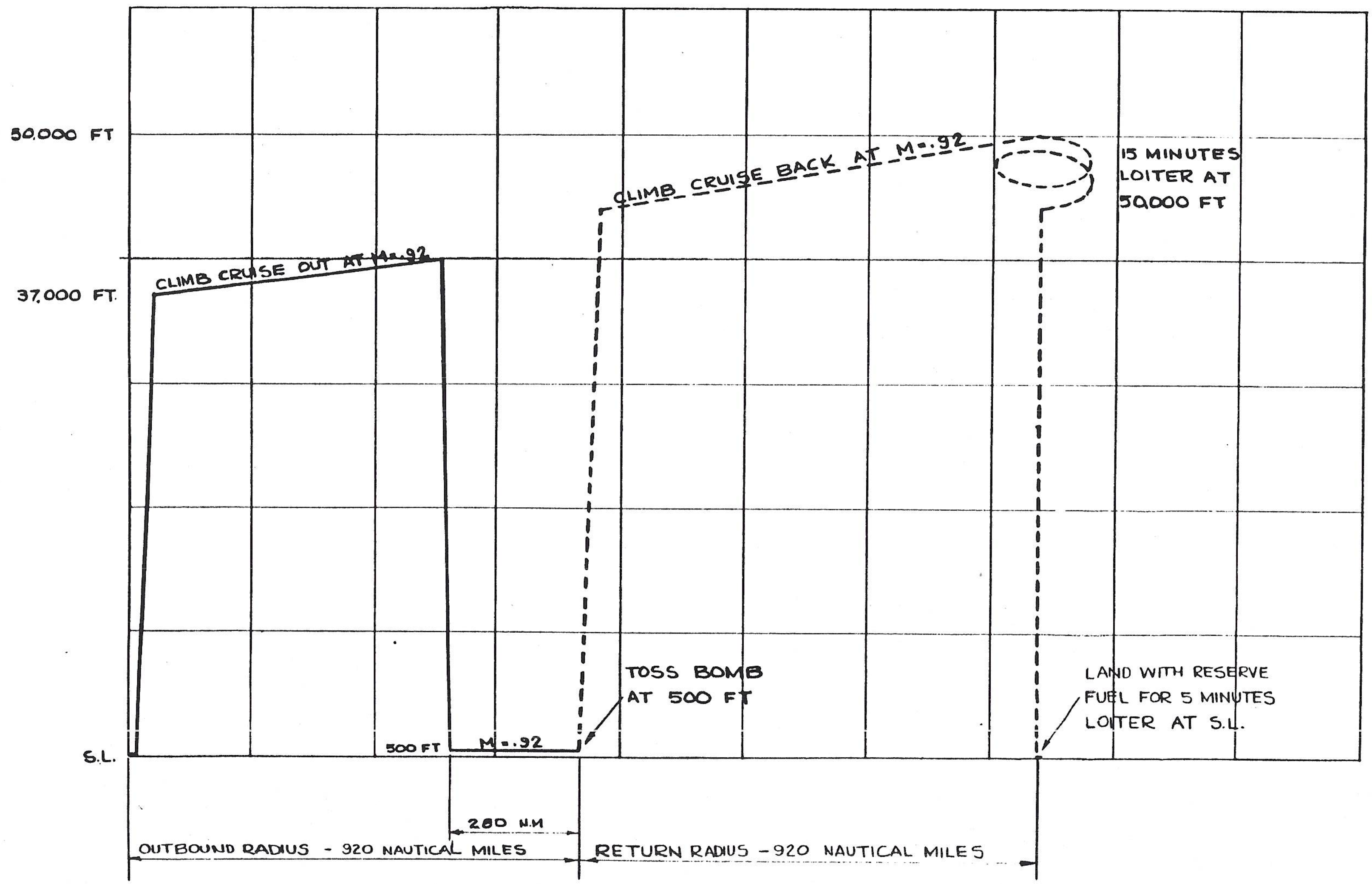
INTERNAL FUEL 25,400 LBS, PLUS 29,200 LBS IN RAMJET PODS.



LONG RANGE ARROW MISSION - 3

SUBSONIC CRUISE OUT

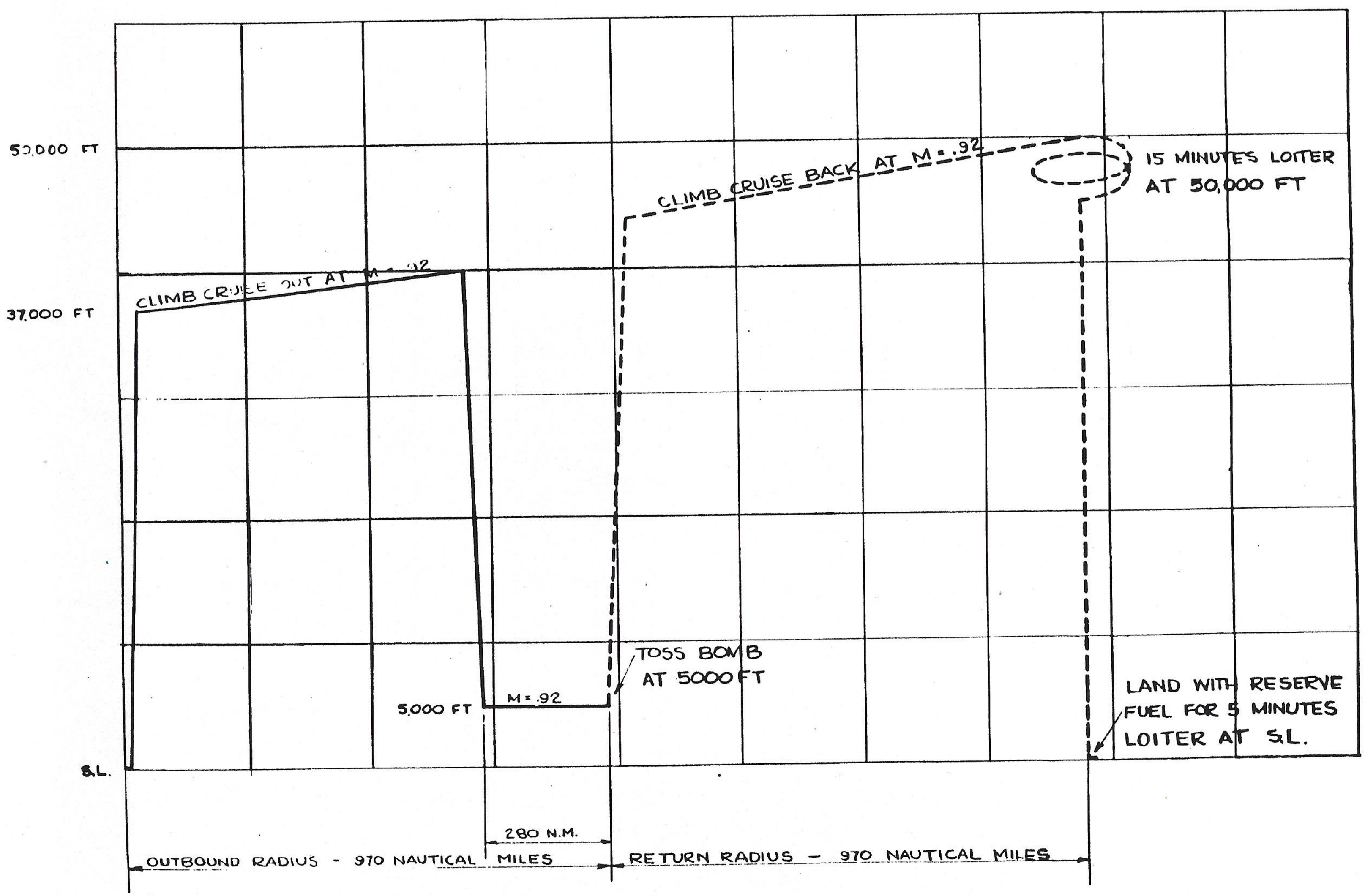
INTERNAL FUEL 25,400 LBS, PLUS 29,200 LBS IN RAMJET PODS.



LONG RANGE ARROW MISSION - 4

SUBSONIC CRUISE OUT

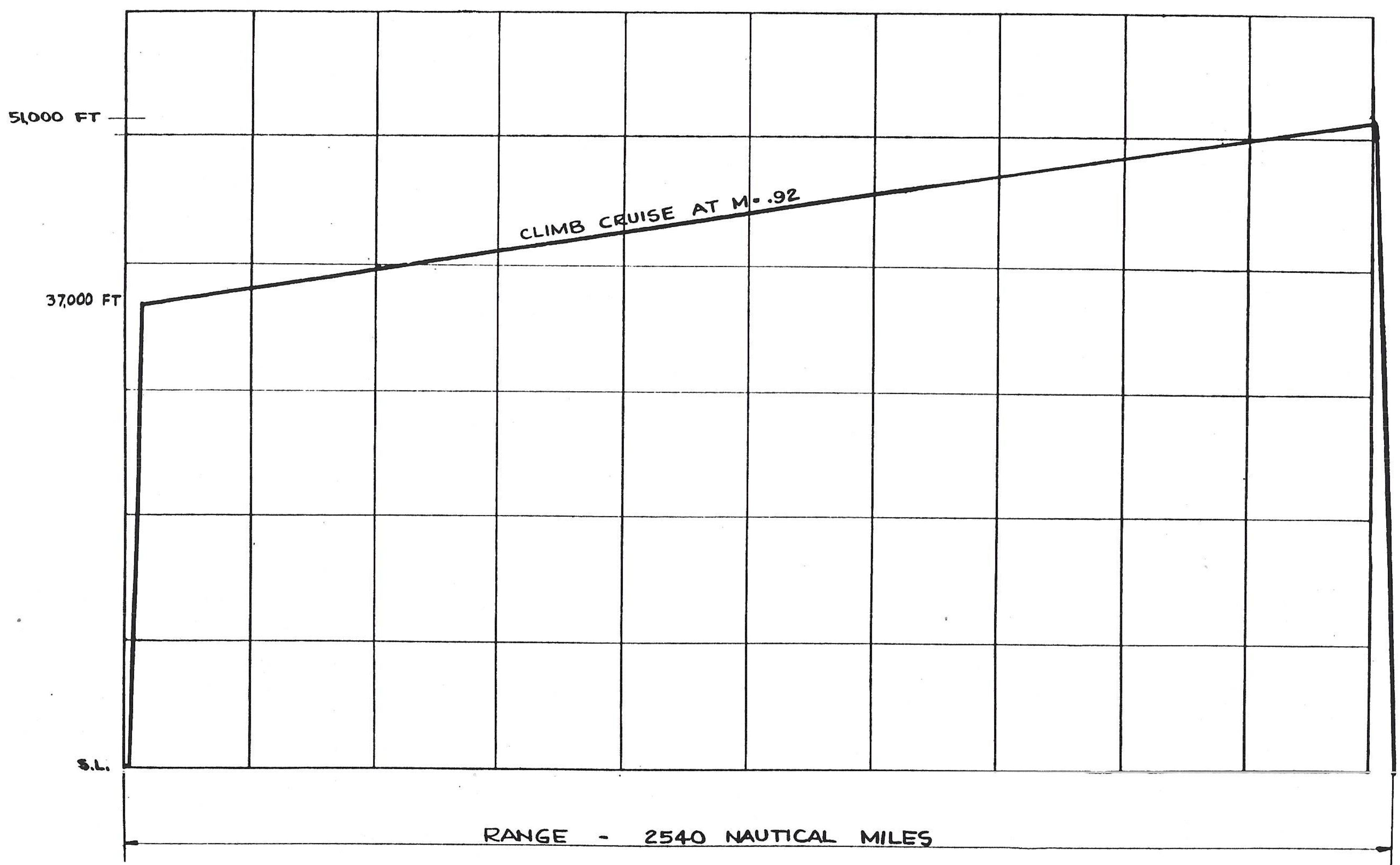
INTERNAL FUEL 25,400 LBS, PLUS 29,200 LBS IN RAMJET PODS.



LONG RANGE ARROW MISSION - 5

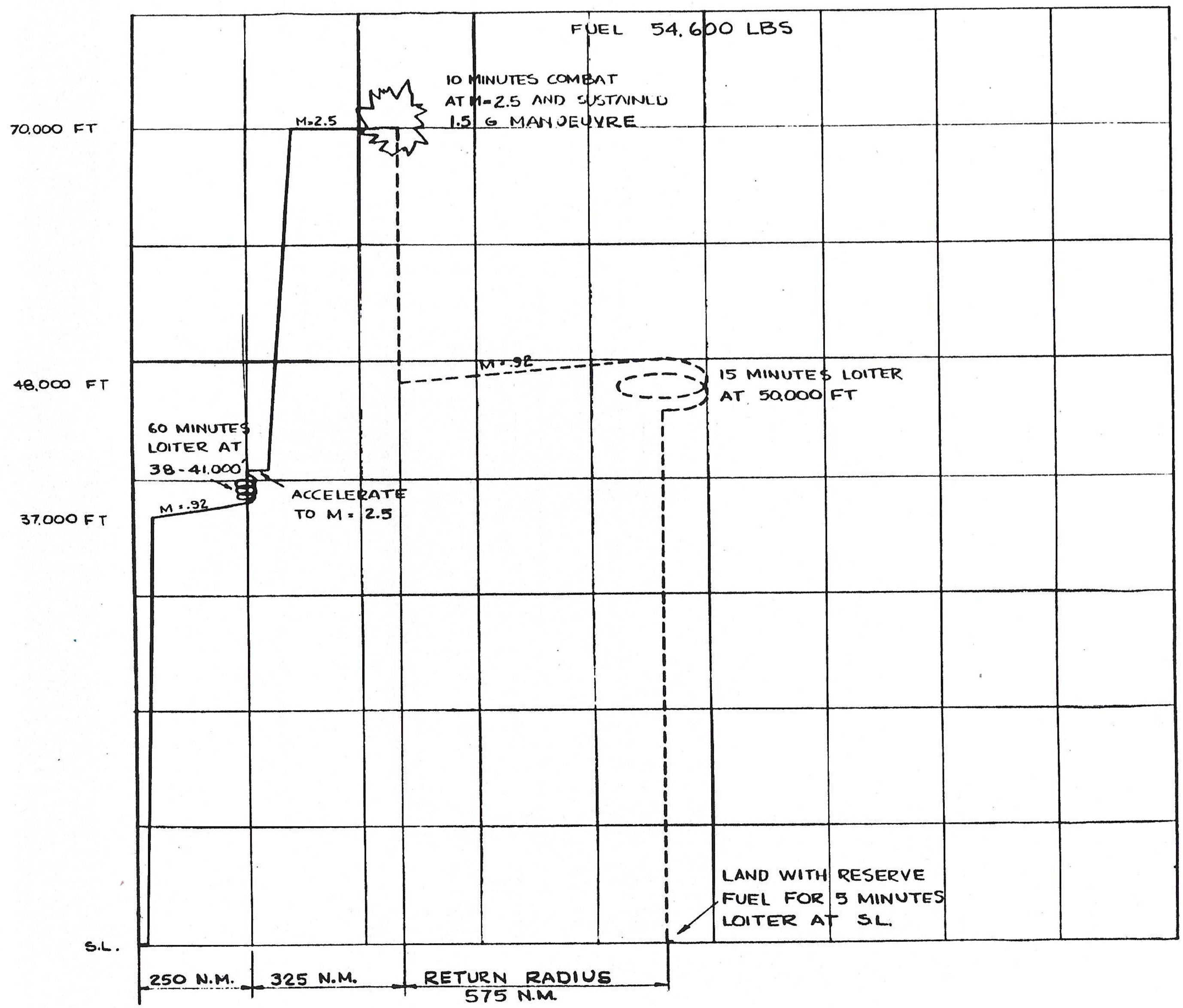
SUBSONIC CRUISE

INTERNAL FUEL 25,400 LBS, PLUS 29,200 LBS IN RAMJET PODS.



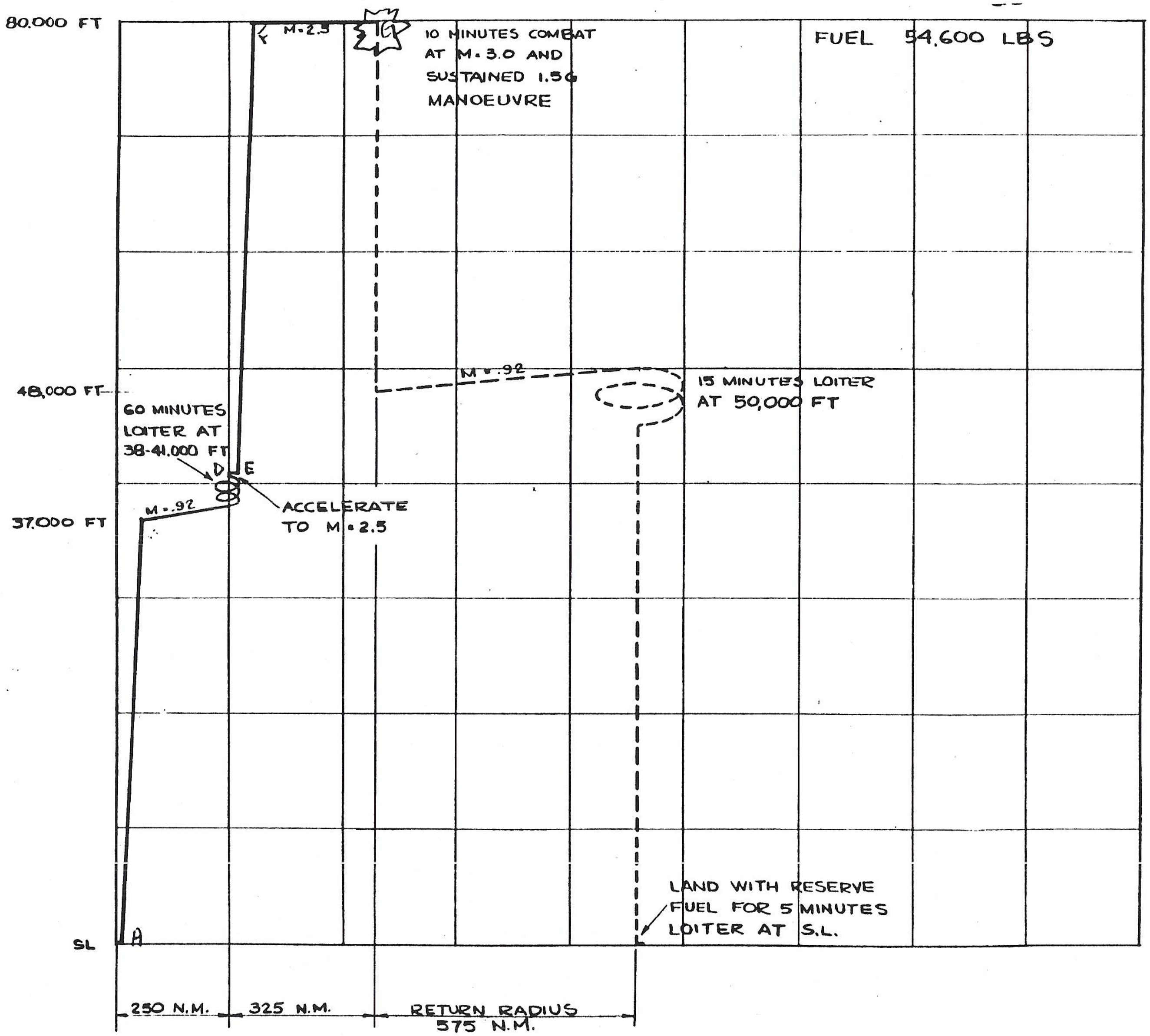
LONG RANGE ARROW MISSION - 6

SUPERSONIC DASH AND COMBAT AT M = 2.5.



LONG RANGE ARROW MISSION - 7

SUPERSONIC DASH AT M = 2.5, AND COMBAT AT M = 3.0.



MISSION No 5. - LONG RANGE FERRY.

Internal fuel 25,400 lbs., plus 29,200 lbs. in ramjet pods.

This mission consists of an economical Mach 0.92 climb cruise between 37,000 and 51,000 ft. altitude, and represents the ultimate range with no reserves on landing. The ultimate ferry range, based on 54,600 lb. of fuel is 2540 nautical miles.

MISSION No 6. - USAF LONG RANGE INTERCEPT MISSION MODIFIED.

This mission consists of an economical climb cruise for 250 nautical miles followed by a 60 minute loiter at 38,000 - 41,000 ft. The aircraft is then accelerated to Mach 2.5 and climbed to 70,000 ft. at which altitude an approximately 280 nautical mile, Mach 2.5 dash is executed, bringing the out-bound radius to 525 nautical miles. This is followed by 10 minutes combat at 70,000 ft. altitude, Mach 2.5 and sustained 1.5g manoeuvre. The return radius consists of a descent to 48,000 ft. altitude, a Mach 0.92 climb cruise followed by 15 minutes loiter at 50,000 ft., and a landing with reserve fuel for 5 minutes loiter at sea level. The deviation of this mission from the requirement is dash and combat at Mach 2.5 in lieu of Mach 3.0.

MISSION No 7. - USAF LONG RANGE INTERCEPT MISSION MODIFIED.

This mission consists of an economical climb cruise for 250 nautical miles followed by a 60 minute loiter at 38,000 - 41,000 ft. The aircraft is then accelerated to Mach 2.5 and climbed to 80,000 ft. at which altitude an approximately 280 nautical mile, Mach 2.5 dash is executed, bringing the out-bound radius to 575 nautical miles. This is followed by 10 minutes combat at 80,000 ft., Mach 3.0 and sustained 1.5g manoeuvre. The return radius consists of a descent to 48,000 ft. altitude, a Mach 0.92 climb cruise followed by 15 minutes loiter at 50,000 ft., and a landing with reserve fuel for 5 minutes loiter at sea level. The operational radius of this mission is 575 nautical miles. The deviation of this mission from the requirement is dash at Mach 2.5 in lieu of Mach 3.0, and combat at 80,000 ft. in lieu of 70,000 ft. altitude.

SUMMARY.

The philosophy behind this proposal was to make every possible use of the engineering that had gone into the Avro Arrow 1, 2 and 3. One might argue that the proposal calls for substantial redesign and that it would have been better to start at the beginning and design a new airplane. However, in the consideration of overall economy and time, it was felt that utilization of the then present engineering systems and airframe centre portions would indeed have been worthwhile.

IN CONCLUSION.

a. Avro Arrow hardware and systems used with minimum modification commensurate with Mach 3.0 capability.

b. Most of the Mk 3 development would have been utilized.

c. Provision for installing mixed fuel operation.

d. Most of the added weight concentrated over redesigned and relocated main undercarriage capable of development for higher take-off weights.

e. Jet pods capable of containing much more than 29,200 lbs. of fuel.

f. Area rule application could reduce parasitic drag.

g. The Long Range Arrow was a means of prolonging the life of the Avro Arrow and extracting the maximum amount of return from the then current and immediate future Arrow investment.

BASIC MODIFICATIONS FOR THE LONG RANGE ARROW.

ITEM	REMARKS
Undercarriage	1. Undercarriage removed and space used for fuel - 2000 lbs. 2. Undercarriage integrated with ramjet pylons, and relocated to the inner and outer wing transport joint.
Mixed Power	Combination of turbojet and ramjet power provides a light and efficient system capable of extremely high performance.
Increased fuel	Ramjet pods serve as fuel pods during cruise-out.
Drag Reduction	1. Addition of canard. 2. Increased wing area. 3. Increased aspect ratio.

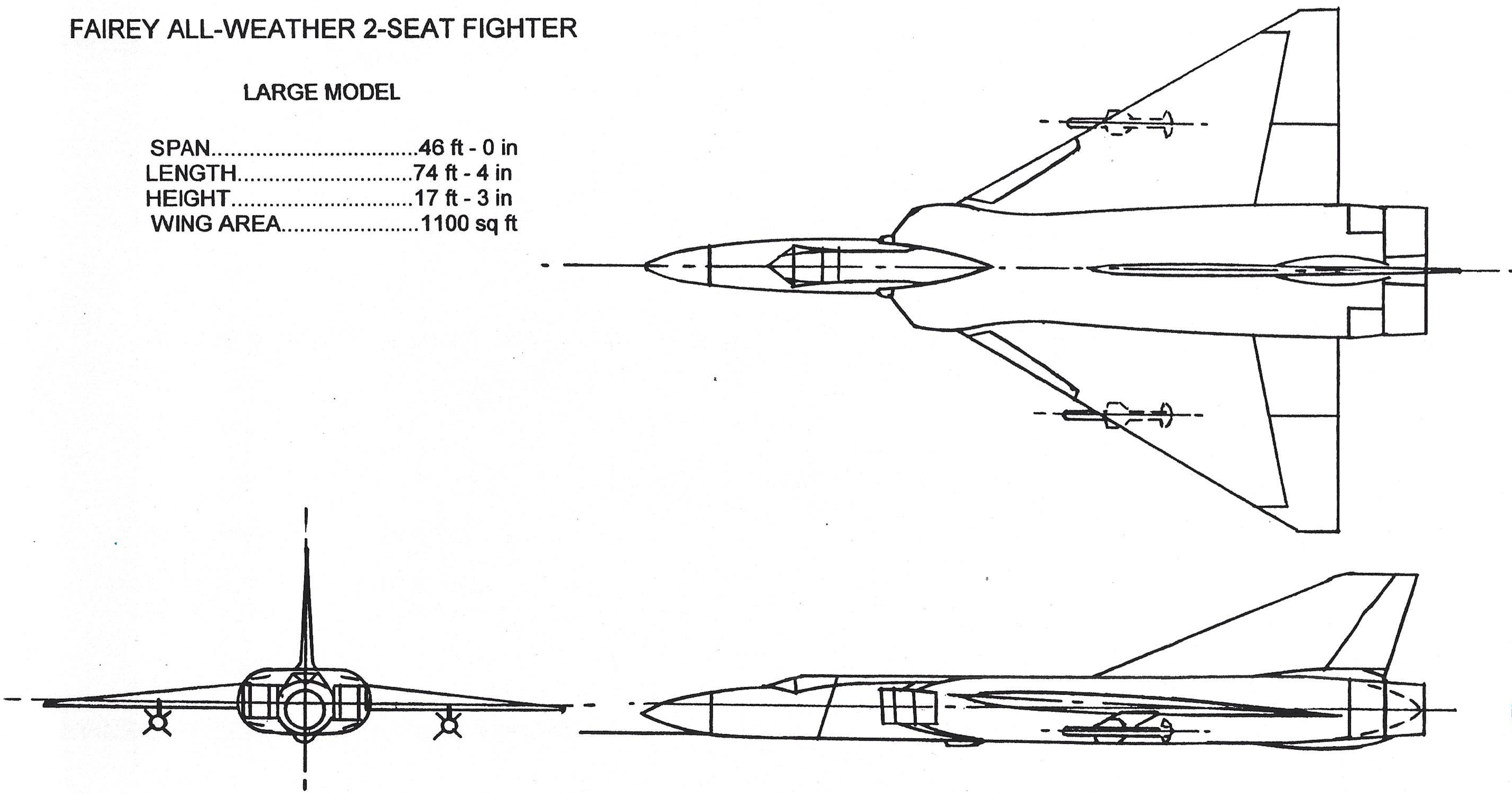
THE ARROW AND GOR 339.

In the Long Range Planning Group at Avro, there were several versions of the Arrow under consideration. As has been stated before, the full potentiality of an aircraft must be explored in order to employ its full use. It must be bourne in mind that the various projected Marks of the aircraft did not necessarily follow in order as different groups were working on solutions to very different specifications.

FAIREY ALL-WEATHER 2-SEAT FIGHTER

LARGE MODEL

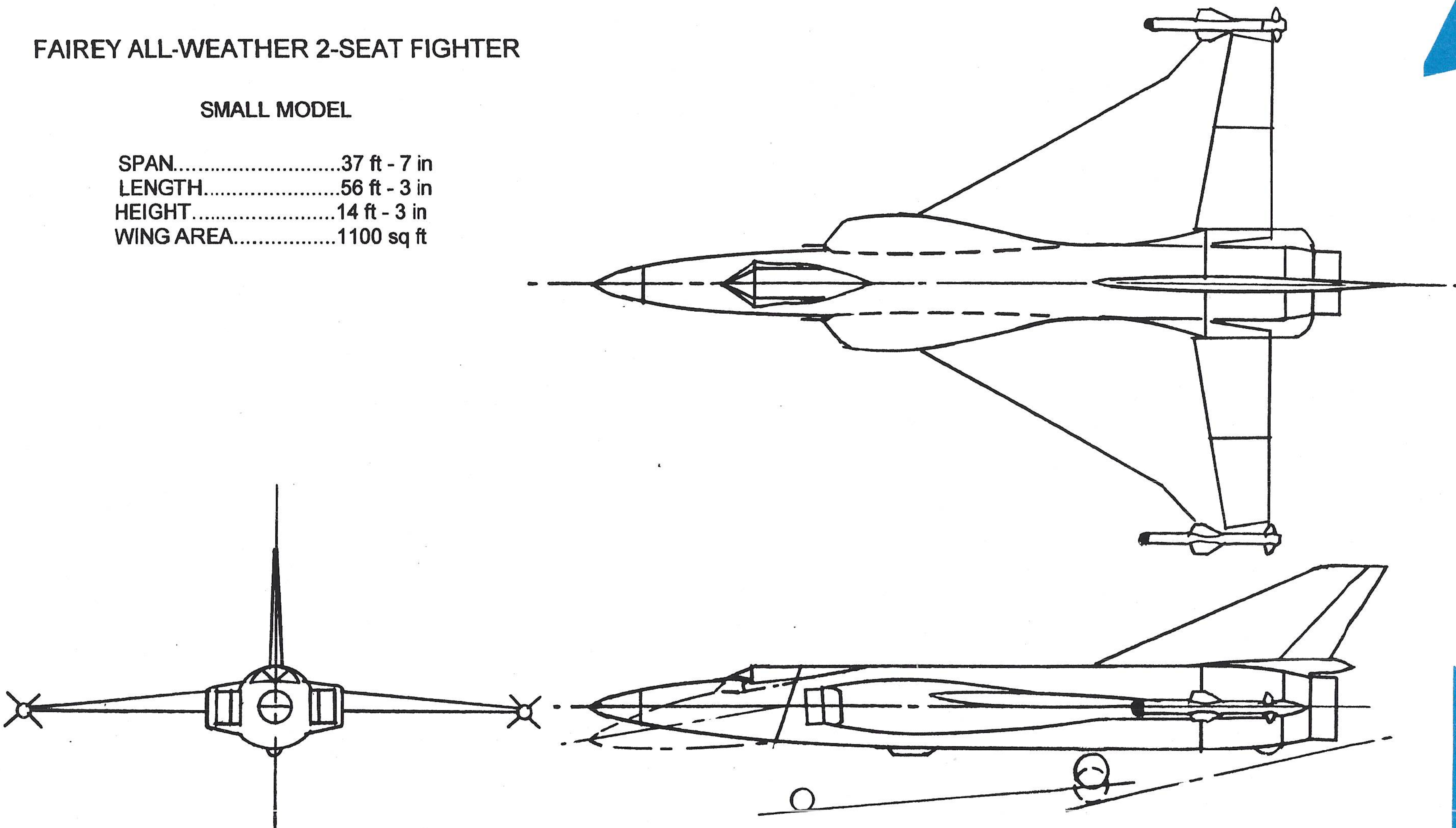
SPAN..................................46 ft - 0 in
LENGTH..............................74 ft - 4 in
HEIGHT...............................17 ft - 3 in
WING AREA........................1100 sq ft



FAIREY ALL-WEATHER 2-SEAT FIGHTER

SMALL MODEL

SPAN.............................37 ft - 7 in
LENGTH.......................56 ft - 3 in
HEIGHT.........................14 ft - 3 in
WING AREA.................1100 sq ft



For example:-

Late in 1957, Sir Roy Dobson contacted Avro Canada with a view to investigate the adaptability of the Arrow to the British Government Specification GOR 339 (which originated in March of 1957), and is probably one of the mot complex and exacting specifications ever issued by any Government. This specification was the beginning of what was, (in the United Kingdom), the TSR.2.

1. Tactical Nuclear Weapon delivery from low altitudes up to maximum range, with all weather performance capability. Low altitudes meant 150 ft (45m) - increased to 500 ft (150m) in blind conditions, with most of the mission being flown at a mean altitude of 1000 ft (305m).

2. Photographic reconnaissance, medium and low level by day and low level by night.

3. Electronic reconnaissance with all weather capability, not to compromise performance in the primary role of nuclear tactical weapon delivery.

4. Effective delivery of tactical nuclear weapons by day or night from medium altitudes under visual conditions or with blind bombing.

5. Effective delivery of high explosive (HE) bombs and rockets under visual conditions.

6. Capability of operating from 3000 ft (915m) strips anywhere in the world.

7. Radius of action initially 600 nm (1111 km) later 1000 nm (1853 km), without flight refueling, and a ferry range of 2000 nm (3700 km) with in-flight refueling available.

8. Penetration speed at sea level to be M=0.95 with additional supersonic dash capability preferred.

9. Weapons.

a.) "Red Beard" - standard nuclear store specified in OR 1127.

b.) 4 - 6 1000 lb (454 kg) bombs.

c.) 74 - 2 in (5 cm) rockets or 12 - OR 1099 - 3 in (7.62 cm) rockets.

10. Speed requirements of M=2.0 at tropopause.

11. Fatigue life aimed at 3000 hours.

12. Service ceiling of 55,000 ft.

13. Take-off roll - 2.400 ft at 96,000 lbs.
- 1.600 ft at 85,000 lbs.

14. Weight - 96,000 lbs (normal).
- 105,000 lbs (overloaded).
- 57,200 lbs (landing).

A later up-graded specification, OR 343, called for a maximum low level altitude in all conditions to be reduced to 200 ft (60 m), a maximum speed at the tropopause of M=2.0, and extra requirements on terrain radar and weapon aiming plus protection against nuclear weapons. No defensive weapons were specified.

It is of great interest that in 1955, the United Kingdom became interested in a two-seat, all-weather fighter for the RAF, and to this end issued GOR 329 and Specification F.155T.

The requirements of GOR 329 and Specification F.155T, were first released in the United Kingdom on January 15, 1955 and presented to industry. Among other Aircraft Companies, the Fairey Aviation Company submissions were of great interest. Not only did they reflect the Company's work on the highly successful FD2, designed and built to Specification ER.103, but bore a striking resemblance to the Avro Arrow, both being "All Weather Fighters." (Referring to the drawings will illustrate just how striking.) This is not surprising, as the Arrow was not only studied by all the Aircraft Companies in the United Kingdom, but was viewed as a contender to the thin-wing Gloster Javelin. The choice of a mid- wing concept is curious in view of the Arrow philosophy of design, which was known at the time.

The Fairey proposal, together with most others under study, was canceled by the Minister of Defence, Duncan Sandys, on April 4, 1957 in his white paper "DEFENCE, AN OUTLINE OF FUTURE POLICY" in the very mistaken impression that manned interceptors were obsolete. (All that he left active at that time were the Lighting and the TSR 2). This could very well have been the incident that influenced John Diefenbaker to subsequently cancel the Arrow. Even at this late stage, it is difficult to understand what was in the minds of these politicians when they made these decisions - unless it was mindlessness. All that Mr Diefenbaker could talk about was the dream that he had for Canada - a dream that was to become a nightmare. There was really no need for lobbyists from the US Aircraft Constructors against the Arrow - they had John Diefenbaker instead.

There exists a report written by the "United Kingdom Joint Air Ministry and

Ministry of Supply Evaluation Team", who visited Avro Canada in 1956, entitled "Evaluation of the Canadian CF-105 as an All-Weather Fighter for the RCAF". Both Avro and Orenda were visited and the report concluded that the Avro CF-105 be purchased by the Royal Air Force. (Avro Canada never saw this report.) A similar report was also written by the CARDE, and agreed with the British one. This report was issued only in 1961 and it took 30 years before it was declassified. Avro never saw this one either.

The Arrow, not being designed to these very stringent specifications could hardly be expected to perform within them, and indeed, they were partially to blame for the demise of the TSR.2 itself in 1965. Reference to the TSR.2 and specifications are made here not only because of Sir Roy Dobson's inquiry regarding the Arrow, but due to the almost parallel occurrences and demise of both aircraft and, the interference of both Governments, and the RAF and RCAF led to the disruption and amalgamation of the aircraft industry in the United Kingdom and to the disappearance of Avro Aircraft in Canada.

ARROW Mk2 to Mk5.

1. ARROW 2.

The production version of the Arrow 2 which contained approximately 19,843 lbs. of internal fuel, does not start to fulfill the GOR 339 specification. The extended range version of the Arrow 2 would have contained a further 3,900 lbs. in an external tank and 4,600 lbs. in the armament bay, totaling 27,938 lbs. of fuel. The weapons would have been carried externally.

2. ARROW 3.

The Arrow 3 contained 28,100 lbs. of internal fuel plus 3,900 lbs. in external tanks, totaling 32,000 lbs. There was no fuel in the armament bay. It was to have a speed of Mach 3.0 with a radius of 500 nm.

3. ARROW 4A.

The Arrow 4A contained 30,000 lbs. of internal fuel plus 27,880 lbs. in the ramjet fuel pods pylon structure. There was no fuel in the armament bay. The wing area was to be increased by 50 sq.ft. It should be noted that an exceptionally long runway would have been required if no additional power was used, that is, of the order of 15,000 ft. of runway. It was to have a speed of Mach 2.7 with a 1,000 nm. radius with external ramjets and fuel pods.

4. ARROW 4B.

The Arrow 4B would have carried 50,895 lbs, of fuel, but this amount would not have provided for a 200 nm. supersonic dash. Although it would have been capable of the toss bomb requirement, the structure would have had to have been strengthened considerably for a speed of Mach 1.5 at sea level, as the basic aircraft had been designed for Mach 1.09 at sea level. This of course would have been prohibitive cost-wise.

5. ARROW 5.

This version of the Arrow would have called for an increase in structural strength by an approximate factor of 1.9 which would have given an operational empty weight increase of 7920 lbs. over the 44,200 lbs. of the Arrow 2. It was to have a speed of Mach 2.0 and a radius of 1,300 nm. with external fuel pods. A total of 4,400 new parts would have been required and several new engines were considered for power:-

a. Iroquois 2 giving an operational take-off weight of 100,000 lbs.

b. Olympus. B.OL.7B. giving an operational take-off weight of 94,413 lbs.

c. Conway. 11R. Stage 3B. giving an operational take-off weight of 92,000 lbs.

CONCLUSION:-

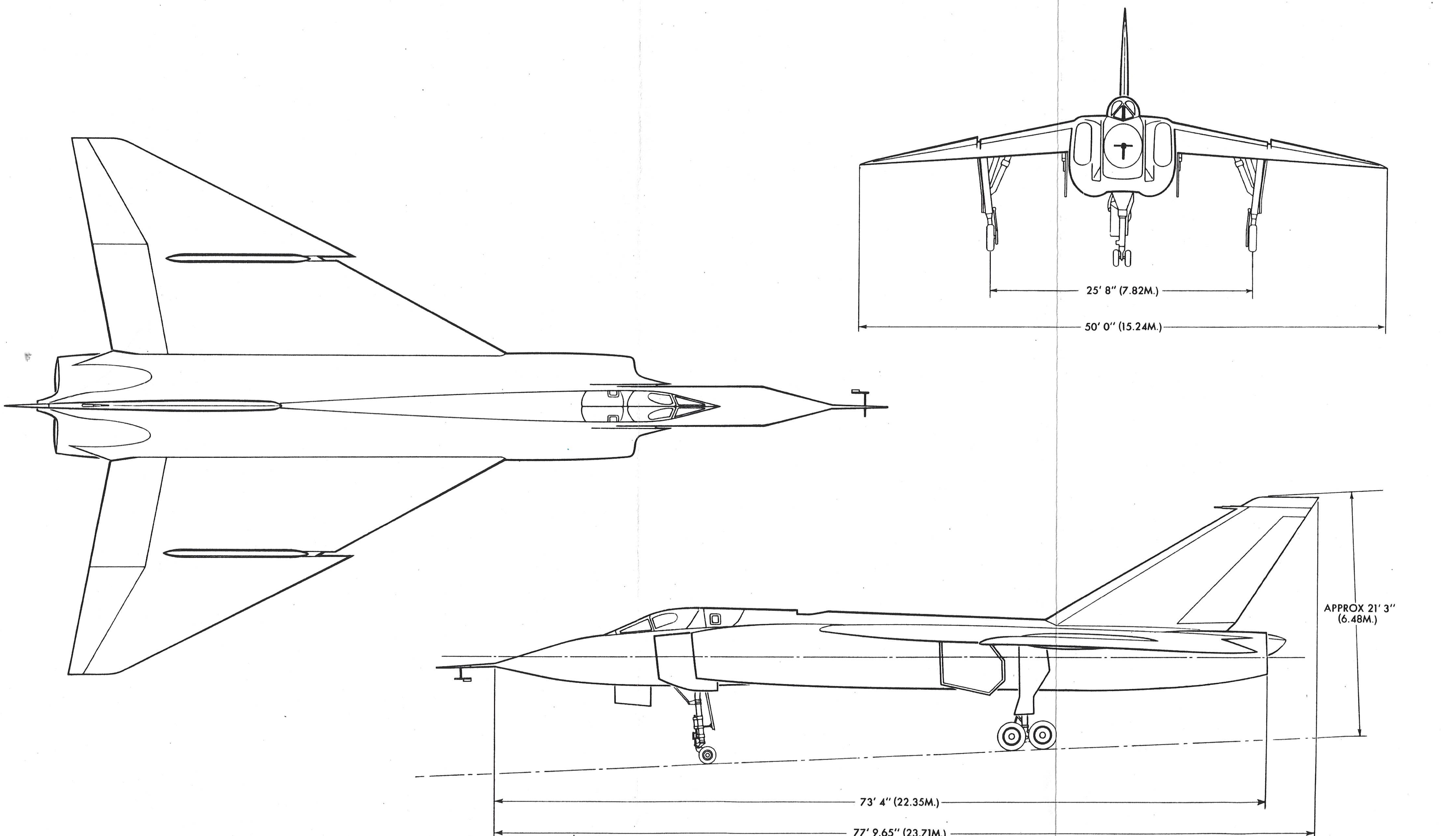
1. Arrow 2 with extra 10,000 lbs. fuel (as per Arrow 3) gave 400 nm. + 60 nm. SL inward and outward radius compared with 400 nm. + 200 nm. SL required according to Ewings and 800 nm. + 200 mm. SL according to GOR 339. Arrow 4 had capability of the order 600 nm. + 200 nm. SL at approximately 110,000 lbs. gross.

2. Very limited SL supersonic dash on Arrow 2 then M = 1.09 which was impractical operationally. Substantial strengthening of the structure required to improve this to M = 1.5, plus heavy drain on radius.

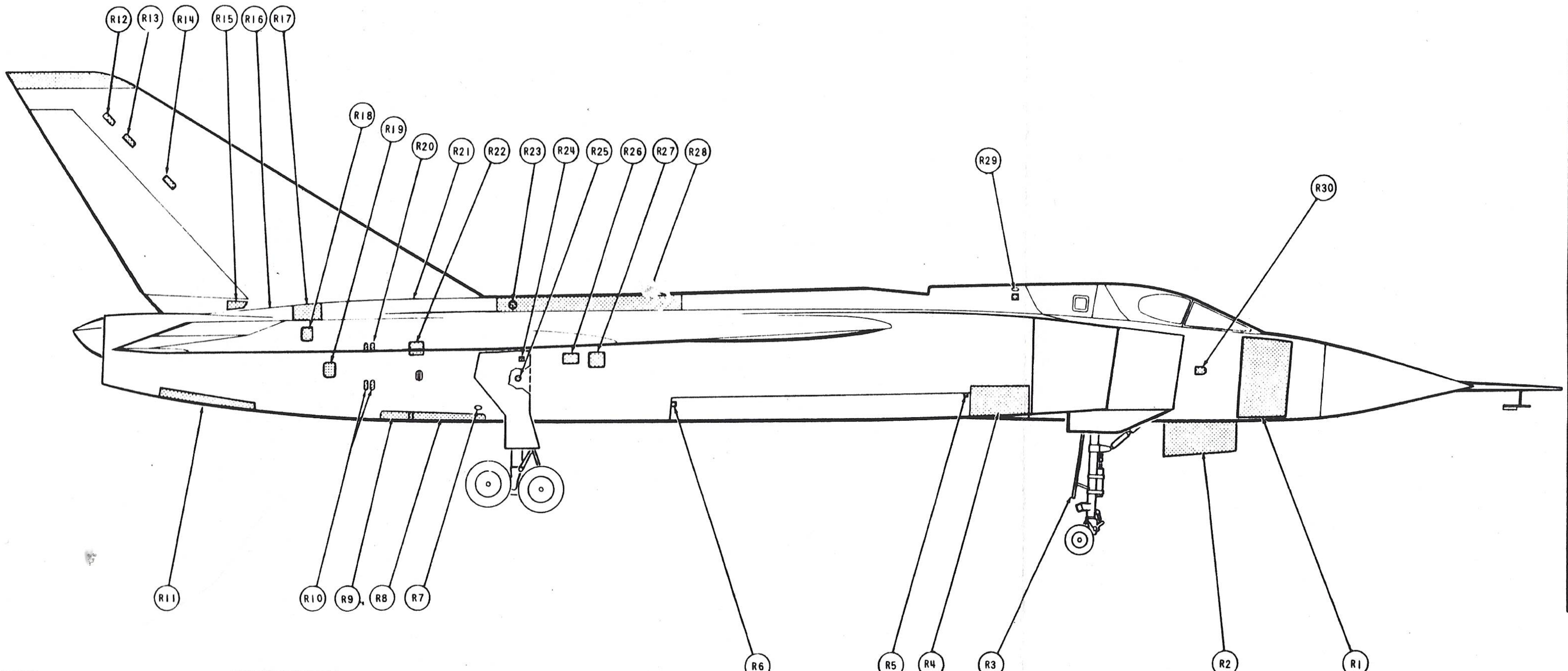
3. Operation of Arrow a problem from dispersed area - at best 3,000 ft. runway, ground support equipment was incompatible with such concept: independence of runways not possible.

4. Crew visibility and communication required indicates side by side seating.

5. Characteristics of GOR 1127 tactical nuclear weapon, (Vickers Red Dean), not known - however 4,000 - 6,000 lbs. bomb load stowage plus rockets indicated quite a payload problem.

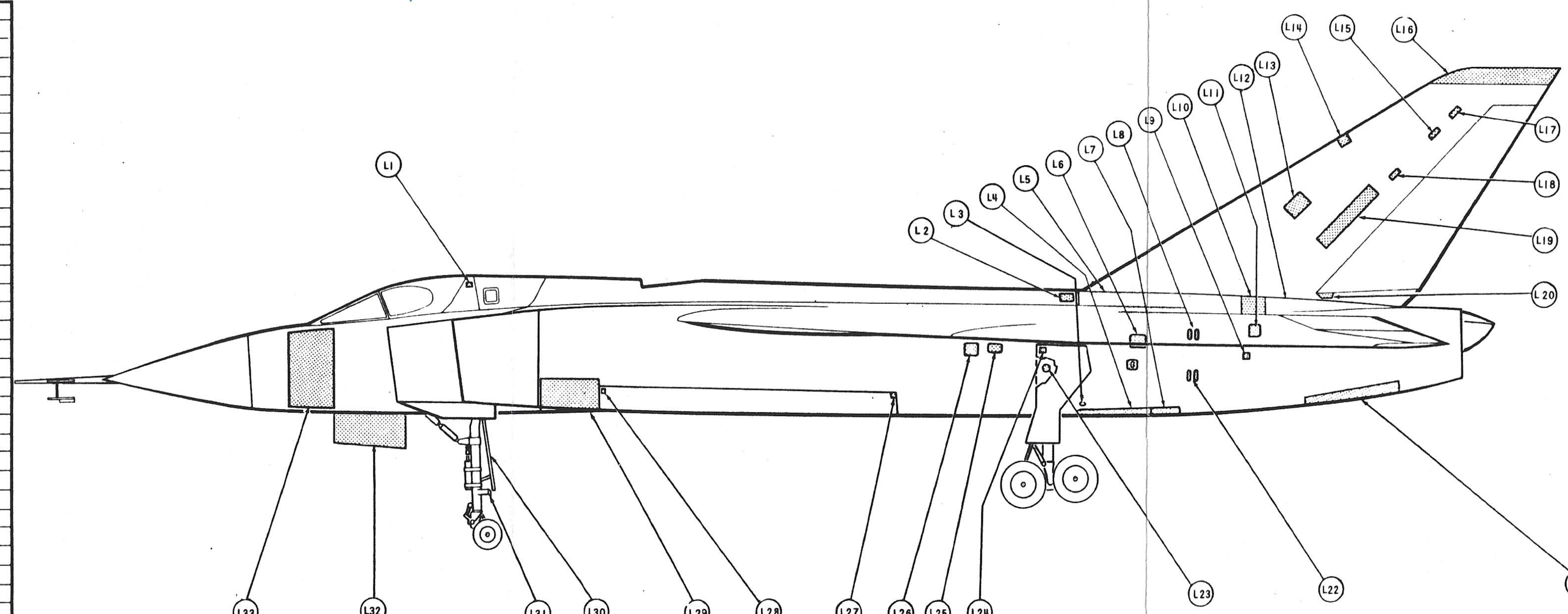


3 VIEW GENERAL ARRANGEMENT OF AIRCRAFT



ITEM	DESCRIPTION
R1	RADAR ACCESS DOOR
R2	NOSE U/C DOOR
R3	NOSE U/C FAIRING
R4	ELECTRONICS ACCESS DOOR
R5	ACCESS ARMAMENT PACK PICKUP F'W'D
R6	ACCESS ARMAMENT PACK PICKUP AFT
R7	ACCESS FOR FIRE EXTINGUISHING
R8	ENGINE ACCESS NO. 1 DOOR
R9	ENGINE ACCESS NO. 2 DOOR
R10	PRESSURE VENT DOORS NO. 3 & 4
R11	ENGINE REMOVAL DOOR
R12	WAVE GUIDE ANTENNA-ACCESS PANEL
R13	TRAILING EDGE ATTACHMENTS-ACCESS PANEL
R14	WAVE-GUIDE-ACCESS PANEL
R15	RUDDER REMOVAL HINGED PANEL
R16	WING FIN FAIRING
R17	WING FIN FAIRING-ACCESS PANEL
R18	REAR ENGINE MOUNT-ACCESS PANEL
R19	VENT
R20	PRESSURE VENT DOORS NO. 1 & 2
R21	WING FIN FAIRING
R22	AIR COND. DISCONNECT-ACCESS PANEL
R23	SENSE ANTENNA-DISCONNECT
R24	FRONT ENG. MOUNT OUTBOARD UPPER ACCESS PANEL
R25	FRONT ENG. MOUNT OUTBOARD LOWER ACCESS PANEL
R26	FLOATING DUCT ATTACHMENTS-ACCESS PANEL
R27	AIR COND. & PRESS. RED. VALVE-ACCESS PANEL
R28	DORSAL FAIRING
R29	STEAM OUTLET DOOR
R30	EMERGENCY CANOPY OPENING DOOR

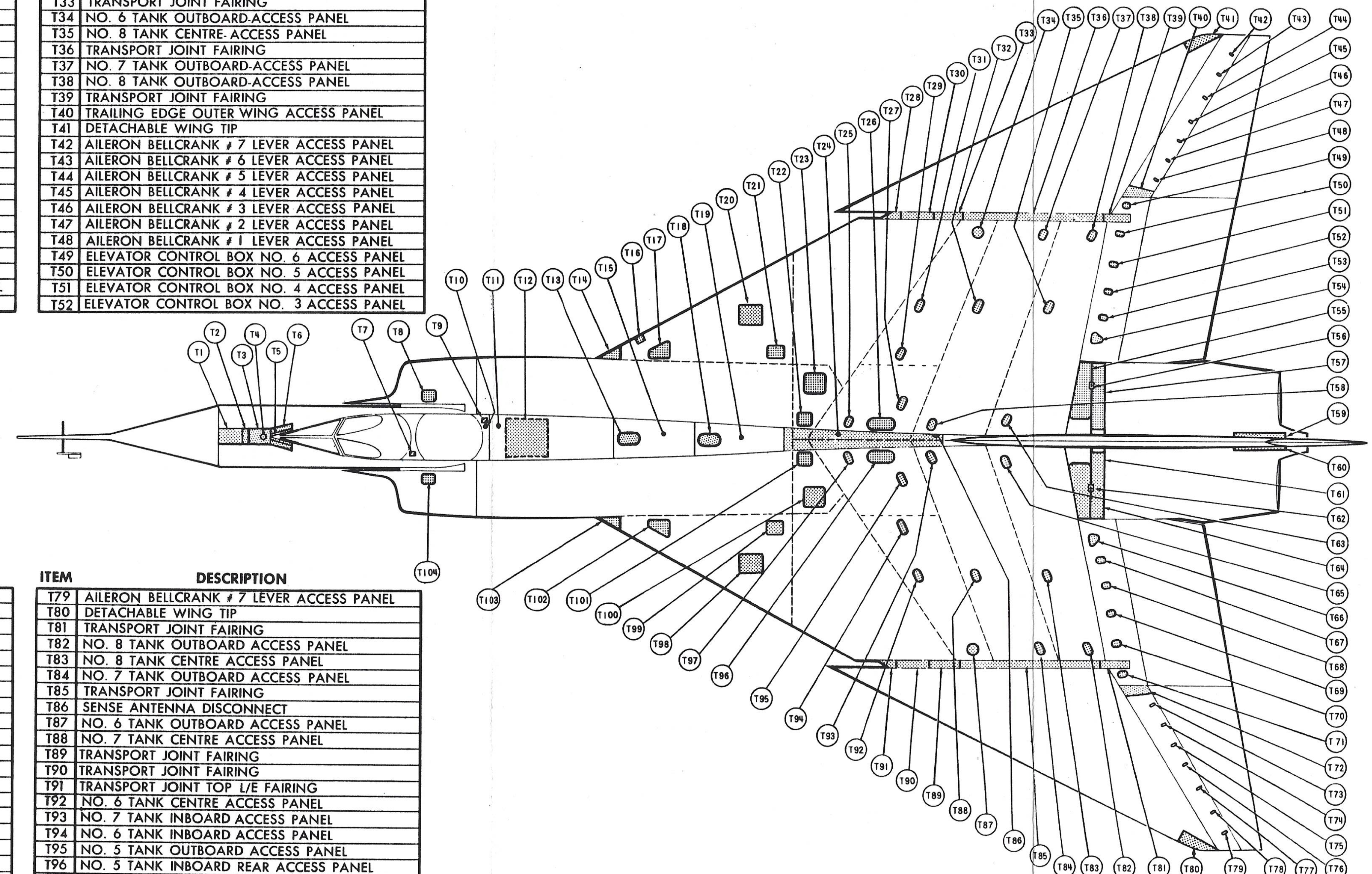
ITEM	DESCRIPTION
L1	ELECTRONICS ACCESS DOOR
L2	WING DORSAL FAIRING-ACCESS FAIRING
L3	ACCESS FOR FIRE EXTINGUISHING
L4	ENGINE ACCESS NO. 1 DOOR
L5	WING FIN FAIRING
L6	AIR. COND. DISCONNECT-ACCESS PANEL
L7	ENGINE ACCESS-NO. 2 DOOR
L8	PRESSURE VENT DOORS NO. 1 & 2
L9	VENTS
L10	WING FIN FAIRING ACCESS PANEL
L11	REAR ENGINE MOUNT-ACCESS PANEL
L12	WING FIN FAIRING
L13	HINGE MOMENT LIMITER-ACCESS PANEL
L14	WAVE GUIDE JOINT-ACCESS PANEL
L15	TRAILING EDGE ATTACHMENT ACCESS PANEL
L16	FIN TIP
L17	WAVE GUIDE ANTENNA-ACCESS PANEL
L18	WAVE GUIDE-ACCESS PANEL
L19	RUDDER JACK-ACCESS PANEL
L20	RUDDER REMOVAL HINGED PANEL
L21	ENGINE REMOVAL DOOR
L22	PRESSURE VENT DOORS NO. 3 & 4
L23	FRONT ENG. MOUNT OUTB'D. LOWER-ACCESS PANEL
L24	FRONT ENG. MOUNT OUTB'D. UPPER-ACCESS PANEL
L25	FLOATING DUCT ATTACHMENTS-ACCESS PANEL
L26	AIR COND. & PRESS. REDUCING VALVE-ACCESS PANEL
L27	ACCESS ARM. PACK PICKUP AFT
L28	ACCESS ARM. PACK PICKUP F'W'D
L29	ELECTRONICS-ACCESS DOOR
L30	NOSE U/C FAIRING
L31	QUICK DISCONNECT ELECTRONICS-ACCESS DOOR
L32	NOSE U/C DOOR
L33	RADAR-ACCESS DOOR



ARROW 2 ACCESS PANELS—R/H & L/H VIEWS

ITEM	DESCRIPTION
T1	DE-ICING EQUIPMENT-ACCESS PANEL
T2	DE-ICING ACCESS PANEL
T3	DE-ICING PANEL
T4	FILLER CAP FOR DE-ICING FLUID
T5	WINDSHIELD FAIRING
T6	RAIN REPELLANT-ACCESS PANEL
T7	CANOPY SWITCHES-ACCESS DOOR
T8	DE-ICER ACCESS PANEL
T9	STEAM OUTLET DOOR
T10	FILLER CAP (BOILER)
T11	DORSAL FAIRING
T12	AIR CONDITIONING ACCESS PANEL
T13	NO. 1 TANK ACCESS PANEL
T14	REMOVABLE CUFF
T15	DORSAL FAIRING
T16	COMPASS SENSING UNIT-ACCESS PANEL
T17	NO. 3 TANK FORWARD-ACCESS PANEL
T18	NO. 2 TANK ACCESS PANEL
T19	DORSAL FAIRING
T20	NO. 3 TANK OUTBOARD- ACCESS PANEL
T21	NO. 3 TANK AFT-ACCESS PANEL
T22	NO. 4 TANK INBOARD-ACCESS PANEL
T23	NO. 4 TANK OUTBOARD- ACCESS PANEL
T24	DORSAL FAIRING
T25	NO. 5 TANK FORWARD INBOARD -ACCESS PANEL
T26	NO. 5 TANK INBOARD REAR-ACCESS PANEL

ITEM	DESCRIPTION
T27	NO. 5 TANK OUTBOARD-ACCESS PANEL
T28	TRANSPORT JOINT TOP L/E FAIRING
T29	NO. 6 TANK INBOARD-ACCESS PANEL
T30	TRANSPORT JOINT FAIRING
T31	NO. 6 TANK CENTRE-ACCESS PANEL
T32	NO. 7 TANK CENTRE-ACCESS PANEL
T33	TRANSPORT JOINT FAIRING
T34	NO. 6 TANK OUTBOARD-ACCESS PANEL
T35	NO. 8 TANK CENTRE- ACCESS PANEL
T36	TRANSPORT JOINT FAIRING
T37	NO. 7 TANK OUTBOARD-ACCESS PANEL
T38	NO. 8 TANK OUTBOARD-ACCESS PANEL
T39	TRANSPORT JOINT FAIRING
T40	TRAILING EDGE OUTER WING ACCESS PANEL
T41	DETACHABLE WING TIP
T42	AILERON BELLCRANK # 7 LEVER ACCESS PANEL
T43	AILERON BELLCRANK # 6 LEVER ACCESS PANEL
T44	AILERON BELLCRANK # 5 LEVER ACCESS PANEL
T45	AILERON BELLCRANK # 4 LEVER ACCESS PANEL
T46	AILERON BELLCRANK # 3 LEVER ACCESS PANEL
T47	AILERON BELLCRANK # 2 LEVER ACCESS PANEL
T48	AILERON BELLCRANK # 1 LEVER ACCESS PANEL
T49	ELEVATOR CONTROL BOX NO. 6 ACCESS PANEL
T50	ELEVATOR CONTROL BOX NO. 5 ACCESS PANEL
T51	ELEVATOR CONTROL BOX NO. 4 ACCESS PANEL
T52	ELEVATOR CONTROL BOX NO. 3 ACCESS PANEL



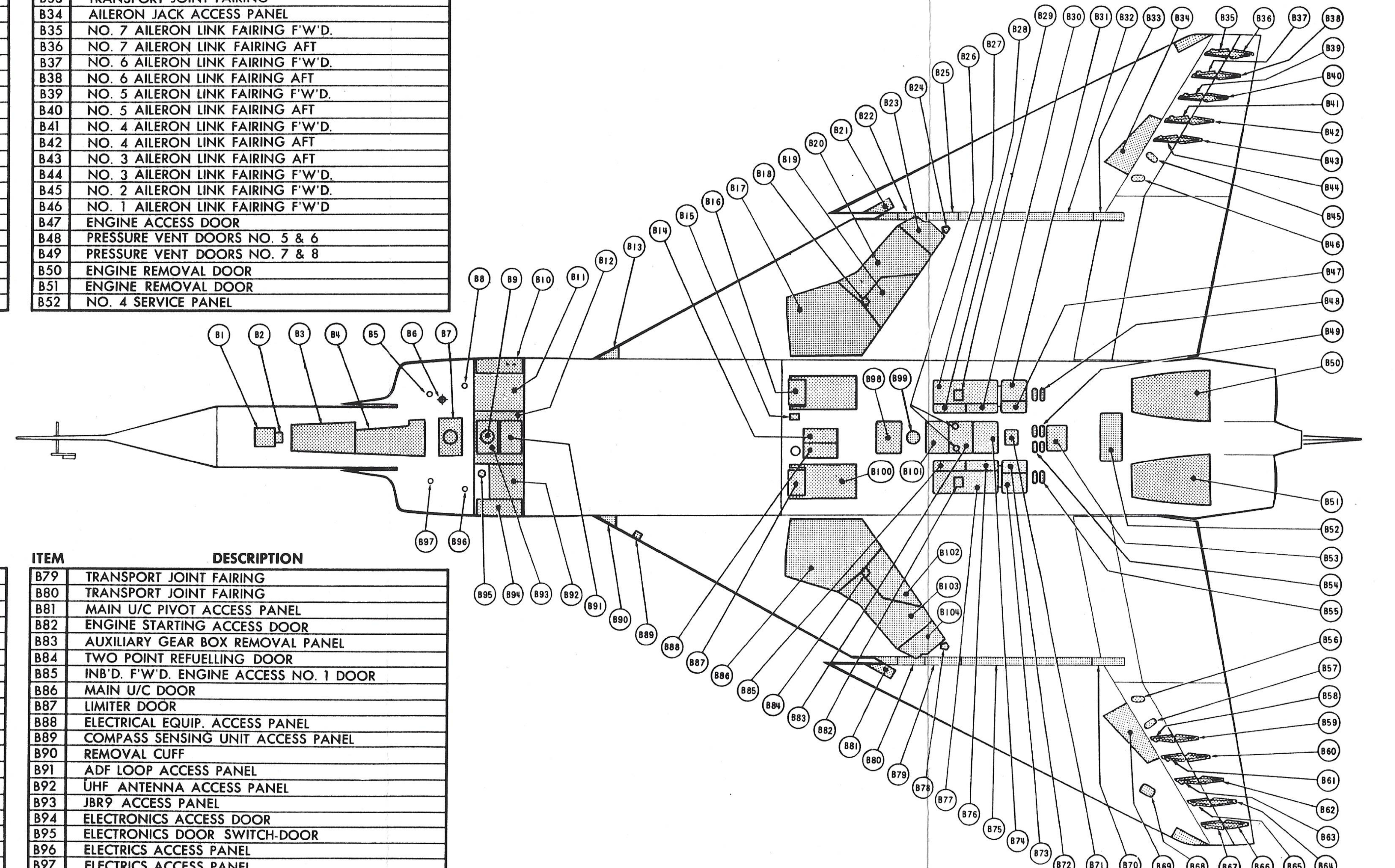
ITEM	DESCRIPTION
T53	ELEVATOR CONTROL BOX NO. 2 ACCESS PANEL
T54	ELEVATOR CONTROL BOX NO. 1 ACCESS PANEL
T55	MAIN UNDERCARRIAGE DOOR
T56	REAR CENTRE ENGINE MOUNT ACCESS PANEL
T57	REAR ENGINE MOUNT ACCESS PANEL
T58	NO. 7 TANK INBOARD ACCESS PANEL
T59	ARRESTER GEAR DOOR
T60	ARRESTER GEAR DOOR
T61	REAR ENGINE MOUNT ACCESS PANEL
T62	REAR CENTRE ENGINE MOUNT ACCESS PANEL
T63	NO. 8 TANK INBOARD ACCESS PANEL
T64	ELEVATOR JACK ACCESS PANEL
T65	NO. 8 TANK INBOARD ACCESS PANEL
T66	ELEVATOR CONTROL BOX NO. 1 ACCESS PANEL
T67	ELEVATOR CONTROL BOX NO. 2 ACCESS PANEL
T68	ELEVATOR CONTROL BOX NO. 3 ACCESS PANEL
T69	ELEVATOR CONTROL BOX NO. 4 ACCESS PANEL
T70	ELEVATOR CONTROL BOX NO. 5 ACCESS PANEL
T71	ELEVATOR CONTROL BOX NO. 6 ACCESS PANEL
T72	TRAILING EDGE OUTER WING ACCESS PANEL
T73	AILERON BELLCRANK #1 LEVER ACCESS PANEL
T74	AILERON BELLCRANK #2 LEVER ACCESS PANEL
T75	AILERON BELLCRANK #3 LEVER ACCESS PANEL
T76	AILERON BELLCRANK #4 LEVER ACCESS PANEL
T77	AILERON BELLCRANK #5 LEVER ACCESS PANEL
T78	AILERON BELLCRANK #6 LEVER ACCESS PANEL

ITEM	DESCRIPTION
T79	AILERON BELLCRANK # 7 LEVER ACCESS PANEL
T80	DETACHABLE WING TIP
T81	TRANSPORT JOINT FAIRING
T82	NO. 8 TANK OUTBOARD ACCESS PANEL
T83	NO. 8 TANK CENTRE ACCESS PANEL
T84	NO. 7 TANK OUTBOARD ACCESS PANEL
T85	TRANSPORT JOINT FAIRING
T86	SENSE ANTENNA DISCONNECT
T87	NO. 6 TANK OUTBOARD ACCESS PANEL
T88	NO. 7 TANK CENTRE ACCESS PANEL
T89	TRANSPORT JOINT FAIRING
T90	TRANSPORT JOINT FAIRING
T91	TRANSPORT JOINT TOP L/E FAIRING
T92	NO. 6 TANK CENTRE ACCESS PANEL
T93	NO. 7 TANK INBOARD ACCESS PANEL
T94	NO. 6 TANK INBOARD ACCESS PANEL
T95	NO. 5 TANK OUTBOARD ACCESS PANEL
T96	NO. 5 TANK INBOARD REAR ACCESS PANEL
T97	NO. 5 TANK FORWARD INBOARD ACCESS PANEL
T98	NO. 3 TANK OUTBOARD ACCESS PANEL
T99	NO. 3 TANK AFT ACCESS PANEL
T100	NO. 4 TANK OUTBOARD ACCESS PANEL
T101	NO. 4 TANK INBOARD ACCESS PANEL
T102	NO. 3 TANK FORWARD ACCESS PANEL
T103	REMOVABLE CUFF
T104	DE-ICER ACCESS PANEL

ARROW 2 ACCESS PANELS—TOP SURFACES

ITEM	DESCRIPTION
B1	UHF ANTENNA ACCESS PANEL
B2	ICE DETECTOR ACCESS PANEL
B3	NOSE U/C DOOR
B4	NOSE U/C FAIRING
B5	ELECTRICS ACCESS PANEL
B6	ATTACHMENT RING- AIR CONDITIONING
B7	AIR COND. EQUIPMENT- ACCESS PANEL
B8	ELECTRICS ACCESS PANEL
B9	ELECTRONIC CIRCUIT BREAKER- ACCESS DOOR
B10	ELECTRONICS ACCESS DOOR
B11	ELECTRONICS ACCESS PANEL
B12	ELECTRONICS EQUIP. BAY CENTRE DOOR
B13	REMOVABLE CUFF
B14	ELECTRICS ACCESS PANEL
B15	GROUND POWER ACCESS DOOR
B16	MASTER REFUELLING DOOR
B17	MAIN U/C DOOR
B18	TWO POINT REFUELLING DOOR
B19	FUEL PROPORTIONER ACCESS DOOR
B20	MAIN U/C FAIRING
B21	MAIN U/C PIVOT ACCESS PANEL
B22	TRANSPORT JOINT FAIRING
B23	MAIN U/C PIVOT DOOR
B24	MAIN U/C JACK ACCESS PANEL
B25	TRANSPORT JOINT FAIRING
B26	GEAR BOX DRAIN ACCESS PANEL

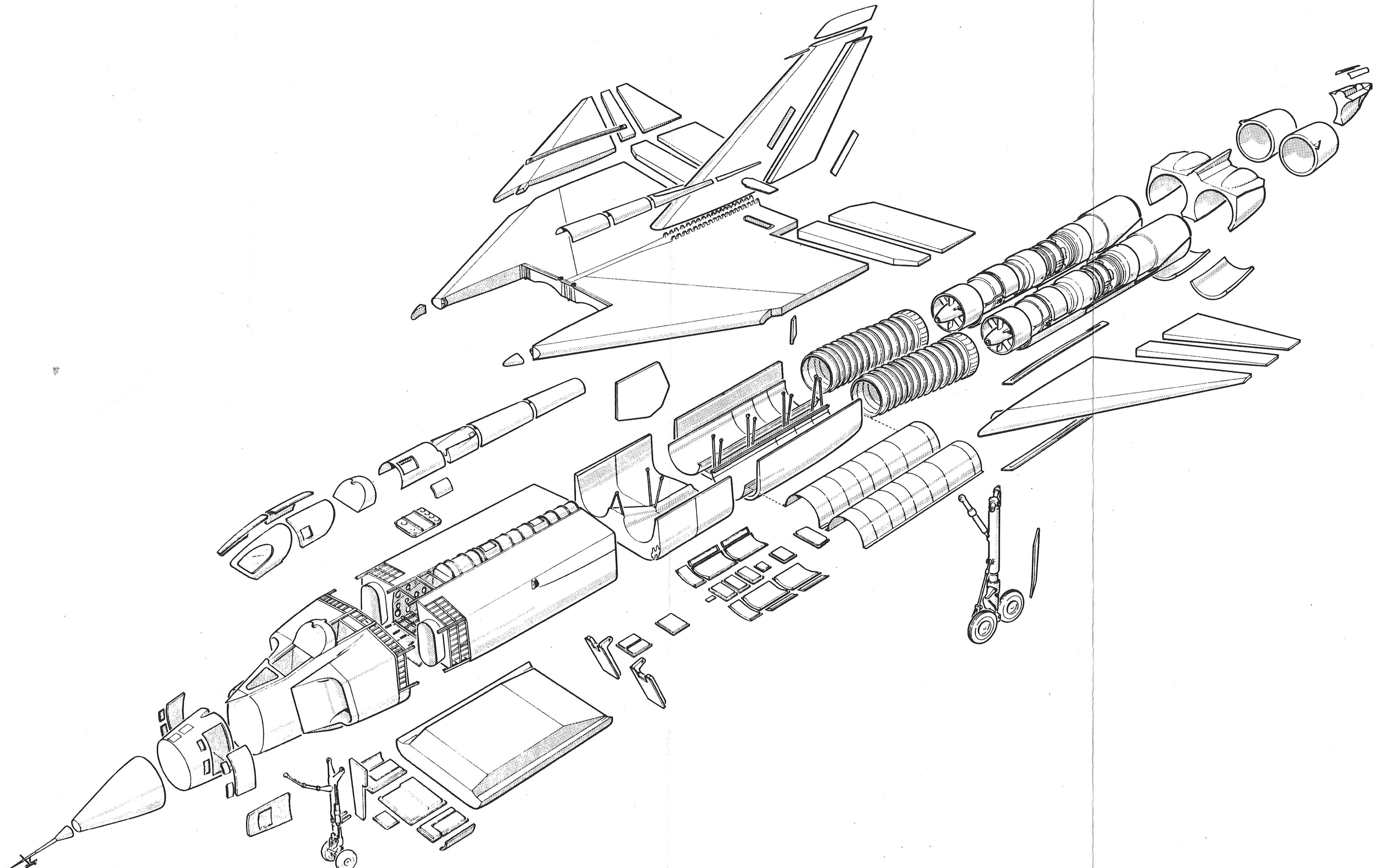
ITEM	DESCRIPTION
B27	ENGINE ACCESS NO. 1 DOOR
B28	INB'D. F'W'D. ENGINE ACCESS NO. 1 DOOR
B29	ENGINE STARTING ACCESS DOOR
B30	INB'D. AFT ENGINE ACCESS NO. 1 DOOR
B31	ENGINE ACCESS NO. 2 DOOR
B32	TRANSPORT JOINT FAIRING
B33	TRANSPORT JOINT FAIRING
B34	AILERON JACK ACCESS PANEL
B35	NO. 7 AILERON LINK FAIRING F'W'D.
B36	NO. 7 AILERON LINK FAIRING AFT
B37	NO. 6 AILERON LINK FAIRING F'W'D.
B38	NO. 6 AILERON LINK FAIRING AFT
B39	NO. 5 AILERON LINK FAIRING F'W'D.
B40	NO. 5 AILERON LINK FAIRING AFT
B41	NO. 4 AILERON LINK FAIRING F'W'D.
B42	NO. 4 AILERON LINK FAIRING AFT
B43	NO. 3 AILERON LINK FAIRING AFT
B44	NO. 3 AILERON LINK FAIRING F'W'D.
B45	NO. 2 AILERON LINK FAIRING F'W'D.
B46	NO. 1 AILERON LINK FAIRING F'W'D
B47	ENGINE ACCESS DOOR
B48	PRESSURE VENT DOORS NO. 5 & 6
B49	PRESSURE VENT DOORS NO. 7 & 8
B50	ENGINE REMOVAL DOOR
B51	ENGINE REMOVAL DOOR
B52	NO. 4 SERVICE PANEL



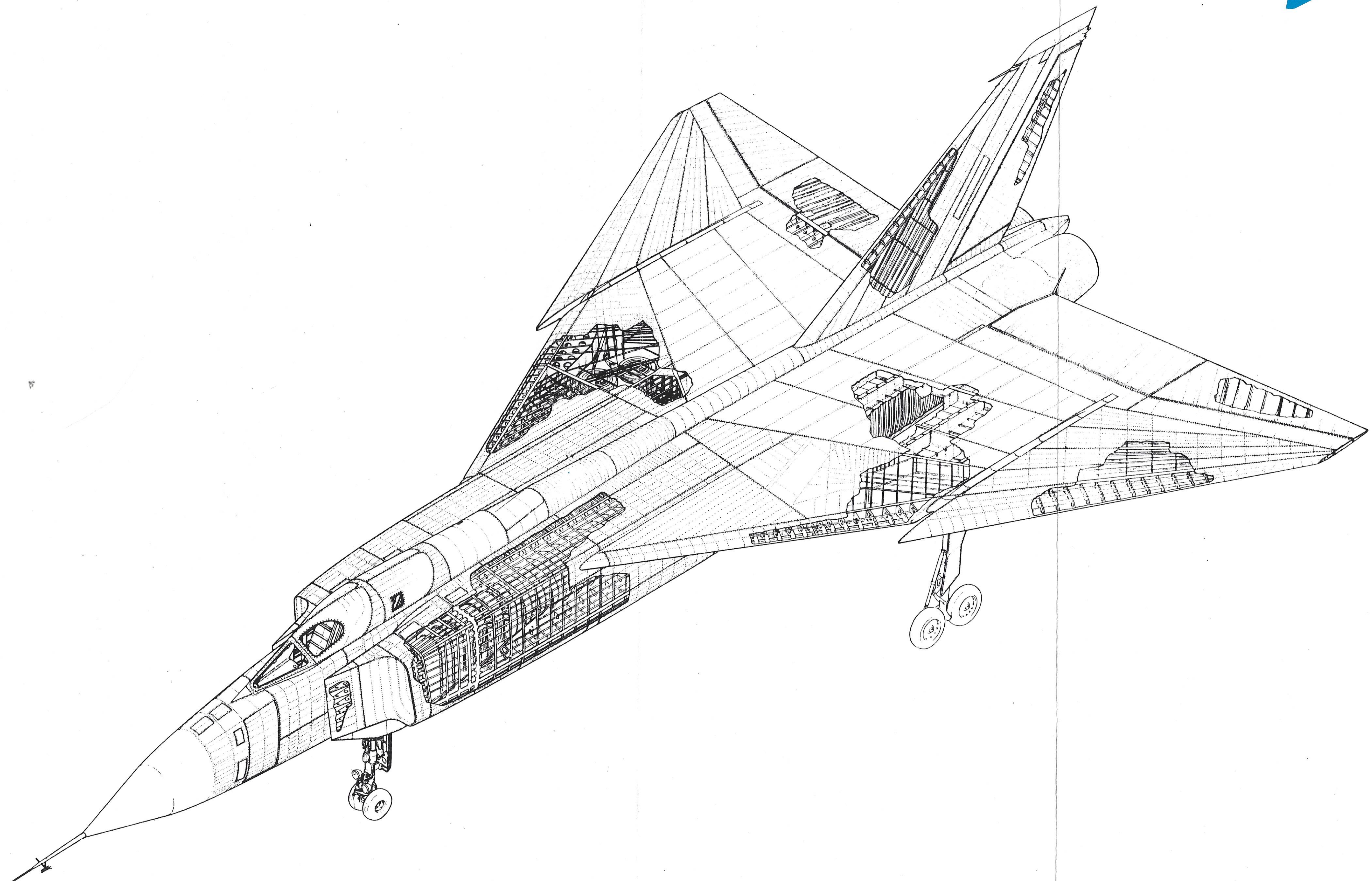
ITEM	DESCRIPTION
B53	NO. 3 SERVICE PANEL
B54	PRESSURE VENT DOORS NO. 7 & 8
B55	PRESSURE VENT DOORS NO. 5 & 6
B56	NO. 1 AILERON LINK ACCESS PANEL
B57	NO. 2 AILERON LINK FAIRING
B58	NO. 3 AILERON LINK FAIRING F'W'D.
B59	NO. 3 AILERON LINK FAIRING AFT
B60	NO. 4 AILERON LINK FAIRING AFT
B61	NO. 4 AILERON LINK FAIRING F'W'D.
B62	NO. 5 AILERON LINK FAIRING AFT
B63	NO. 5 AILERON LINK FAIRING F'W'D.
B64	NO. 6 AILERON LINK FAIRING AFT
B65	NO. 6 AILERON LINK FAIRING F'W'D.
B66	NO. 7 AILERON LINK FAIRING AFT
B67	NO. 7 AILERON LINK FAIRING F'W'D.
B68	ROLL INDICATOR ACCESS PANEL
B69	AILERON JACK ACCESS PANEL
B70	TRANSPORT JOINT FAIRING
B71	FLYING CONTROL COMPENSATOR REMOVAL PANEL
B72	ENGINE ACCESS DOOR
B73	ENGINE ACCESS NO. 2 DOOR
B74	NO. 2 SERVICE PANEL
B75	TRANSPORT JOINT FAIRING
B76	INB'D AFT NO. 1 ENGINE ACCESS DOOR
B77	ENGINE ACCESS NO. 1 DOOR
B78	MAIN U/C JACK ACCESS PANEL

ITEM	DESCRIPTION
B79	TRANSPORT JOINT FAIRING
B80	TRANSPORT JOINT FAIRING
B81	MAIN U/C PIVOT ACCESS PANEL
B82	ENGINE STARTING ACCESS DOOR
B83	AUXILIARY GEAR BOX REMOVAL PANEL
B84	TWO POINT REFUELLING DOOR
B85	INB'D. F'W'D. ENGINE ACCESS NO. 1 DOOR
B86	MAIN U/C DOOR
B87	LIMITER DOOR
B88	ELECTRICAL EQUIP. ACCESS PANEL
B89	COMPASS SENSING UNIT ACCESS PANEL
B90	REMOVAL CUFF
B91	ADF LOOP ACCESS PANEL
B92	UHF ANTENNA ACCESS PANEL
B93	JBR9 ACCESS PANEL
B94	ELECTRONICS ACCESS DOOR
B95	ELECTRONICS DOOR SWITCH-DOOR
B96	ELECTRICS ACCESS PANEL
B97	ELECTRICS ACCESS PANEL
B98	HYDRAULICS ACCESS PANEL
B99	DE-AERATOR ACCESS PANEL
B100	SPEED BRAKE
B101	NO. 1 SERVICE PANEL
B102	FUEL PROPORTIONER ACCESS DOOR
B103	MAIN U/C FAIRING
B104	MAIN U/C PIVOT DOOR

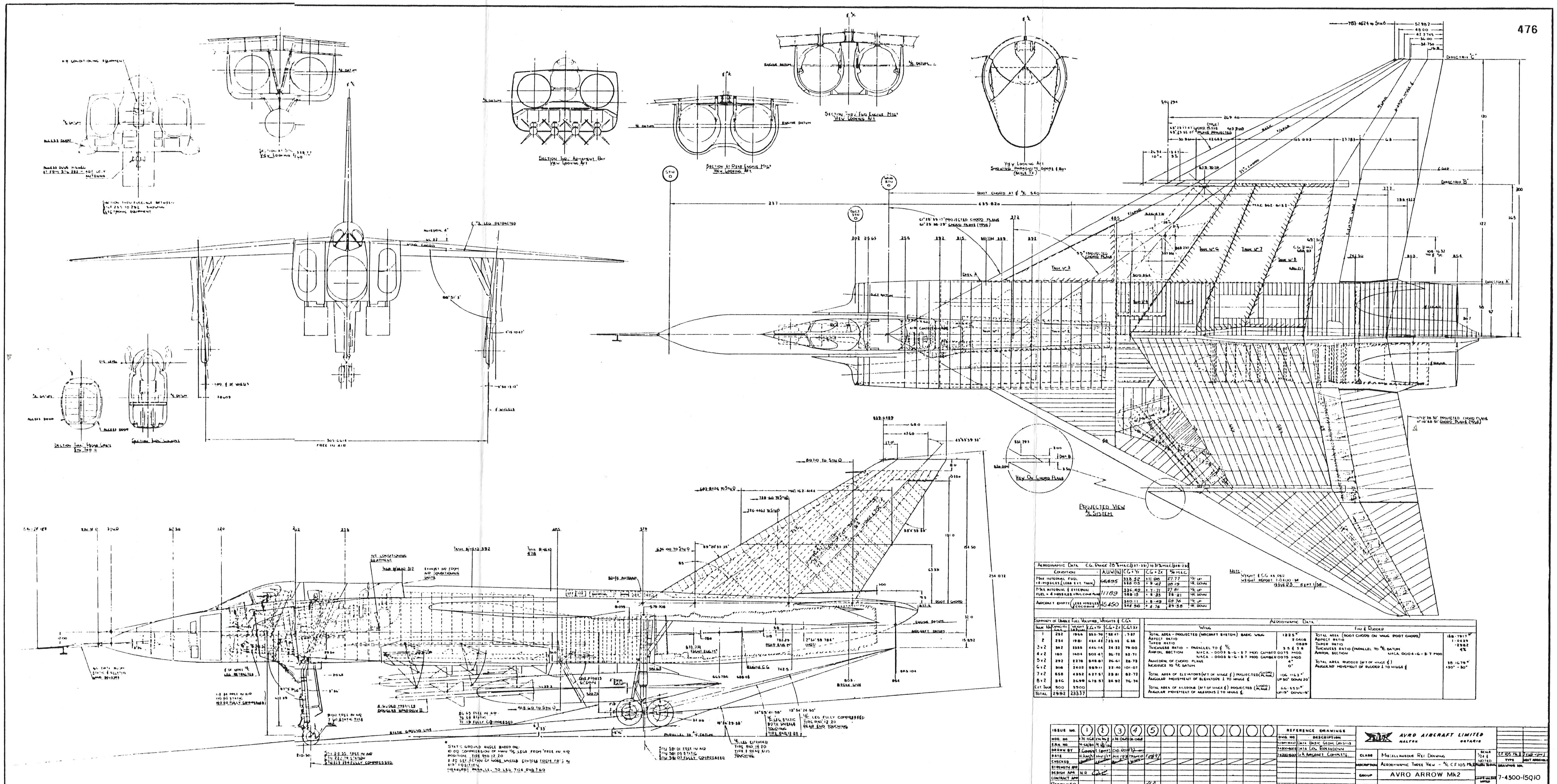
ARROW 2 ACCESS PANELS—BOTTOM SURFACES



ARROW 2 COMPONENT BREAKDOWN



ARROW 2 STRUCTURE CUTAWAY



Aerodynamic Data C.G. Range 28% MAC (537·351) to 31% MAC (540·230)					
Condition	AUW (lb)	CG + YF	CG + ZF	% MAC	
Max internal fuel +4 missiles (less ext. tank)	66695	538·52	+11·86	27·77	U/C up
		538·05	+9·42	28·19	U/C down
Max internal & external fuel + 4 missiles + tail cone plug	71189	536·69	+7·71	27·81	U/C up
		588·15	+8·33	28·21	U/C down
Aircraft empty (less missiles & cocoons)	45450	540·11	+8·49	28·76	U/C up
		542·56	+4·76	29·58	U/C down

Summary of Usable Fuel Volumes, Weights & C.G's					
Tank No.	Capacity Gall.	Weight 7.8 lb/gal	C.G. + YF	C.G. + ZF	C.G. ± XF
1	252	1966	351·70	+22·47	7·87
2	254	1981	434·42	23·08	6·88
3 × 2	302	2355	446·14	24·22	79·00
4 × 2	180	1404	502·41	26·72	82·71
5 × 2	292	2278	548·87	26·61	28·73
6 × 2	308	2402	589·11	22·40	101·07
7 × 2	558	4352	627·51	23·81	82·72
8 × 2	346	2690	675·57	24·92	76·74
Ext. Tank	500	3900			
Total	2992	23337			

Aerodynamic Data

Wing	
Total area - projected (aircraft system) basic wing	1225 $^{\square'}$
Aspect ratio	2·0408
Taper ratio	·0889
Thickness ratio - parallel to ℄ A/C	3·5 & 3·8
Airfoil section	NACA - 0003·5-G-3·7 Mod Camber 0075 Mod; NACA - 0003·6-G-3·7 Mod Camber 0075 Mod
Anhedral of chord plane	4°
Incidence to A/C datum	0°
Total area of elevators (aft of hinge ℄) projected (chord plane)	106·1163 $^{\square'}$
Angular movement of elevators ⊥ to hinge ℄	Up 30° Down 20°
Total area of ailerons (aft of hinge ℄) projected (chord plane)	66·5531 $^{\square'}$
Angular movement of ailerons ⊥ to hinge ℄	Up 19° Down 19°

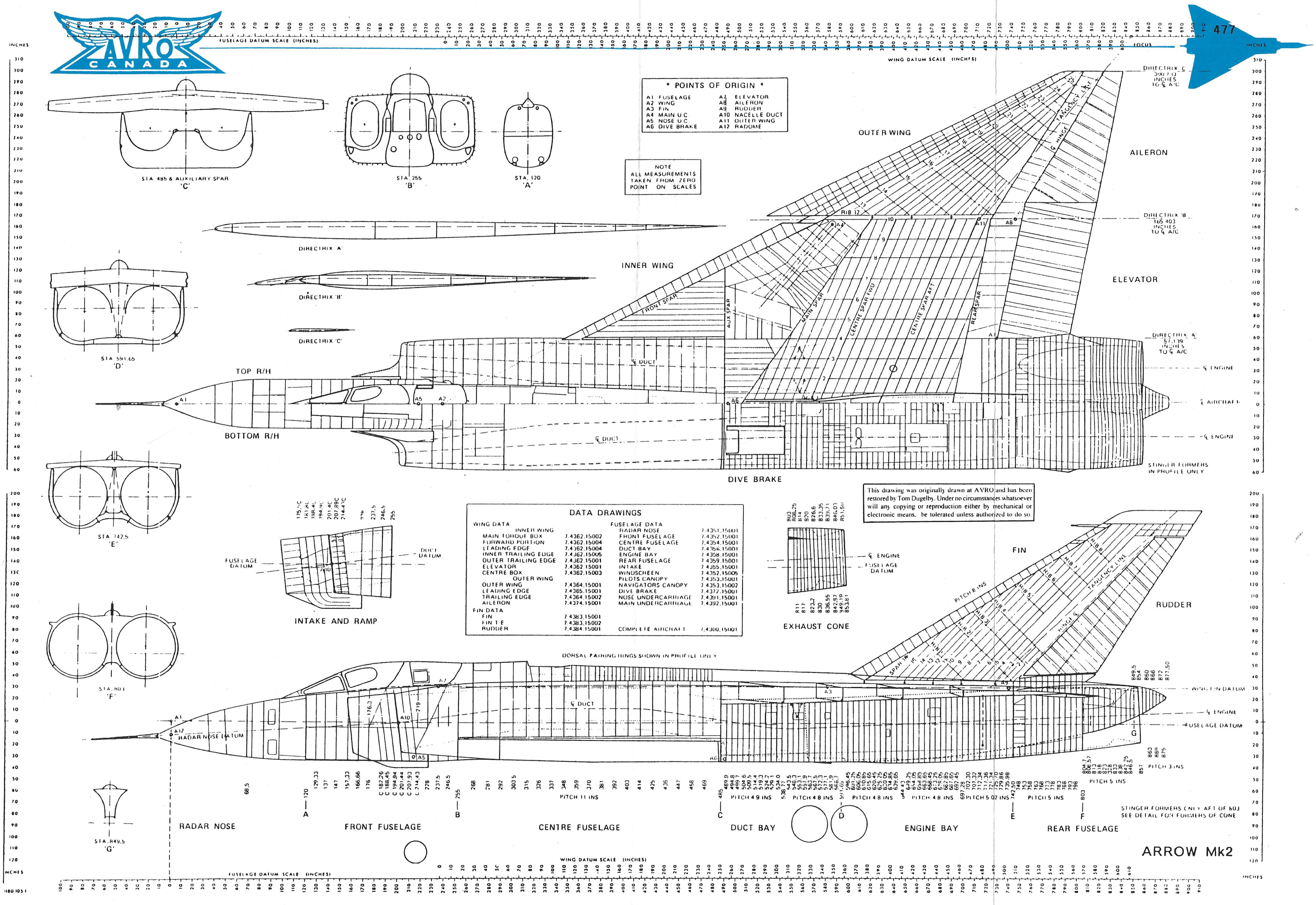
Fin & Rudder	
Total area (root chord on wing root chord)	168·7917 $^{\square'}$
Aspect ratio	1·0439
Taper ratio	·2982
Thickness ratio (parallel to A/C datum)	4%
Airfoil section	NACA 0004-6-3·7 Mod
Total area rudder (aft of hinge ℄)	38·1679 $^{\square'}$
Angular movement of rudder ⊥ to hinge ℄	+30° - 30°

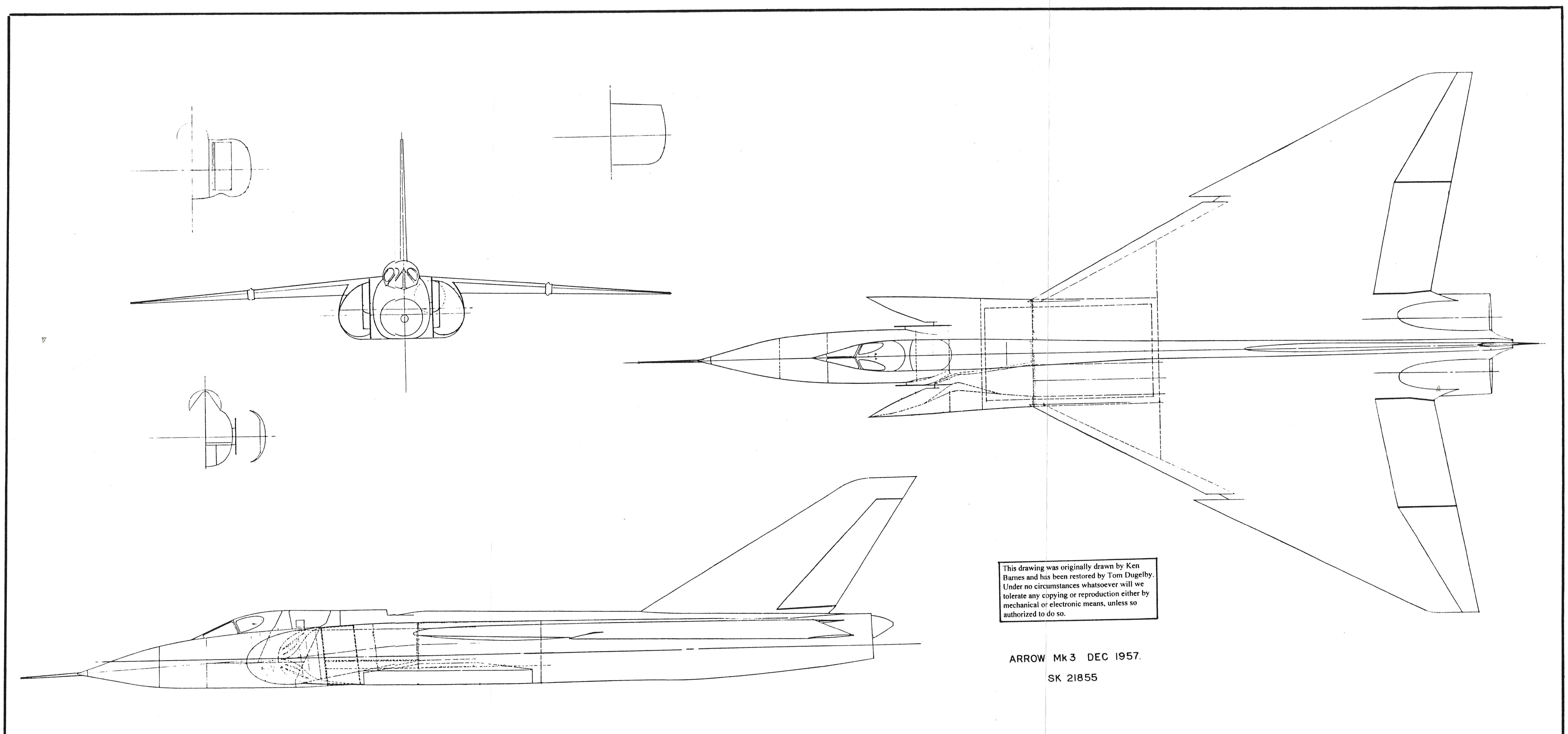
Issue No.	1	2	3	4	5
Mod. No.	74-068	74-[illegible]	74-068	74-068	
E.R.N. No.	74-68/80	74-68/106			
Drawn by	[illegible]	[illegible]	D.G. Roy	[illegible]	
Date	14 June/57	Nov 1/57	Jan 10/58	29 Sept 58	Feb 97
Checked					
Strength App.					
Design App.	N.R.				
Contract App.					
Restored					[illegible]

Reference Drawings	
Dwg. No.	Description
[illegible]	Data Basic Geom. Criteria
74300-6003	Data Col. Breakdown
74200-6000	G.A. Aircraft Complete

AVRO AIRCRAFT LIMITED
Malton Ontario

Class	Miscellaneous Ref. Drawing
Description	Aerodynamic Three View - A/C CF105 Mk II
Group	AVRO ARROW Mk2
Component	
Scale	1/24 & Noted
Type	CF 105 Mk II
Drawing No.	7-4300-15010


AVRO CANADA
477
FUSELAGE DATUM SCALE (INCHES)
WING DATUM SCALE (INCHES)
FOCUS
INCHES
* POINTS OF ORIGIN *
A1 FUSELAGE
A2 WING
A3 FIN
A4 MAIN U C
A5 NOSE U C
A6 DIVE BRAKE
A7 ELEVATOR
A8 AILERON
A9 RUDDER
A10 NACELLE DUCT
A11 OUTER WING
A12 RADOME
NOTE
ALL MEASUREMENTS TAKEN FROM ZERO POINT ON SCALES
STA 485 & AUXILIARY SPAR 'C'
STA 255 'B'
STA 120 'A'
DIRECTRIX 'A'
DIRECTRIX 'B'
DIRECTRIX 'C'
STA 591.65 'D'
STA 742.5 'E'
STA 803 'F'
STA 849.5 'G'
DIRECTRIX 'C' 300.713 INCHES TO ℄ A/C
DIRECTRIX 'B' 165.403 INCHES TO ℄ A/C
DIRECTRIX 'A' 57.139 INCHES TO ℄ A/C
OUTER WING
AILERON
INNER WING
ELEVATOR
TANGENCY LINE
HINGE ℄
RIB 12
FRONT SPAR
AUX SPAR
MAIN SPAR
CENTRE SPAR FWD
CENTRE SPAR AFT
REAR SPAR
TOP R/H
BOTTOM R/H
℄ DUCT
℄ ENGINE
℄ AIRCRAFT
DIVE BRAKE
STINGER FORMERS IN PROFILE ONLY
This drawing was originally drawn at AVRO and has been restored by Tom Dugelby. Under no circumstances whatsoever will any copying or reproduction either by mechanical or electronic means. be tolerated unless authorized to do so.
DATA DRAWINGS
WING DATA
INNER WING
MAIN TORQUE BOX 7.4362.15002
FORWARD PORTION 7.4362.15004
LEADING EDGE 7.4362.15004
INNER TRAILING EDGE 7.4362.15005
OUTER TRAILING EDGE 7.4362.15001
ELEVATOR 7.4362.15001
CENTRE BOX 7.4362.15003
OUTER WING
OUTER WING 7.4364.15001
LEADING EDGE 7.4365.15001
TRAILING EDGE 7.4364.15002
AILERON 7.4374.15001
FIN DATA
FIN 7.4383.15001
FIN T E 7.4383.15002
RUDDER 7.4384.15001
FUSELAGE DATA
RADAR NOSE 7.4351.15001
FRONT FUSELAGE 7.4352.15001
CENTRE FUSELAGE 7.4354.15001
DUCT BAY 7.4356.15001
ENGINE BAY 7.4358.15001
REAR FUSELAGE 7.4359.15001
INTAKE 7.4355.15001
WINDSCREEN 7.4352.15005
PILOTS CANOPY 7.4353.15001
NAVIGATORS CANOPY 7.4353.15002
DIVE BRAKE 7.4372.15001
NOSE UNDERCARRIAGE 7.4391.15001
MAIN UNDERCARRIAGE 7.4392.15001
COMPLETE AIRCRAFT 7.4300.15001
FUSELAGE DATUM
DUCT DATUM
INTAKE AND RAMP
EXHAUST CONE
FIN
RUDDER
PITCH 8 INS
DORSAL FAIRING RINGS SHOWN IN PROFILE ONLY
WING FIN DATUM
RADAR NOSE DATUM
PITCH 11 INS
PITCH 4.9 INS
PITCH 4.8 INS
PITCH 5.02 INS
PITCH 5 INS
PITCH 3 INS
STINGER FORMERS ONLY AFT OF 803
SEE DETAIL FOR FORMERS OF CONE
RADAR NOSE
FRONT FUSELAGE
CENTRE FUSELAGE
DUCT BAY
ENGINE BAY
REAR FUSELAGE
ARROW Mk2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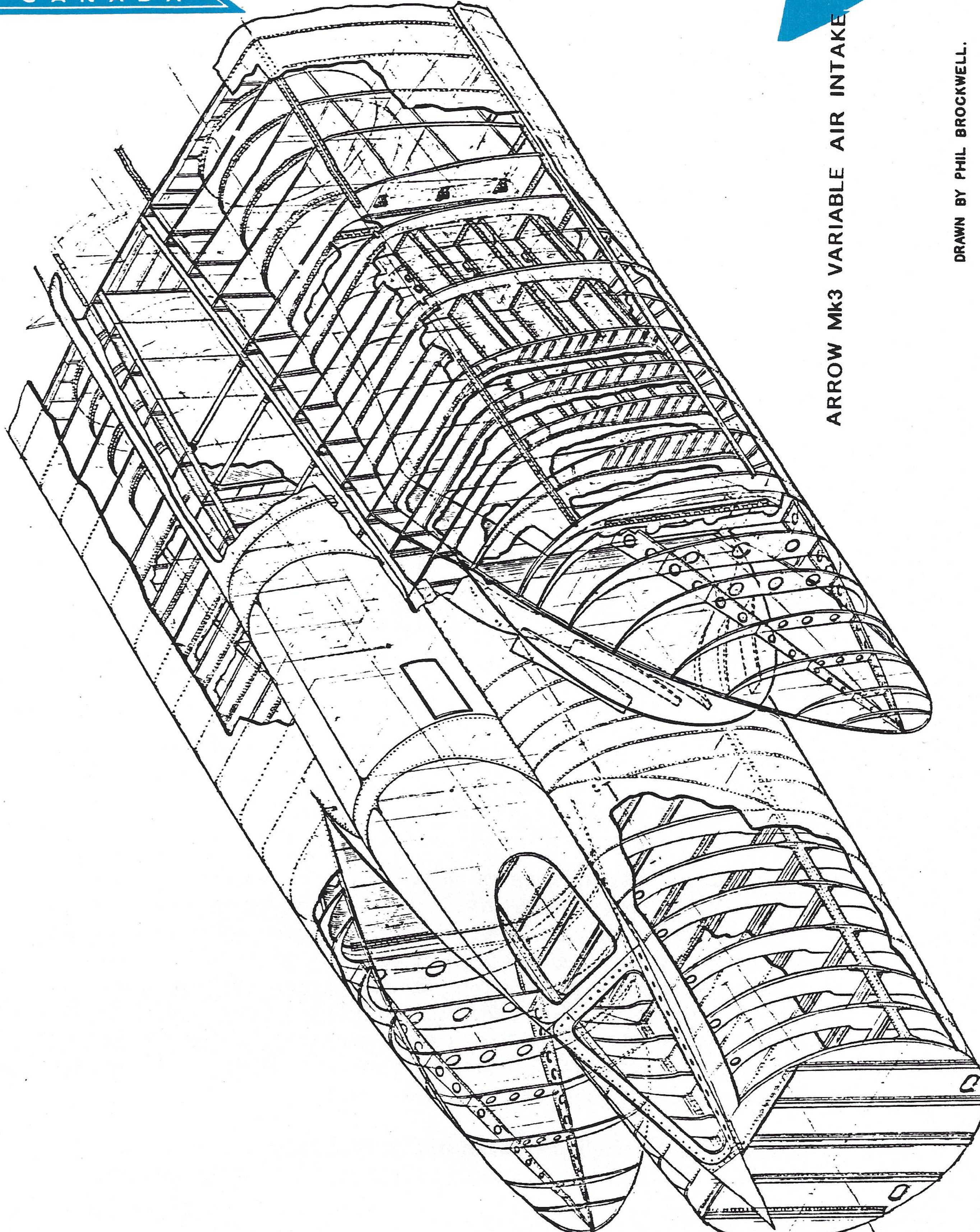
ARROW Mk 3 DEC 1957.
SK 21855



ARROW Mk3 VARIABLE AIR INTAKE

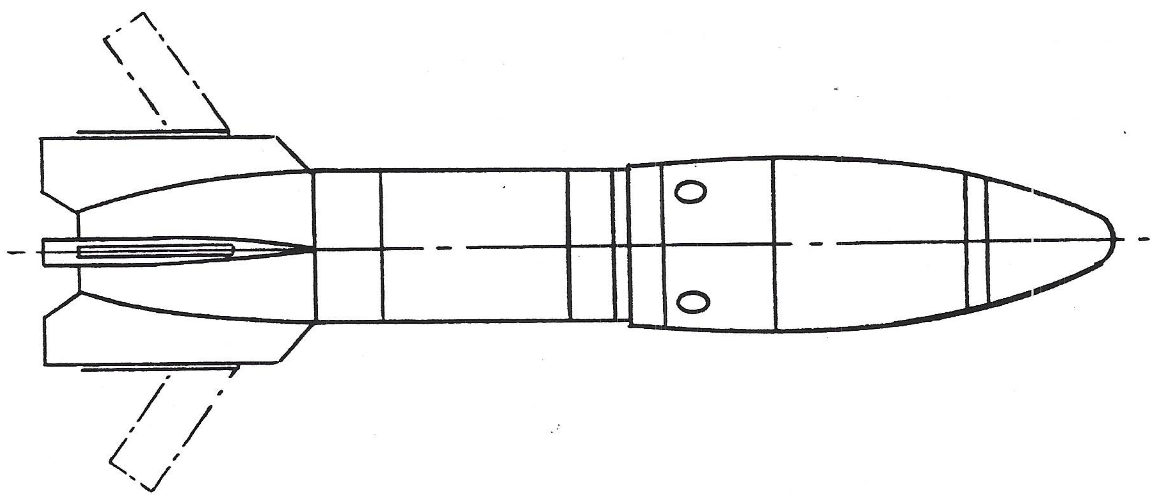
DRAWN BY PHIL BROCKWELL.

THE MB-1 (AIR-2) GENIE MISSILE.

This was an air-to-air unguided missile carrying a nuclear warhead and was developed by the McDonnell-Douglas Corp. Its statistics are as follows:

Description

Length......................9 ft. 0 inches.
Diameter..................17 inches.
Weight......................814 lbs.
Speed........................Mach 3.
Range........................6 miles.
Propulsion.................Aerojet solid rocket.



The launching of the Genie was automatic under the control of the Hughes MA-1 fire control system, which also detonated the warhead when the aircraft was at a safe distance away from the blast. Development began in 1954 and the first successful tests were carried out from an F-86D aircraft in 1956 and the YF-102 later in the same year. A further version of the Genie, the AIR-2B, termed the Super Genie, was under development and according to reports, was to have been a guided version, but work was suspended. The Genie became operational with the USAF in 1957 and was carried by the F-89J with the E-9 fire control system, the F-101 and F-106 aircraft. Some thousands were made until production ceased in 1962.

The fitting of the MB-1 Genie missile to the Avro Arrow, was conceived on Sept.4/57 by the 7th Ad Hoc Committee and on Jan.20/58, the RCAF instructed Avro to begin design for the installation of two Genie missiles in an alternate armament pack.

Avro did so and provided the RCAF with two reports. 1. "The Installation of Two Genie Missiles In the ARROW Aircraft" - Report No. 72/SYSTEMS 26/165 and 2. "Program Proposal for Genie Rocket Installation in ARROW Aircraft" - Report No. 72/ENG. PLAN/20. In early Sept./58, the RCAF informed Avro that the thirty eigth and subsequent aircraft must have complete provisions to carry either Sparrow 2 or Genie weapons packs. The proposed installation would have provided for the carriage of two Genie, long range rockets, capable of being fired in separate attacks. The installation would have allowed additional internal fuel to be carried within the weapons pack structure. It was proposed that the re-arming with Genie rockets would be accomplished without lowering the weapon pack from the aircraft. Needless to say, additional ground support equipment etc. would have been required. There were some Senior Officers in the RCAF at the time who attempted to restore some degree of sanity to the Arrow armament program when A/V/M Hendrick wrote to A/V/M Smith on July 29 1958 by stating that:-

> "You will recall when we analyzed Genie versus Sparrow in the CF-100, we came to the conclusion that both were of the same kill probability, and that the Sparrow was probably to be preferred because it had no side effects on aircrew, no escape problem and was far better against countermeasures.
>
> We are now being stampeded into considering Genie as the weapon merely because it makes a big atomic bang. I suggest that it still has the same inadequacies as it did when we considered it for the CF-100, and that an analysis of the kill probabilities of the Sparrow versus the Genie on the Arrow may well show that the Sparrow is to be preferred again. Therefore, I urge that we be practical in our decision to use Sparrow or Genie, and base it on our estimate of the kill probability of the Weapon System. If the kill probability of Genie is adequate, then we should make a decision to have one weapon only on the Arrow as an interim weapon until a suitable atomic headed airborne weapon is available. That the interim weapon should be either Genie or Sparrow 2, and the decision as to which it should be should be made now."

It had been shown by this time that the Genie showed a kill rate of only 11% over that of the Sparrow 2 in ideal conditions. Also, the USAF had no interest in updating the Genie and were developing an atomic warhead for the Falcon GAR 1Y (AIM 26) which could have been more readily fitted to the existing designs of the armament pack. In the RCAF report S1038CN-183-5, it appears that Avro had only general information pertaining to the Genie as at the time, all nuclear information was classified and in control of the USAF Nuclear Weapons Systems Safety Group. Negotiations were still in progress at the time of cancellation. The method of release had been investigated by the USAF and a rail type was preferred over the gravity or compressed air release. It is of interest to read in the CARDE reports 183/58, "The CF-105 Assessment Study" of March 1958 and 317/59, "A Limited Technical Evaluation Of The Avro Arrow Interceptor System" of January 1961, the MB-1 Genie was judged to be no better than the Sparrow, and its usefulness doubtful.

6. Self-contained navigation quite a problem according to Stephens and Hurley in USAF experience - a major obstacle to successful development of weapon system.

The above indicated that the Arrow would require complete re-engineering to fulfill mission, and it was unlikely that Foreign Aircraft would be acceptable in the UK.

The Avro Arrow however, was designed for high altitude interception and not for low altitude high speed work.

ZERO LENGTH LAUNCH ARROW.

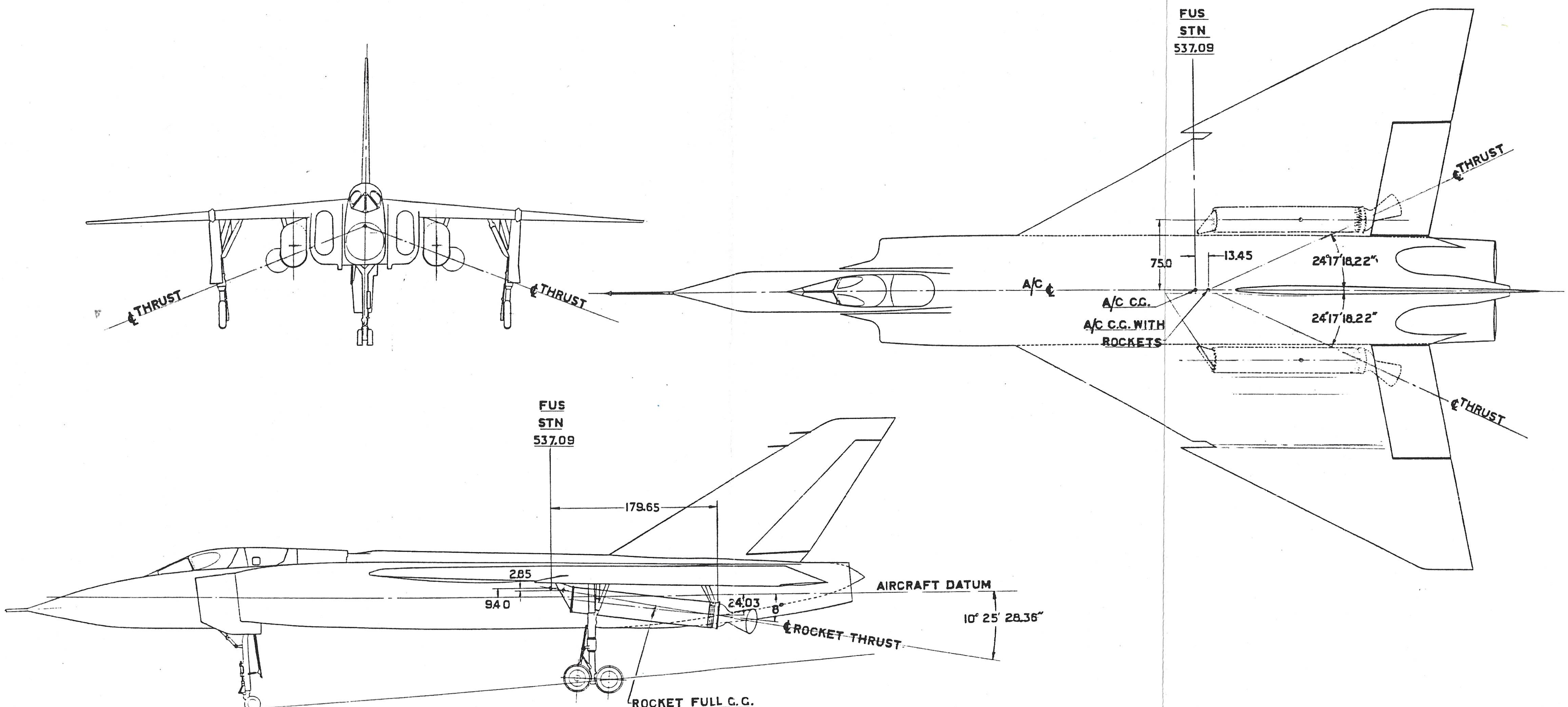
In 1958, Avro was requested by the RCAF to investigate the feasibility of a method of launching the Arrow to flying speed without the use of any ground run. It was assumed that the Zero Launch operation would be required to be located at any point in the country and would be set up on a 24 hour "at the ready" basis. This request appeared to be a solution to the location of Arrows in areas where runways of a compatible nature for the Arrow were unavailable, or at the least, only at great cost.

The concept of Zero Length launch was and is not a new one. In 1939, in Peenemunde, Dr Wernher von Braun wrote a paper study on such a weapon system. During World War 2, the Technical Director of Fieseler, Dipl-Ing Erich Bachem became interested and designed a system around this paper, the result being the Bachem Ba349 Natter (Viper). In April 1944, the RLM showed interest in the project, and Erich Bachem set up his own company of Bachem-Werke GmbH in Waldsee in the Black Forest. The Viper was designed out of shear necessity due to the mounting air attacks by the Allied Air Forces. It was designed as a manned interceptor that would be stationed along the flight paths of the Allied bomber streams, and as they passed overhead, it would be blasted off the ground from a vertical tower by rockets, thereafter climbing with an internal rocket engine. Upon reaching the same altitude as the bombers, the pilot would fire a salvo of 24 Hs 217 Fohn 73 mm missiles at the target, after which he would dive down, release himself from the aircraft, and parachute to safety.

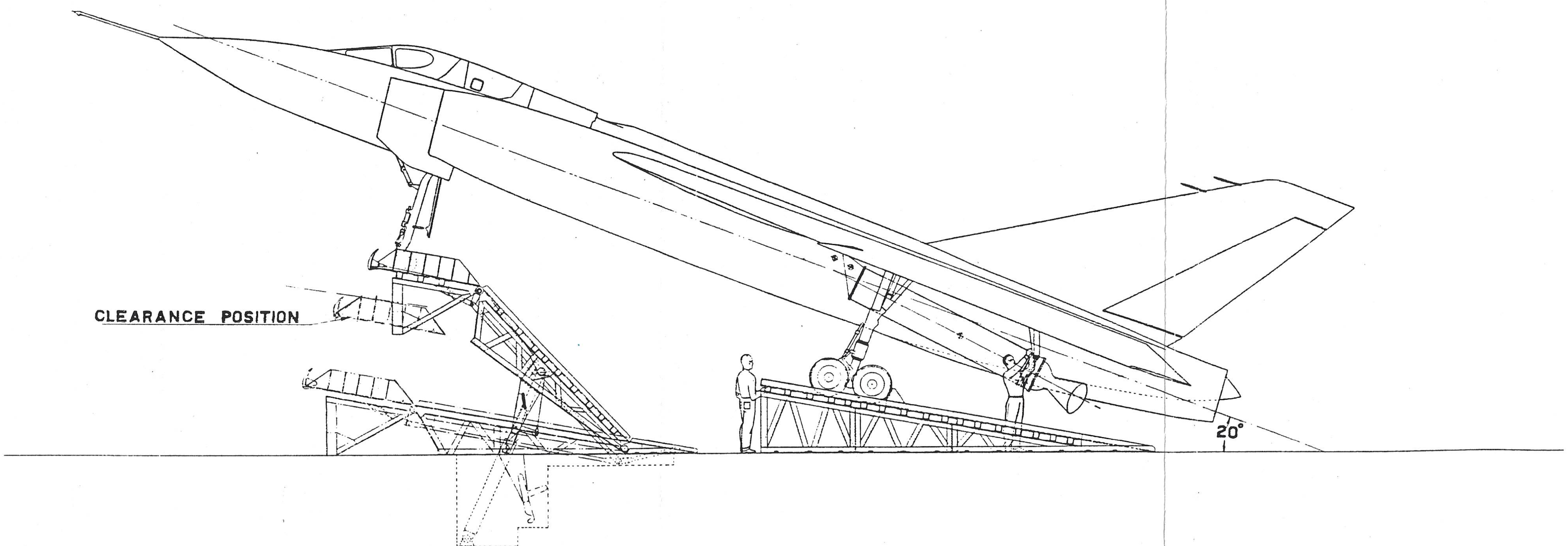
This concept worked very well on paper, but the only recorded case of the missile being fired with a live pilot on board, Oberleutnant Lothar Siebert, resulted in the breaking of his neck. Fortunately, both for the bombers and the Luftwaffe personnel, the test facility was overrun by Allied troops before it could become operational.

As far as is known, the only other considerations to this method of launch, for a manned aircraft, appear to have been with:-

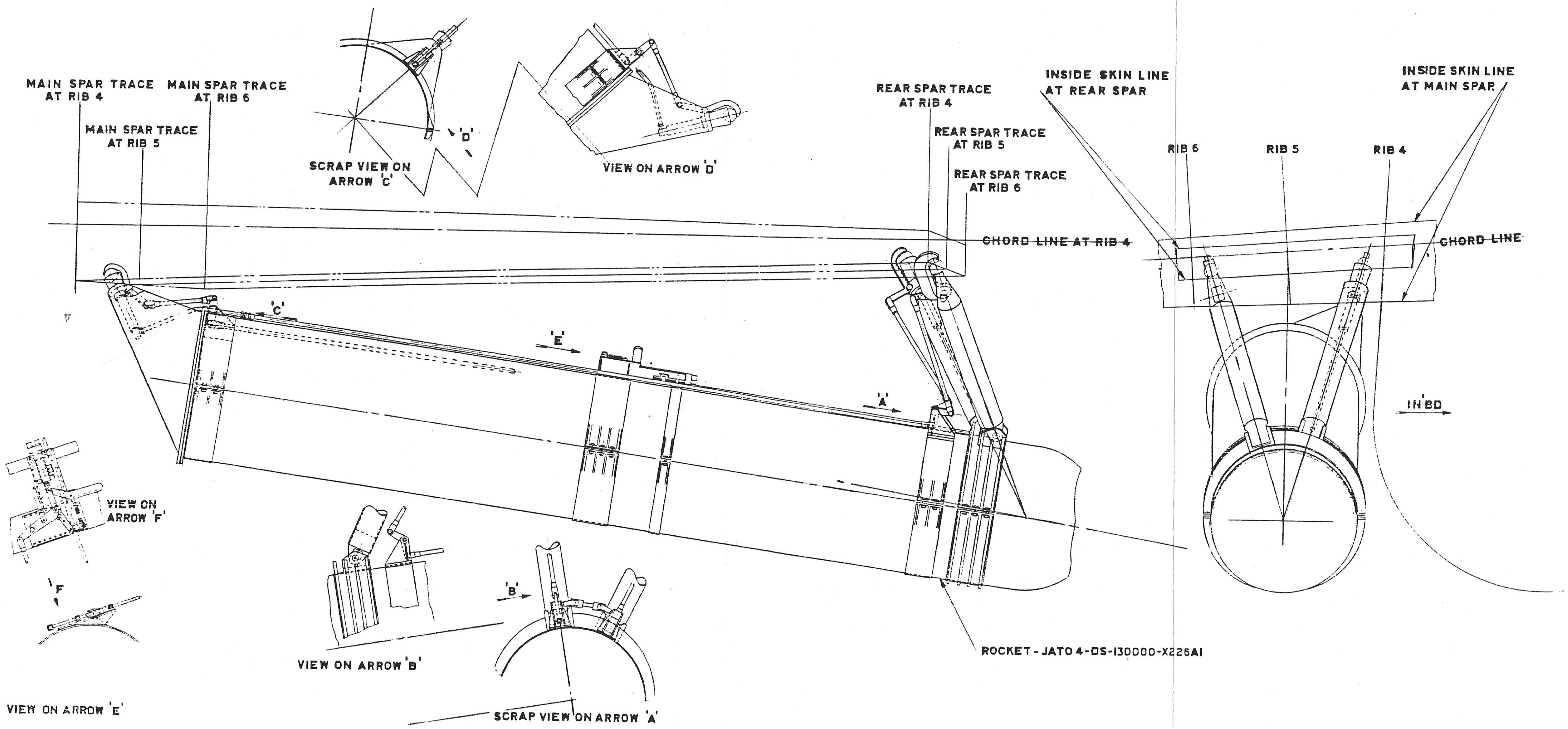
1. The British Government in 1951 requested the Fairey Aviation Company to design and build such an aircraft - the FD 1. The aircraft was built and flown, but the



ROCKET GEOMETRY ZERO LENGTH LAUNCH



ARROW ZERO LENGTH LAUNCHING POSITION



ARROW ZERO LAUNCH BOOSTER ARRANGEMENT

vertical or zero launch capability was dropped - again fortunately.

2. The Republic F - 84 THUNDERJET in 1953 was zero length launched with rocket assist from a mobile platform at Edwards Airforce Base in California.

3. The Convair XFY - 1 "POGO", in 1954. Albeit, this was a vertical take-off and landing aircraft under its own power.

4. The Lockheed XFV - 1 of Nov 1954 was launched from a mobile platform. Again, this was a vertical take-off and landing aircraft under its own power.

5. The Ryan X-13 VERTIJET of Nov 28 1956. This was launched from a hooked position from a tower.

6. The launching of an F-100D airplane by a single booster of similar size to that contemplated for the Arrow. The pilot is quoted in "Making Like a Missile" by A.W. Blackburn from Flying Safety, Sept 1958 - USAF, as saying, "For the normal launch, from the very first shot, it was evident that ZEL acceleration forces do not have the surprise effect that identical forces experienced on the steam catapult have. With ZEL I felt that I was flying the airplane off the launcher with no apparent time for recovery from the initial jolt."

7. In the mid-1950 period, the then USSR conducted zero length take offs with the MIG 19 from a converted wheeled vehicle.

The method proposed by Avro consisted of the mounting of two JATO Type 121 Rocket Units under the wings, the take-off being accomplished from a ramp supporting the aircraft by means of its undercarriage.

The general configuration of the aircraft, method of mounting the booster units, arrangement of the ramps and method of ejecting the boosters, are shown on the referenced drawings. A preliminary study was made of the dynamic characteristics of the launch by the Aerodynamics Department in Report No. 72/STAB/45, dated Sept. 1958. This study included the effects of misalignment of thrust, variation of CG position and effects of temperature. The report indicated the importance of the CG position tolerance, and booster thrust axis alignment. Examination of the loads and stresses indicated that some modifications would be required in the vicinity of the booster attachment points to the wing, but these did not appear to be of a serious nature.

Today, the vertical method of launch is used by NASA in launching the Space Shuttles.

THE ARROW AS A TAC BOMBER.

In October, 1957, there was a feeling at Avro that not only was the Arrow capable of much more, but there was a possibility that other Countries might be interested in it in one of these several other roles. To this end, W.R. Stephens, the Avro sales Manager contacted Mr J.C.Floyd with the following suggestion:-

"As you probably know, the USAF does not have in being the development of a new tactical bomber, although the Douglas B-65 and the Martin B-57 are phasing out. Since cancellation of the Martin B-68 program early this year (1957), several Companies have tried to interest the USAF in the TAC bomber versions of existing aircraft, but TAC is very low on the totem pole as far as priority and funding are concerned. In that respect, they are not a very good prospective customer. However, there has been some rumor that TAC may be absorbed by SAC, which has No. 1 priority. It is also my belief that the most likely actual need for a combat weapon is in the TAC area.

The following presents the latest stated USAF requirements for a TAC bomber. It is suggested that your people take a look at a version of the Arrow to satisfy them in anticipation of renewed interest by the USAF, or other user, in this mission area."

The TAC bomber must:-

a. Be capable of disbursed base operation.

b. Have all-weather capabilities.

c. Be capable of level bombing and toss bombing. It is essential that a terrain clearance system be incorporated and it is understood that North American are in the final stages of developing such a system.

d. Have automatic bombing and navigation capabilities. It is understood that two new systems of navigation are being developed, namely:-

1. "Tangent Plane Navigation" - this system becomes inaccurate beyond 1500 miles.

2. "Local Vertical Navigation" - this system is independent of range, but is time limited.

e. Operate from 5,000 ft. runways having a Unit Construction Index of 85 or less.

f. Carry a military load of 3,500 lbs. It is understood that this item is not too critical and if necessary this figure may be relaxed considerably.

g. Possess good maintenance features; 30 minute turn around time etc.

MISSION PROFILES.
(Fuel reserves to be in accordance with MIL Spec definition.)

MISSION A. - Take off and proceed at M = 0.9 on a "terrain clearance" course to the target area 600 nautical miles from base.

- Return toward base at M = 0.9 for a distance of 200 nautical miles under "terrain clearance" conditions.

- At the Mean Line of Resistance (400 nautical miles from base) climb to economical cruise altitude and return to base at economic cruising speed.

MISSION B. - Take off and climb to 40,000 ft.

- Accelerate to M = 0.9 and cruise to target area 1,000 nautical miles from base.

- Return to base at 40,000 ft. at M = 0.9 to point of descent.

MISSION C. - Take off and climb to 40,000 ft. at M = 0.9.

- Climb to 60,000 ft. and accelerate to M = 2.0 to MLR.

- Proceed target area 600 miles from base at M = 2.0.

- Return to base at economical speed and altitude course."

Needless to say, history has shown that nothing became of this proposal.

THE ROLE OF THE AVRO ARROW.

DEW Line Support for the Arrow - Introduction.

By October, 1958, it had become very apparent that the Canadian Government was beginning to dis-engage itself from the Canadian Aircraft Industry which it had done so much in the past to help develop, and was beginning to fall under the spell of the power originating from Washington. The "Bomarc" was making its appearance, and for reasons that were only known to himself, the Canadian Prime Minister was allowing himself to fall "in love with it", and out of love with the Arrow.

The following dissertation, dated October 30, 1958, is by Mr W Kusyk, a former Senior Research Engineer at Avro.

> "It has become very apparent that the stand-off bomb threat, and the supersonic bomber threat necessitates that the interception point of battle be moved northward away from our populated areas. It is also evident that in the light of the aforementioned 1963 threat, the Pine Tree Line, whether equipped with support Arrows and/or Bomarc is merely a defence for American industry and population, and this in effect affords virtually no protection for Canadian population and industry of the Southern Ontario region. The defence system as it now stands and proposed in the light of Bomarc and/or Arrow, virtually turns Canada into a no man's land and a destructive field of battle polluted with possible nuclear radiation fallout. This is an untenable situation for Canada to be in in time of war, and to be left without direct means of retaliation and/or defence. For the attacker will try to immobilize our defence centres, most of which would be located in or near populated areas of Ontario. The combat zone must be pushed further north, and this should be done within the bounds of our economy."

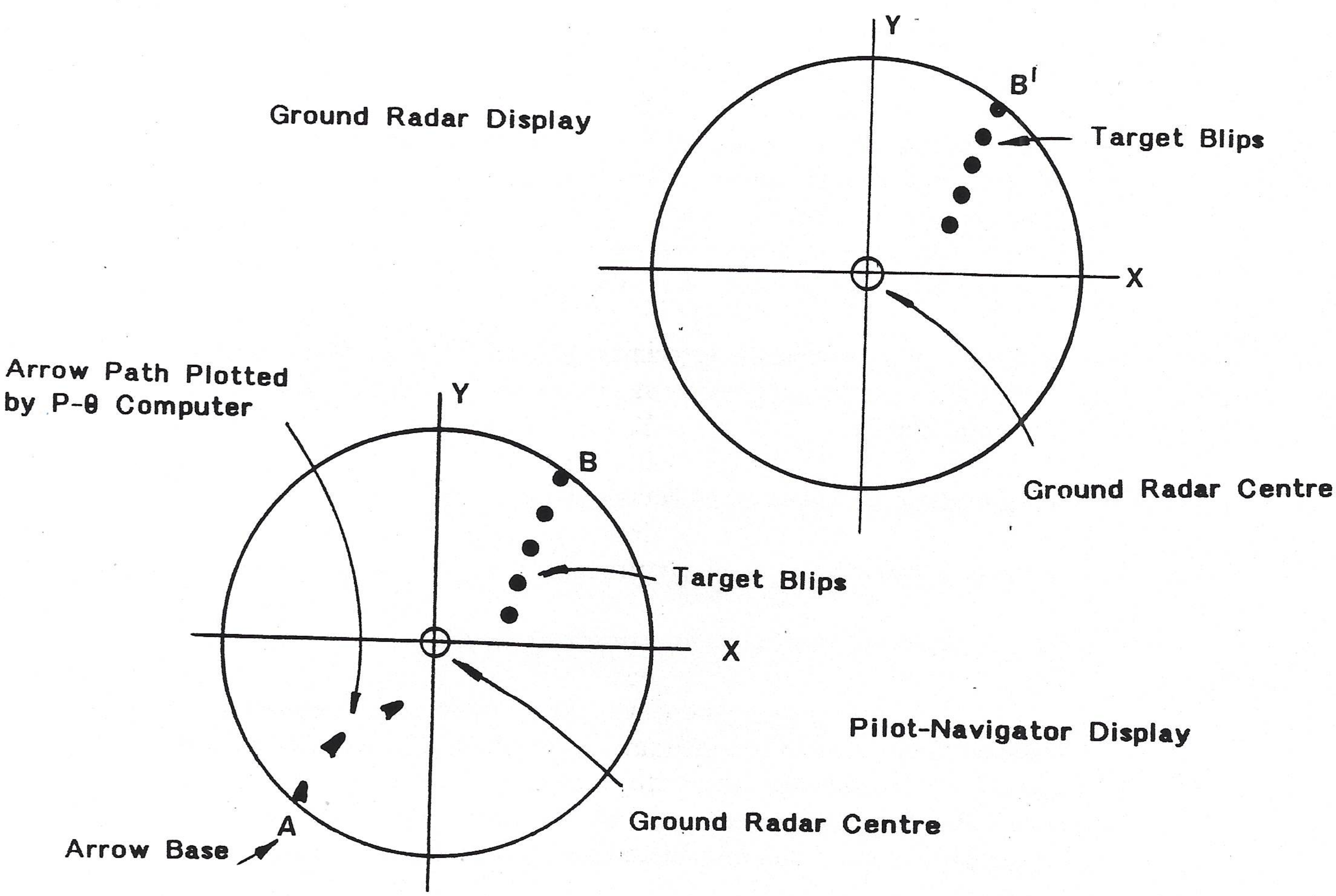
The Americans had already told us that if we did not buy the Bomarc, that they would put their Bomarc bases right on the border, thus in effect making Canada a nuclear wasteland if they were to be used.

Mr Kusyk went on to say:-

> "There exists at the DEW Line six main ground radar stations and about four substations in between the main ones. Barrow Point and Barter Island are on American soil and hence are supported by American jet fighters, whereas Cape Perry, Cambridge Bay, Foxe Basin and Cape Dyer are on Canadian soil. These ground radar posts, totaling about 25 in all, are basically surveillance posts, but are also equipped to transmit intelligence concerning the location of enemy invaders, spotted by ground radar, via a radio communication link to a support aircraft located within a radius of 500 miles.
>
> It is therefore proposed to locate Arrow squadrons at each of the Canadian DEW Line bases for the purpose of intercepting a subsonic threat, and other strategically located squadrons further south, say 200 - 500 miles, for the purpose of intercepting a supersonic threat. These threats of course will have been alerted by the DEW Line radar and possibly some of the northern weather stations, and in the future, the Frost Line.

OPERATION OF THE ARROW.

The prepared method of utilizing the Arrow with DEW Line support employs the full capacities of the pilot and navigator, the existence of a DEW Line to Arrow radio communications link, and a P-0 computer. In addition, the navigator will be equipped with a screen which is identical with that viewed by the operators at ground level support stations. The trajectory of the target will be transmitted by the ground radar operator as x, y and z as such on the navigator's screen. The path of the interceptor carrying the pilot and navigator is also traced on the same screen by a P-0 computer. This picture is then displayed to the pilot, who steers the airplane to within lock-on range of the target. The pilot-navigator display and ground radar display are shown.



This somewhat primitive example shows that the support Arrow is at point A, about 200 miles south of the ground radar post, and this position permits the Arrow to intercept and harass if necessary, a supersonic target. The sequence of events would be as follows:-

1. Enemy aircraft detected at B1 by ground radar post.

2. The ground radar station alerts its support aircraft to scramble.

3. The navigator receives by radio communication the co-ordinates of the enemy aircraft which he plots at B.

4. The P-0 computer plots the intercept path at A.

5. The navigator display is transmitted to the pilot who steers on a course for interception.

6. The final kill may then be directed by the pilot in the event that enemy ECM prevents the establishment of the lock-follow mode.

The ground radar support aircraft can be located wherever it is possible to facilitate a take-off, and within the 500 mile radio communication limit. A subsequent requirement would of course be the availability of a landing strip for the Arrow on completion of the mission. This then calls for some drastic changes to the Avro Arrow, viz:-

a. Re-design the undercarriage system so that the Arrow can operate off runways having a unit construction index of 35 - 40 instead of 100 as is now required.

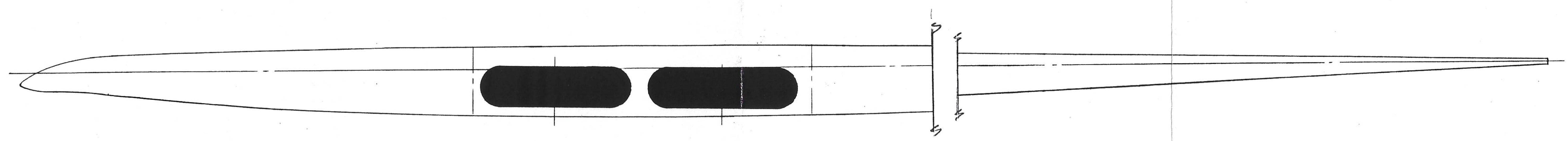
b. Equipping the Arrow for JATO assisted take-off.

c. Modify the Arrow to facilitate zero launching.

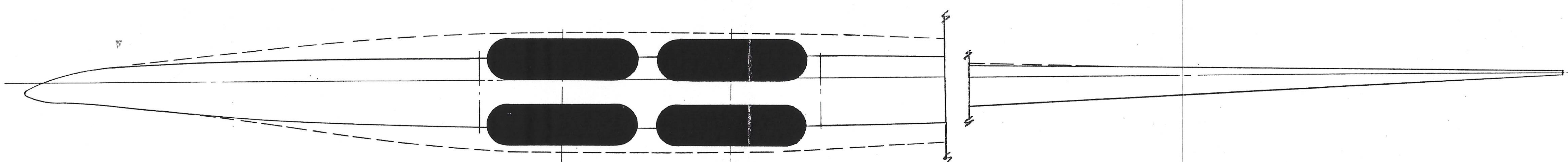
d. Incorporate arrester hooks for carrier type landings.

The most desirable arrangement would be to operate the Arrow as a self contained unit from a suitable airfield, in which case it would be very desirable to look into the possibility of lowering the runway unit construction index from 100 to about 35 - 40. The Arrow would then be able to operate off existing and projected runways and utilize the existing ground support equipment.

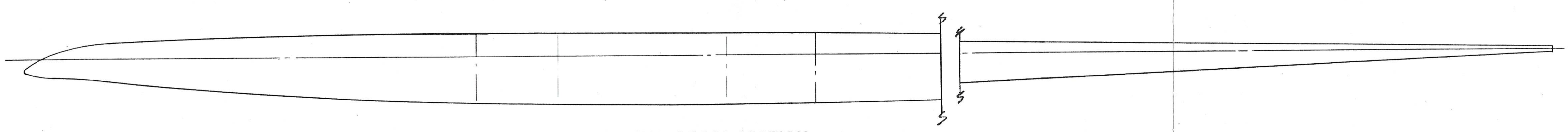
An alternative procedure would be to fly the Arrow to the DEW Line,



STANDARD UNDERCARRAIGE RETRACTED



MODIFIED UNDERCARRAIGE RETRACTED



STANDARD WING CROSS SECTION

SUGGESTED MODIFICATIONS TO ARROW UNDERCARRAIGE AND WING FOR NON-STANDARD RUNWAYS undercarriage down and with oversize tires, land and orient on zero launch pads. The Arrow could then be zero launched for interception in its normal configuration, that is, with regular tires fitted, complete the interception and head for a runway capable of facilitating a normal landing, (unit construction index of 100). This latter method is involved and would require considerable ground support. This mode of operation becomes more functional with a long range Arrow, say the Arrow 4 version which is capable of operating at 80,000 ft. altitude and at speeds up to Mach 2.7.

In the best interest of our defensive system, it is recommended that every effort be made to re-equip the Arrow with larger wheels to permit operation off existing DEW Line and other similar air bases.

It is appropriate to mention that Arrows operating from the immediate vicinity of the ground radar posts will be capable of intercepting and harassing a subsonic threat such as the "Bison". However, in the event of a supersonic threat, the Arrows must operate with DEW Line support from bases say 200 - 500 miles south of the ground radar posts in order to execute interception. Alternatively the Arrows can operate from DEW Line bases and claim support from ground radar bases located at the Frost Line."

DEW LINE SUPPORT FOR THE ARROW.

The DEW Line consisted of ground radar stations about 100 miles apart. Each radar station was serviced by runways capable of accepting a fully loaded Globemaster. Base runways were from about 200 ft. wide by 5,200 ft. long and up. It was been reported that runway extension programs were under way to increase the lengths to the 10,000 ft. mark. The runways were a vital link to the DEW Line, consequently they were kept open on a 24 hour basis throughout the year. Most of the ground radar posts were equipped with a heated hanger, capable of accommodating two Arrows. Each ground radar post was well equipped with radio communication, HF a la CW and AM, VHF - AM and UHF - AM with receiving abilities of SSB. This radio communication gave a reliable radio link of at least a 500 mile range to supporting aircraft.

The ground radar posts fulfilled basically a surveillance function, for example, there were facilities to track both the target and interceptor with respect to location and velocity, and in effect, interceptor instructions could be radioed to the interceptor. A communication system similar to teletype interconnected all the ground radar posts within themselves and Denver, and on a priority basis to any telephone outlet in North America. It is noteworthy that the interception range and altitude of the ground radar was extremely accurate. The altitude of low speed aircraft up to 200 miles away could be determined within a few hundred feet. The DEW Line was also assisted by the various weather stations scattered throughout the Arctic region, for example, it could have been very easy for 300 "Bison" invaders to be detected long before the DEW Line picked them up along a route say southward through the Hudson Bay to Toronto.

The DEW Line was supported by a year round airlift which was designed to operate on a runway construction unit index of at least 30. In addition, a sea lift was used to supply fuel oil to the DEW Line radar stations which were almost all located on coastal sights. It is noteworthy that there existed between the ground radar posts alternate landing strips. This brought landing strips to every 50 miles along the DEW Line.

The Frost Line was also being built north of the eastern sector of the DEW Line. This additional detection was made necessary by the mountainous terrain, so that any further "Mass invasion" of 300 or more "Bisons" may be detected in time. There existed air bases in Thule and other northern points on Baffin Island and Greenland and these air bases appeared to be made capable of supporting the Avro Arrow. The basic requirement was the extension of the 5,000 ft. runways to between 8,000 - 10,000 ft. This program, as mentioned previously, was underway. This brief review of the DEW Line would indicate therefore that there existed ground support equipment for DC3, DC6, Globemasters, and in the eastern sector, ground support for jet fighters.

OPERATING ARROWS FROM DEW LINE BASES.

Another dissertation from Mr W Kuzyk concerned the Arrow undercarriage design for operating from these bases:-

> "It has been ascertained that the Unit Construction Index (UCI) for runways located at the DEW Line to be in the vicinity of 34 - 39 (the CI24 and CI33 requirements respectively). Although complete information on these runways is not available, it is known that some are of gravel construction and sized 150 ft. wide by 5,000 - 6,000 ft. long. The placement of landing mats on these runways would indeed raise the UCI to over 40.
>
> The UCI requirement for the present Arrow is well over 100 and this number must be substantially reduced if tactical operations are to be considered. It is proposed to replace the tandem gear with a twin-tandem arrangement and halve the tire pressure utilizing the original tires, wheels and brakes. This arrangement could reduce the UCI requirement for an Arrow weighing 65,000 lbs. from its present value of 100 to about 30. This would then permit operation from DEW Line air bases and with DEW Line Ground Support as outlined in the previous notes.

It follows that the UCI varies with the aircraft weight, and illustrations of a twin-tandem arrangement in the wing, together with the fairing to enclose them are shown. It should be noted that this is a cursory examination of the feasibility of lowering the UCI requirements for the Arrow. Suffice it to say, at this time, that it can be done and a more thorough investigation into this undercarriage problem is strongly recommended."

To this end, a request was sent by Mr J.C.Floyd, the Vice-President of Engineering, to Mr C.W.Smith, the Chief Engineer, Airport Development for the Department of Transport in Ottawa:-

"One of our many projects under study is concerned with the development of Northern Canada. In this respect we require certain information on runways in this region, to which task the bearer of this letter, Mr W. Kuzyk, has been assigned, i.e.:-

a. Bearing characteristics.
b. Width, length and direction.
c. Material of construction and thickness.
d. Unit Construction Index (UCI) and /or Load Carrying Number (LCN) limits of the runways.
e. Airport facilities.

The above information is required for the following bases:-

CANADA. Whitehorse, Watson Lake, Fort Nelson, Yellowknife, Cold Lake, Edmonton, Churchill, Coral Harbor, Frobisher Bay, Weenusk, Great Whale, Aklavik, North Bay, Bagotville, St. Hubert, Uplands, Comox, Kapuskasing, Val d'Or and Casey.

USA. Thule, Nome, Fairbanks, Anchorage, Adoak, Eielson, Elmandorf, King Salmon, Narsarssuak and Sondrestrom.

and, in addition, any other 6,000 ft. (or more) hard-surfaced runways in this region that we have overlooked".

DEVELOPMENT OF THE AVRO ARROW.
THE BASIC ARROW 2.

Based on a minimum time to height, the combat radii for the basic Arrow 2 with full normal internal fuel are:-

1. 264 Nautical miles for Mach 1.5 combat speed.

2. 216 Nautical miles for Mach 2.0 combat speed.

Therefore, the maximum interception distance from 45 degrees latitude is:-

3. 564 N.M. for M 1.5 interceptor) Interceptors based on the

4. 516 N.M. for M 2.0 interceptor) Pine Tree Line.

5. 414 N.M. for M 1.5 interceptor) Interceptors based 150 n.m.

6. 366 N.M. for M 2.0 interceptor) south of Pine Tree Line.

Cases marked thus (+) in Tables 1 and 3 indicate that the combat radius of the present Arrow is insufficient for this interception point.

It can be seen that to take advantage of improved initial detection and reduce delay time, - especially against a M 0.9 bomber - a greater combat radius for the Arrow would be required. Under the existing environment the present combat radii are, in most cases, more than adequate.

POTENTIAL FOR THE AVRO ARROW. CASE 1.

The Threat:- Conventional medium/high altitude subsonic bomber with free falling bombs of H.E. or nuclear type.
Operating altitude:- 30,000 ft. up to 50,000 ft.
Mach number:- 0.90 - 1.0

Consider a bomber making an attack from due North at M = 0.9 at 50,000 ft. altitude. The following table gives detail results.

Table 1. Distance of Interception points North of 45th line of latitude for head on attacks. (non-manoeuvring)

a. Initial detection 200 n.m. North of Pine Tree Line.

1. Bomber speed & height............................M=0.9 @ 50,000 ft.
   Interceptor speed and height.....................M=1.5 @ 50,000 ft.
   Pine Tree Line, 10 mins. delay.................364 nm.
   150 nm south of PTL, 10 mins. delay......308 nm.
   Pine Tree Line, 2.5 mins. delay................404 nm.
   150 nm south of PTL, 2.5 mins delay......348 nm.

2. Bomber speed and height..........................M=0.9 @ 50,000 ft.
   Interceptor speed and height.....................M=2.0 @ 60,000 ft.

Pine Tree Line, 10 mins. delay.................350 nm. *
150 nm south of PTL, 10 mins. delay......320 nm.
Pine Tree Line, 2.5 mins. delay...............411 nm.
150 nm south of PTL, 2.5 mins. delay.....364 nm.

b. Initial detection at Mid-Canada Line.

1. Bomber speed and height.........................M=0.9 @ 50,000 ft.
Interceptor height and Speed...................M=1.5 @ 50,000 ft.
Pine Tree Line, 10 mins. delay.................426 nm.
150 nm south of PTL, 10 mins. delay......370 nm.
Pine Tree Line, 2.5 mins. delay...............466 nm.
150 nm south of PTL, 2.5 mins. delay......410 nm.

2. Bomber speed and height.........................M=0.9 @ 50,000 ft.
Interceptor speed and height....................M=2.0 @ 60,000 ft.
Pine Tree Line, 10 mins, delay................435 nm.
150 nm south of PTL, 10 mins. delay......389 nm. +
Pine Tree Line, 2.5 mins. delay...............480 nm.
150 nm south of PTL, 2.5 mins. delay......433 nm. +

c. Initial detection 200 nm. North of Mid-Canada Line.

1. Bomber speed and height.........................M=0.9 @ 50,000 ft.
Interceptor speed and height....................M=1.5 @ 50,000 ft.
Pine Tree Line, 10 mins. delay...............551 nm.
150 nm south of PTL, 10 mins. delay......495 nm. +
Pine Tree Line, 2.5 mins. delay..............592 nm. +
150 nm south of PTL, 2.5 mins. delay.....535 nm. +

2. Bomber speed and height........................M=0.9 @ 50,000 ft.
Interceptor speed and height....................M=2.0 @ 60,000 ft.
Pine Tree Line, 10 mins. delay...............573 nm. +
150 nm south of PTL, 10 mins. delay.....526 nm. +
Pine Tree Line, 2.5 mins. delay..............618 nm. +
150 nm south of PTL, 2.5 mins. delay.....571 nm. +

The following notes are relevant to the derivation of the data given in Table 1.

Delay time - is defined here as the elapsed time between the bomber crossing the relevant initial detection line, and the interceptor being airborne at 50 ft.

The 10 min. delay used in part of Table 1 was assumed by DSE based on Pine Tree Line radar pick-up. It allowed:-

2 min. detection (2 mins. after 200 nm. radar pick-up)
2 min. for identifying and tracking.
2 min. to transmit information to interceptors.
4 min. to get interceptors airborne.

It was felt that with maximum utilization of DEW line warning (and Mid-Canada where applicable) this delay time could be reduced considerably. The 2.5 min. delay used was considered to be a minimum.

The bases, radar lines, and related distances used in Table 1 are generalized to give the overall picture. Local conditions should not vary excessively from this.

For these cases, the interceptor took off in a southerly direction, and completed a 180 degree turn during the climb, just meeting the bomber at the top of the climb. It was conditional that the interceptor reached the quoted combat speed and height before interception. However, further North interception points could be obtained in these cases if the interceptor accelerated to an optimum speed of between $M = 1.5$ and $M = 2.0$, and only climbed to an intermediate altitude, using weapon "jump-up" capability if necessary.

The $M = 2.0$ interceptor showed up better compared to the $M = 1.5$ interceptor if the due North attack was displaced to the side of the interceptor base, or if the bomber manoeuvres. The table has shown the most pessimistic case as far as the $M = 2.0$ interceptor was concerned.
Table 2 - Distance of interception points North of the 45th line of latitude, for due North attacks. Non-manoeuvring bomber, manoeuvring interceptor.

Initial detection 200 nm. North of Pine Tree Line.
10 min. delay.
$M = 0.9$ bomber at 50,000 ft.
$M = 1.5$ interceptor at 50,000 ft, based on Pine Tree Line.
Interceptor can make 2g turn.

Head-on attack	Beam attack	Tail attack
364 nm.	362 nm.	356 nm.

In the above table, it was assumed that the interceptor had perfect GCI positioning.

The results given in Tables 1 and 2 will now be examined.

1. Arrow 2 at $M = 1.5$ at 50,000 ft. Bomber at $M = 0.9$ at 50,000 ft. Under existing

environments, (see Table 1 (a)) attacks against this type of target from both Defence Bases are possible, and interceptors based on the Southern Defence Line only lose 56 nm. in interception distance compared with Northern Defence Line interceptors, that is, roughly 37 1/2% of the distance between bases. If the delay time is reduced from 10 mins. to 2,5 mins. a forward gain in interception distance of 40 nm. results.

The effect of interceptor positioning is shown in table 2. It can be seen that the time change in interception point distance when making a beam instead of a head-on attack is insignificant. Even with a tail attack the bomber only penetrates a further 8 nm. compared with the head-on attack. These results hold true for interceptor speeds between M = 1.3 and 1.9 under the then present ground environments. If the initial detection range was increased, the relatively small difference in interception point distance between head-on, beam and tail attacks is maintained.

2. Although not essential in this case for attacking one bomber, if initial detection is considered at the Mid-Canada Line, (see Table 1 (b)) instead of 200 nm. North of the Pine Tree Line, then for the 100 nm. increase in initial detection range, we would have gained a 62 nm. further North interception point for all interceptor bases and delay times considered. Again, reduction of delay time from 10 mins. to 2.5 mins. gives a 40 nm. forward gain in interception distance, and Southern Defence Line interceptors only lose 56 nm. in interception distance compared with Northern Defence Line interceptors.

If initial detection is considered 200 nm. north of the Mid-Canada Line instead of the Pine Tree Line, (see Table 1 (c)) then for the 300 nm. increase in initial detection range, we would have gained a 187 nm. further North interception point for all bases and delay times considered, that is, a 62% gain, which is the same percentage gain as that obtained by using the Mid-Canada Line as initial detection line. The effects of delay time and base position are as before.

3. Consider the effect of boosting the Arrow 2 performance to M = 2.0 at 60,000 ft. against the threat of a M = 0.9 bomber at 50,000 ft. Under then existing environments (see Table 1 (a)), with the interceptor based on the Pine Tree Line and a 10 min. delay, in order to intercept the bomber at the top of the climb, the interceptor has to take-off in a Southerly direction and then carry out at 180 degree turn during the climb. In all other cases, (see Tables 1(b) and 1(c)) direct head-on attack is possible.

The change in interception distance with change of interceptor base is constant for all initial detection ranges considered, and is roughly 31% of base separation, that is, 47 nm. loss for 150 nm. base separation.

The gain in forward interception distance is 69% of the increase in initial detection range. For the M = 2.0 interceptor against a M = 0.9 bomber, the extra time delay of

7 1/2 mins gives a 44 nm. greater bomber penetration, that is, the effective penetration rate is 5.91 nm./min. of delay or 68.4% of the actual bomber speed.

The interception point distance gained by boosting the interceptor speed from M = 1.5 to 2.0 is as shown in Tables 1 (a), (b) and (c).

CONCLUSIONS.

1. Increasing the interceptor speed from M = 1.5 to 2.0 gives only moderate gains in interception distance and increased number of possible attacks, and cannot be strongly recommended for this particular threat.

POTENTIAL FOR THE AVRO ARROW. CASE 2.

The Threat:- Conventional medium/high altitude supersonic bomber with free falling bombs of H.E. or nuclear type.

Operating altitude:- 60,000 ft.
Mach number:- 2.0

Consider a bomber making an attack from due North at M = 2.0 at 60,000 ft. altitude. The following table gives detail results.

Table 3. Distance of Interception points North of 45th line of latitude for head on attacks. (non-manoeuvring)

a. Initial detection 200 n.m. North of Pine Tree Line.

1. Bomber speed & height..........................M=2.0 @ 60,000 ft.
   Interceptor speed and height...................M=1.5 @ 60,000 ft.
   Pine Tree Line, 10 mins. delay................Not possible.
   150 nm south of PTL, 10 mins. delay......207 nm.
   Pine Tree Line, 2.5 mins. delay...............354 nm.
   150 nm south of PTL, 2.5 mins delay......268 nm.

2. Bomber speed and height.......................M=2.0 @ 60,000 ft.
   Interceptor speed and height...................M=2.0 @ 60,000 ft.
   Pine Tree Line, 10 mins. delay................Not possible.
   150 nm south of PTL, 10 mins. delay......168 nm. *
   Pine Tree Line, 2.5 mins. delay...............311 nm. *
   150 nm south of PTL, 2.5 mins. delay.....281 nm.

b. Initial detection at Mid-Canada Line.

1. Bomber speed and height......................M=2.0 @ 60,000 ft.
   Interceptor height and Speed..................M=1.5 @ 50,000 ft.
   Pine Tree Line, 10 mins. delay...............313 nm. *
   150 nm south of PTL, 10 mins. delay......250 nm.
   Pine Tree Line, 2.5 mins. delay..............397 nm.
   150 nm south of PTL, 2.5 mins. delay.....311 nm.

2. Bomber speed and height.......................M=2.0 @ 60,000 ft.
   Interceptor speed and height....................M=2.0 @ 60,000 ft.
   Pine Tree Line, 10 mins, delay................268 nm. *
   150 nm south of PTL, 10 mins. delay......260 nm.
   Pine Tree Line, 2.5 mins. delay...............406 nm.
   150 nm south of PTL, 2.5 mins. delay.....331 nm.

c. Initial detection 200 nm. North of Mid-Canada Line.

1. Bomber speed and height.......................M=2.0 @ 60,000 ft.
   Interceptor speed and height....................M=1.5 @ 60,000 ft.
   Pine Tree Line, 10 mins. delay................421 nm.
   150 nm south of PTL, 10 mins. delay......335 nm.
   Pine Tree Line, 2.5 mins. delay...............482 nm.
   150 nm south of PTL, 2.5 mins. delay.....397 nm.

2. Bomber speed and height.......................M=2.0 @ 60,000 ft.
   Interceptor speed and height..................M=2.0 @ 60,000 ft.
   Pine Tree Line, 10 mins. delay...............435 nm.
   150 nm south of PTL, 10 mins. delay......369 nm.
   Pine Tree Line, 2.5 mins. delay..............506 nm.
   150 nm south of PTL, 2.5 mins. delay.....431 nm. +

All the notes given for Table 1 apply to Table 2.

CONCLUSIONS.

1. Initial detection 200 nm. North of the Mid-Canada Line is required for adequate defence, especially if CCM action has to be taken, or the application rate is low.

2. A manoeuvring bomber with a speed of M = 2.0 requires a M = 2.0 interceptor with as much lead time as possible.

3. With a M = 1.5 interceptor, a 10,000 ft. "jump-up" capability of the missile is required in all cases.

ARRESTER WIRE RUNWAY BARRIER.

SUMMARY.

At the request of the RCAF, an investigation was conducted to determine a satisfactory runway barrier for the Arrow aircraft, using the arrester wire principle. Various approaches to the problem were examined, and a proposal employing this principle was offered. This involved some redesign of the rear fuselage and a weight penalty of the order of some 200 lbs.

Considerable thought was put into the solution of this problem, as an Arrow, either taking-off or landing in an emergency condition weighed around 70,000 lbs., traveling at approximately 150nm/hr., and stopping distances of about 1,000 ft. were required after engagement with the barrier at the end of the runways in the "overshoot area". In addition, a deceleration force of some 2'g' was anticipated.

Several methods were suggested. These are as follows:-

1. NOSE WHEEL ENGAGEMENT.

A steel cable across the runway was proposed for this. It was the simplest apparent method but, the nose leg was not stressed to withstand the forces that would be encountered and would have been torn away, and severe damage done to the rest of the aircraft.

2. NYLON RIBBON ENGAGEMENT.

A method of engagement designed to ensure that the arrester wire is not engaged by the nose undercarriage by having the wire lying on the runway and attached to a nylon harness suspended across the runway. This harness, when engaged by the nose-gear, would lift the arrester wire off the runway to sufficient height to enable it to fall over the main wheels and around the shock absorber struts. It had been shown that the undercarriage legs could have withstood decelerations of 1.0 'g' to 1.5 'g', depending on the weight. This cable could become entangled with the tie-rods or lower legs, there was a danger that not only could the undercarriage sustain damage but it too could be ripped-off, thus greatly damaging the aircraft. In addition, if the aircraft were either taking-off or landing with the external fuel tank attached, there was a great danger that the cable could become ensnared around it and thus create a total explosive destruction. Therefore, both of these methods were dismissed.

3. HOOK TYPE ENGAGEMENT - UNDERCARRIAGE MOUNTED.

In view of the above mounted difficulties, consideration

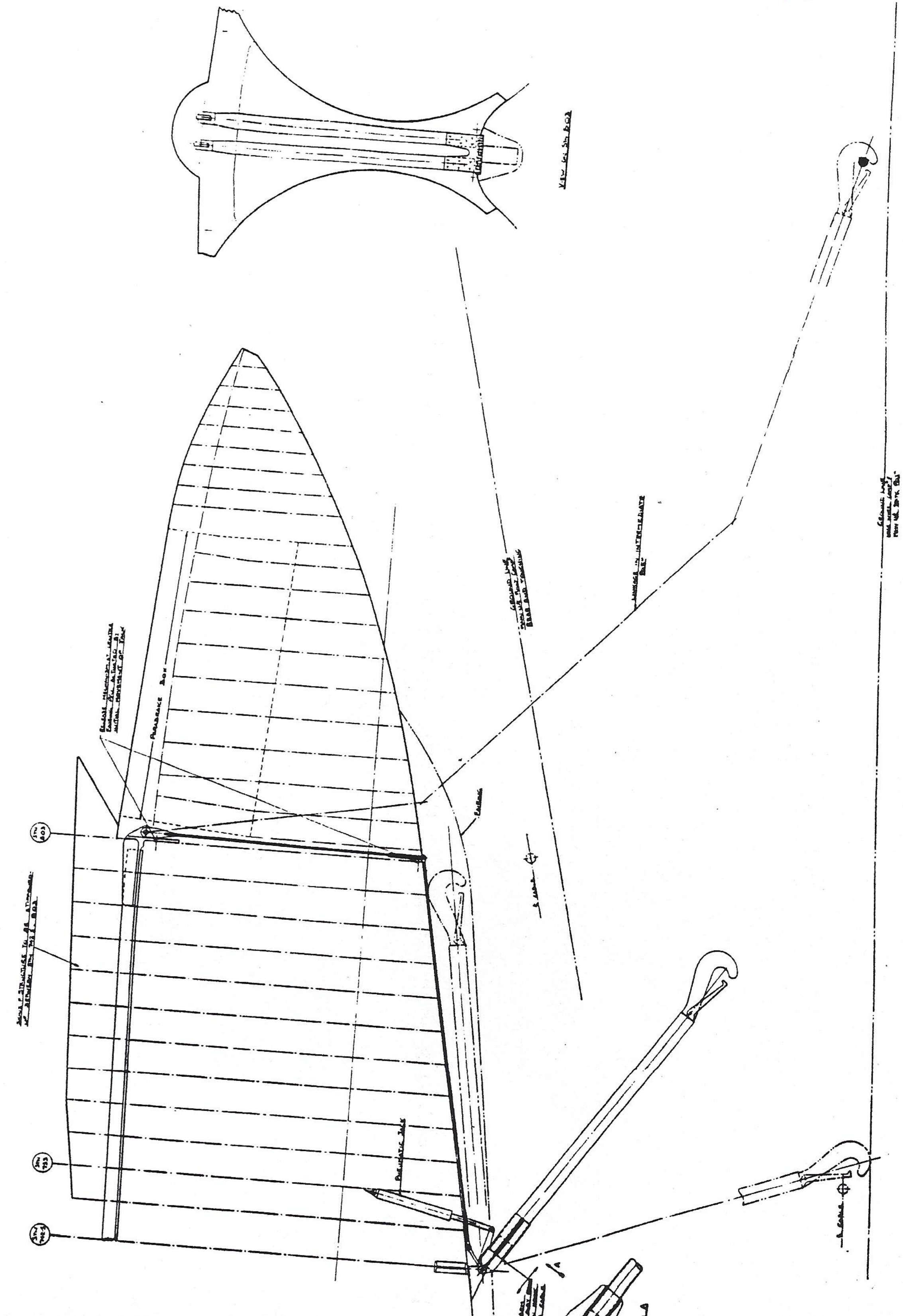
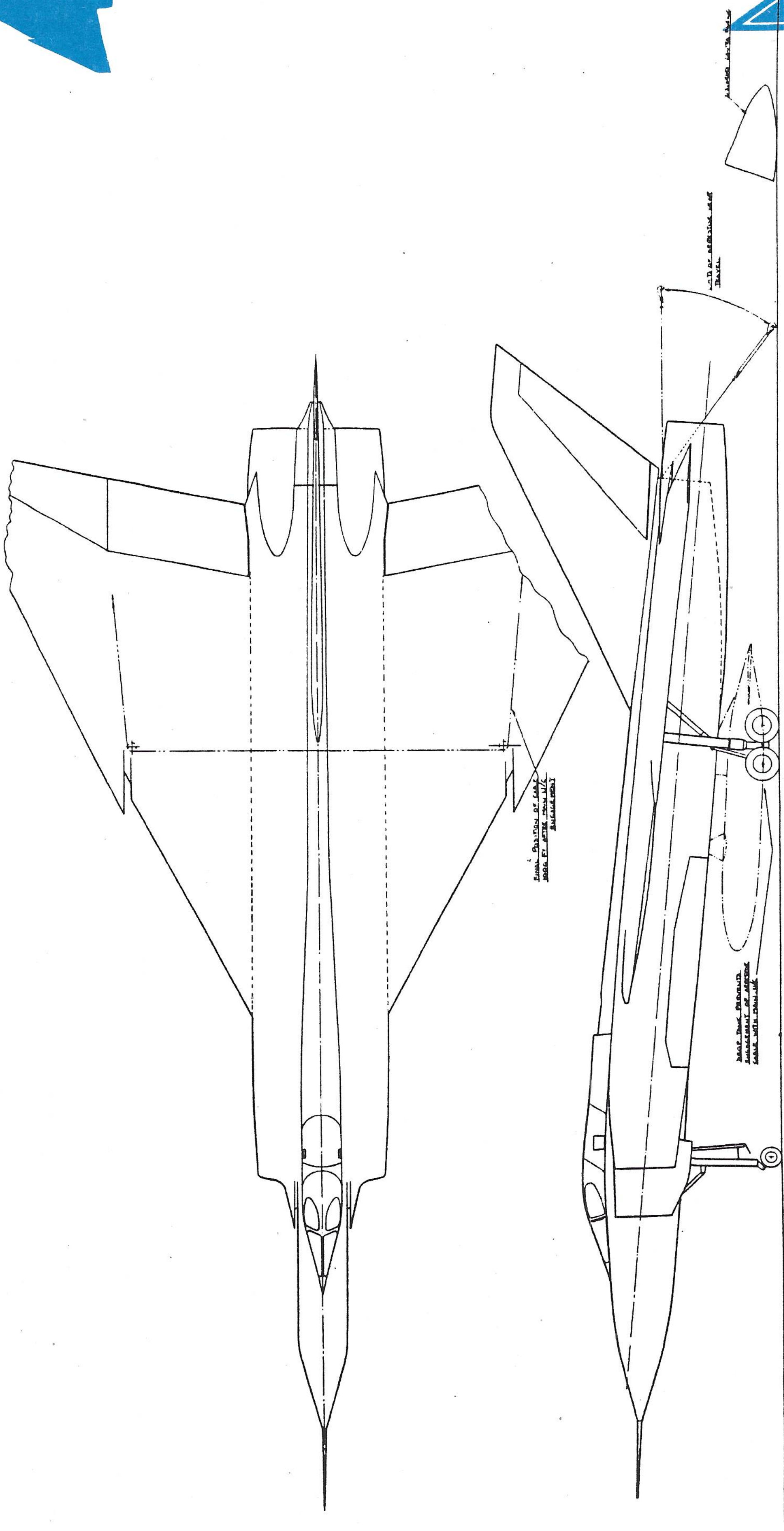


FIG. 1

TAIL HOOK ARRANGEMENT ARROW 2



ARRESTER WIRE ARRANGEMENT ARROW 2

was given to use an arrester hook to engage the wire. An arrester hook mounted on the main undercarriage, although attractive in principle, presented its own difficulties. Side load components would have been critical for bogie strength and would also have imposed critical torques about the leg vertical axis. Within the space limitations of the undercarriage bay, it would have been most difficult to have provided adequately wide hook attachments to resist the side loads.

4. HOOK TYPE ENGAGEMENT - FUSELAGE MOUNTED.

A possibility appeared to lie in the use of a fuselage mounted arrester hook. Here the limitation lay in the fact that the underside of the body had no suitably strong structure on which to mount the hook at any point aft of the rear end of the weapon bay which was just forward of the main wheels.

The most promising approach was to attach the arrester hook to the bottom of Frame 742.5. As this point was not sufficiently strong to withstand full drag loads, the scheme would have allowed the hook to carry away from the mounting on engaging the arrester wire, and at the same time remaining attached to the aircraft by steel cables or ties secured to the structure adjacent to the parachute attachment at the top of Former 803.

During this operation, the sting would detach itself from the rear fuselage in order to allow the hook mechanism to extend and lower itself to the runway in order to engage with the arrester wire.

The impact effects of the cable on the nose wheel and main wheels when they rode over it had to be given due consideration as rebound forces could effect an unwanted engagement with the undercarriage which of course could have led to a disaster.

CONCLUSIONS.

The various methods of engaging an arrester wire were considered and rejected as unsatisfactory and, under some conditions, downright impossible and dangerous, particularly if an external fuel tank was carried.

The final remaining suggestion was in the employment of a Nylon net across the runway. This method had been developed by the Swedish Air Board, and from the information available at the time, it appeared that this system might very well have provided a simple and effective solution to the Arrow emergency braking problems with minimum, if any, damage to the aircraft.

The two illustrations following show the main-leg cable and rear hook methods of arresting.

ARMAMENT TEST AND STORAGE FACILITY.

INTRODUCTION.

In May of 1956, the RCAF made available to Avro Aircraft Ltd the plans and the development specification for Rocket Assembly and Storage Facilities which were to be built in the (then) immediate future at the prepared all-weather bases which operated CF-100 aircraft armed with 2.75"FFAA rockets in wing-tip pods. Concurrently, the Company were supplied with a draft entitled "RCAF Logistics and Servicing Policy for Sparrow 2 Missiles on the CF-100 Aircraft". The Company was asked to pass comment, as soon as was possible, on this information with particular regard to the operation of CF-105 aircraft armed with Sparrow 2 missiles. Since complete information on the handing and testing procedures of the Sparrow 2 missile was not available and since the servicing and testing procedures of the CF-105 armament installation could not be stated exactly, it was decided to issue a Preliminary Study Report on the proposed Armament Facility. It was the Company's intention to supersede this preliminary report in due course with a Final Study Report, when all necessary information about the aircraft and its armament were made available.

CONCLUSIONS.

1. Armament storage and test facility was considered essential for each all-weather interceptor air base and that it should be located as close as possible to the aircraft loading or turn-around point.

2. All buildings and fixed equipment should be designed for handling the largest weapons that were likely to be carried on CF-100 and CF-105 aircraft. This could include ordnance of up to 15 ft. in length and 1200 lbs. in weight.

3. The armament facility as planned by the RCAF for handling 2.75" rockets and pods was considered to be adequate for the concept of operations that was specified.

4. When air-to-air guided missiles were introduced, special installations would be required, including air-conditioned, dust-free rooms for testing and assembling the guidance and control systems and heated areas for storing these components. It was recommended that these facilities be in a special building inside the armament compound.

5. The armament facility as proposed by the RCAF for supporting two CF-100/Sparrow 2 squadrons was considered to be adequate for the concept of operations that was outlined.

6. If a requirement was to be introduced for combined armament, such as arming

a CF-100 aircraft with 4-Sparrow 2 missiles and 2.75" rockets in pods, then additional storage buildings and possibly another fusing building would be needed. Explosive regulations would probably have necessitated building a separate armament facility.

7. Reloading the CF-105 aircraft by changing the armament pack appeared to have been the best way of meeting the specified aircraft turn-around time of 10 minutes, as far as the armament was concerned.

8. With the introduction of armament packs, an additional building would probably have been required in the armament compound with facilities for storing, maintaining and servicing these weapon packs.

9. The water mains, sanitary sewers and power lines to the armament compound should be made from the start to be adequate to serve the facility in its final stage of development.

10. Detailed requirements for the test and handling equipment could not be specified at that time, since information was not available concerning the assembly, testing and servicing procedures for the Sparrow 2 missile. Also, testing and servicing instructions for the CF-105/Sparrow 2 armament pack was not available either, since the design was still in an early stage.

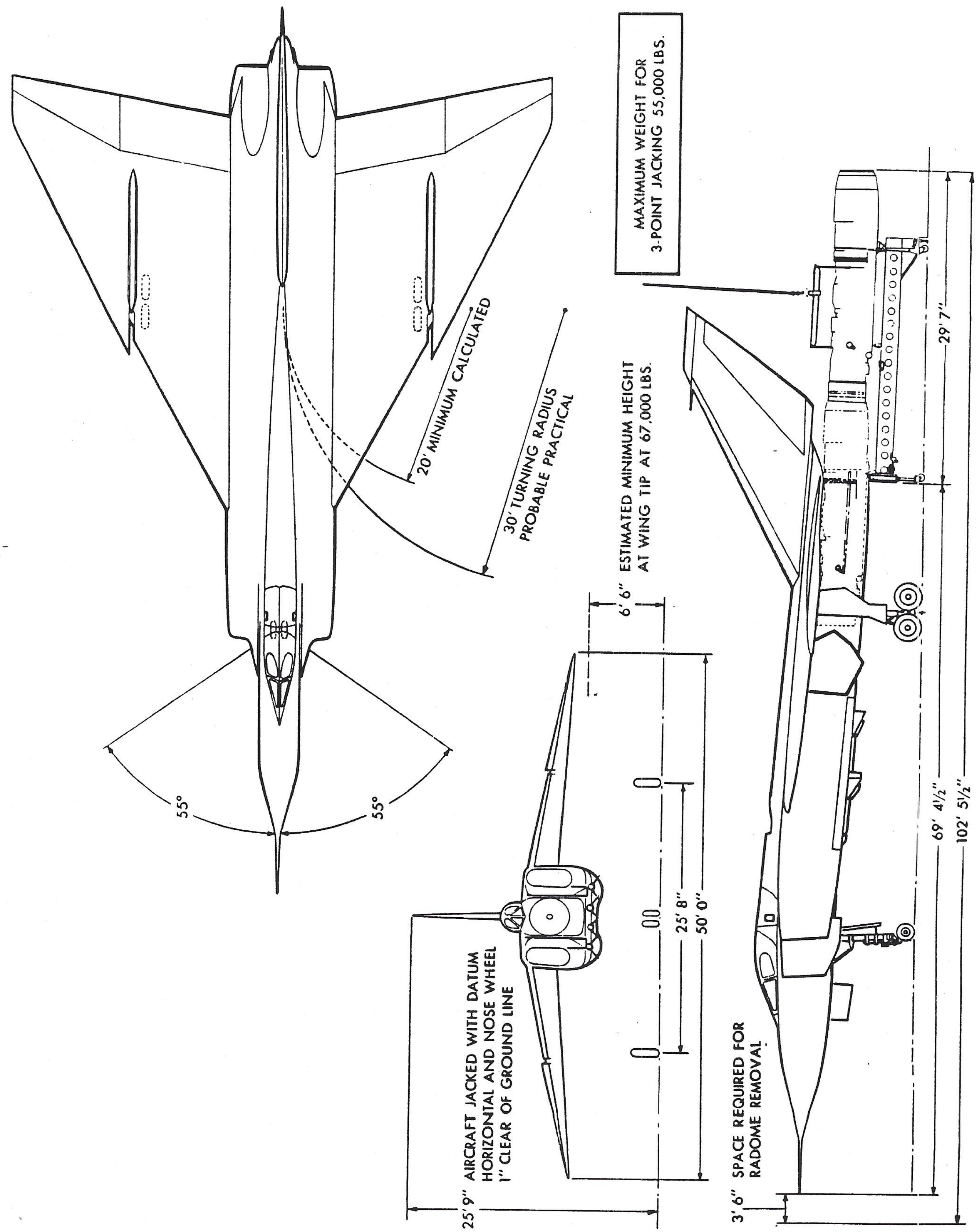
ARROW READINESS FACILITY.

INTRODUCTION.

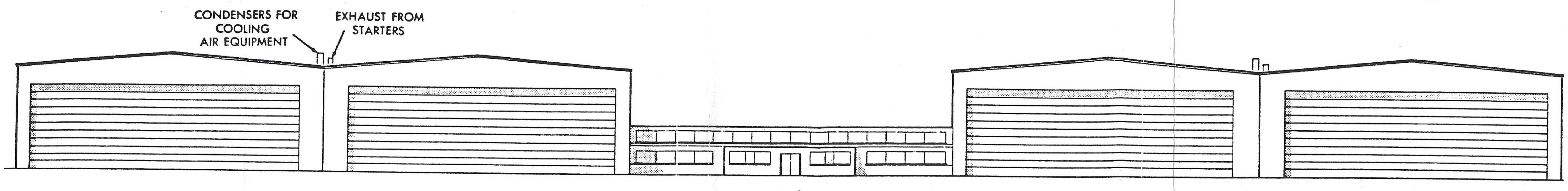
In October, 1955, the RCAF requested Avro Aircraft Ltd to conduct certain engineering studies in order to ensure that the RCAF would be adequately prepared to support and maintain Arrow 2 aircraft in the field. One of these studies was to cover the mobile equipment and stationary ground facilities that would be required to maintain the Arrow 2 aircraft at readiness.

CONCLUSIONS.

1. The use of readiness hangers would be necessary with the Arrow 2 in order to meet the scramble and mission requirements for this aircraft under all conditions of weather. These hangers were required in order to shade fuel tanks and cockpits during hot weather, to protect the aircraft from deposits of snow and freezing rain during bad weather, and to heat the hydraulic systems to at least O degrees F during cold weather. The RCAF standard readiness hangers would have been suitable for use with Arrow 2 aircraft but some alterations were required to accommodate ground support equipment and services to the aircraft. It was noted that the RCAF standard readiness hangers were sited to provide a lateral clearance of 1000 ft. from the main

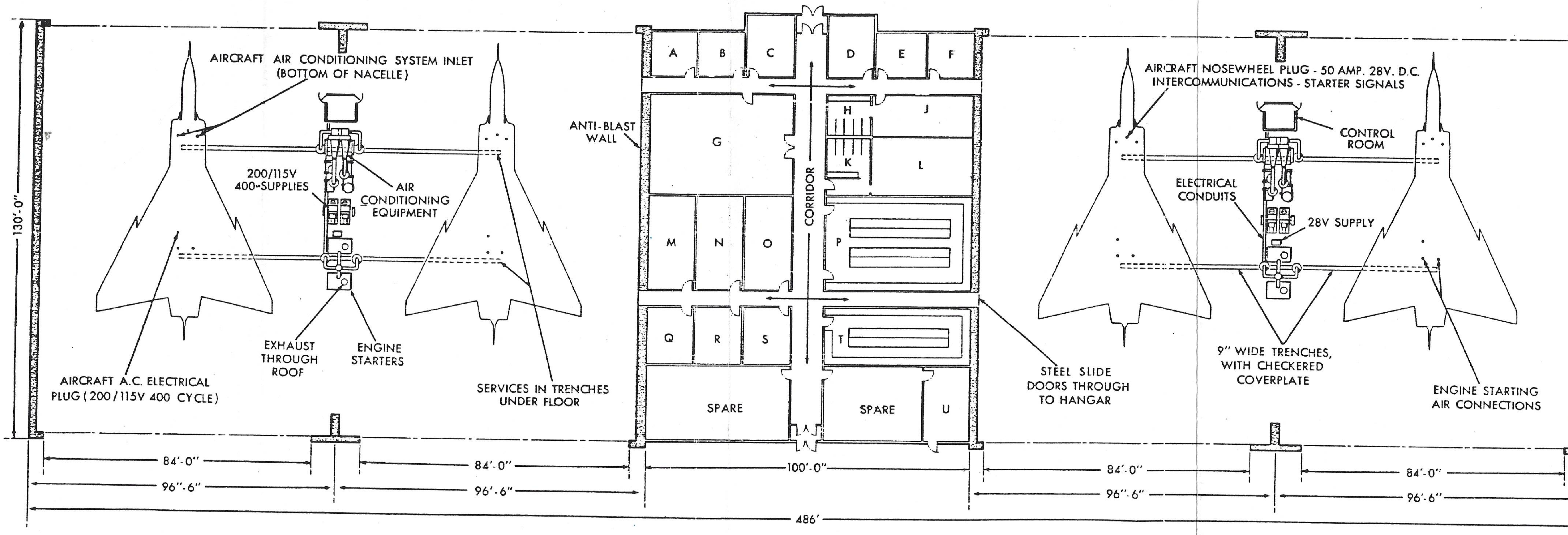


CLEARANCES REQUIRED FOR SERVICING



NOTE: ANTI BLAST WALLS BETWEEN BAYS MAY BE DESIRABLE TO ISOLATE RISK AND REDUCE NOISE. IN THIS CASE THE MACHINERY MUST BE SPLIT AND DOORS THROUGH PROVIDED.

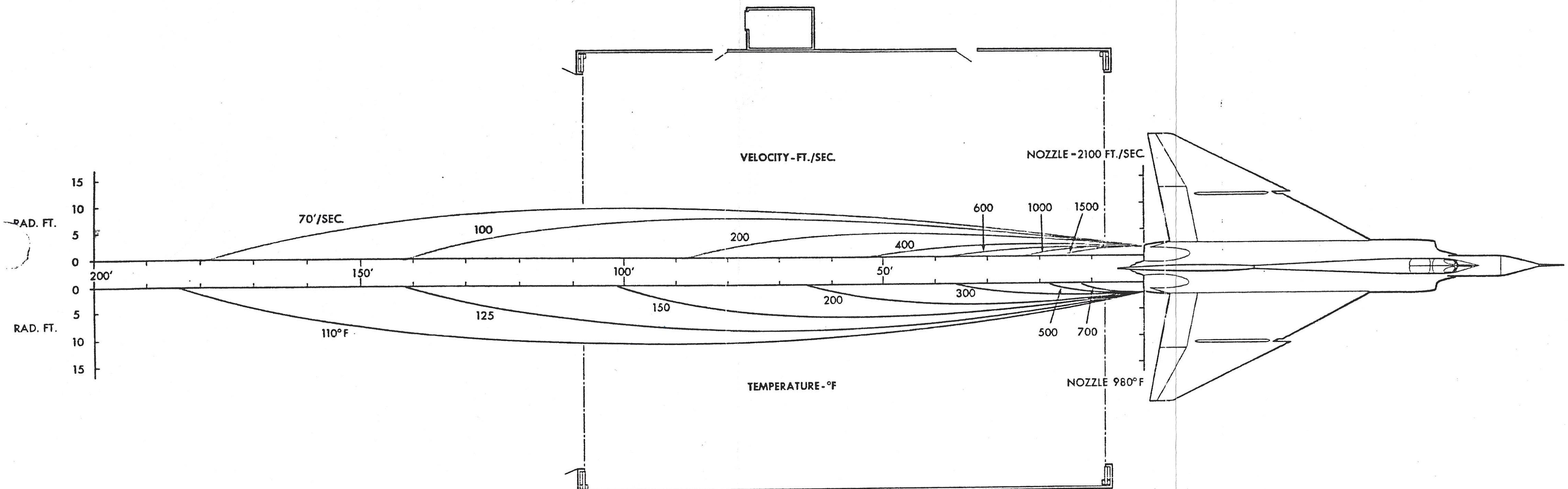
FRONT ELEVATION



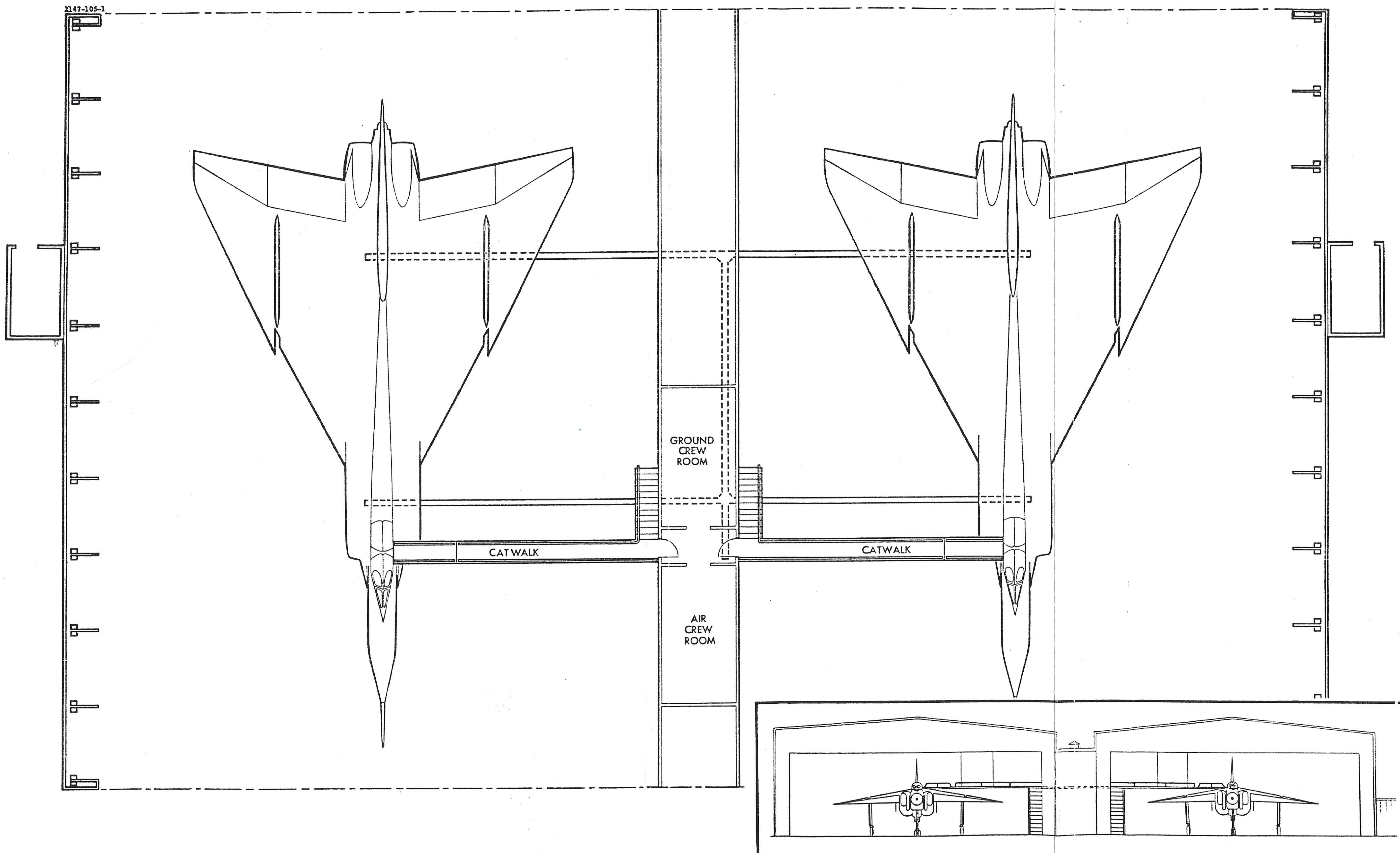
KEY

A	SPARE	H	WASHROOM	P	STORES
B	L 14	J	WOMEN'S LOCKERS	Q	ARMAMENT SHOP
C	LINE CREW	K	WASHROOM	R	TELECOMMUNICATIONS
D	MAINTENANCE CONTROL	L	MEN'S LOCKERS	S	INSTRUMENTS
E	MAINTENANCE CONTROL	M	ELECTRIC SHOP	T	TOOL CRIB
F	RECORDS	N	ELECTRONICS	U	INFLAMABLE STORES
G	SMOKE ROOM	O	BATTERY SHOP		

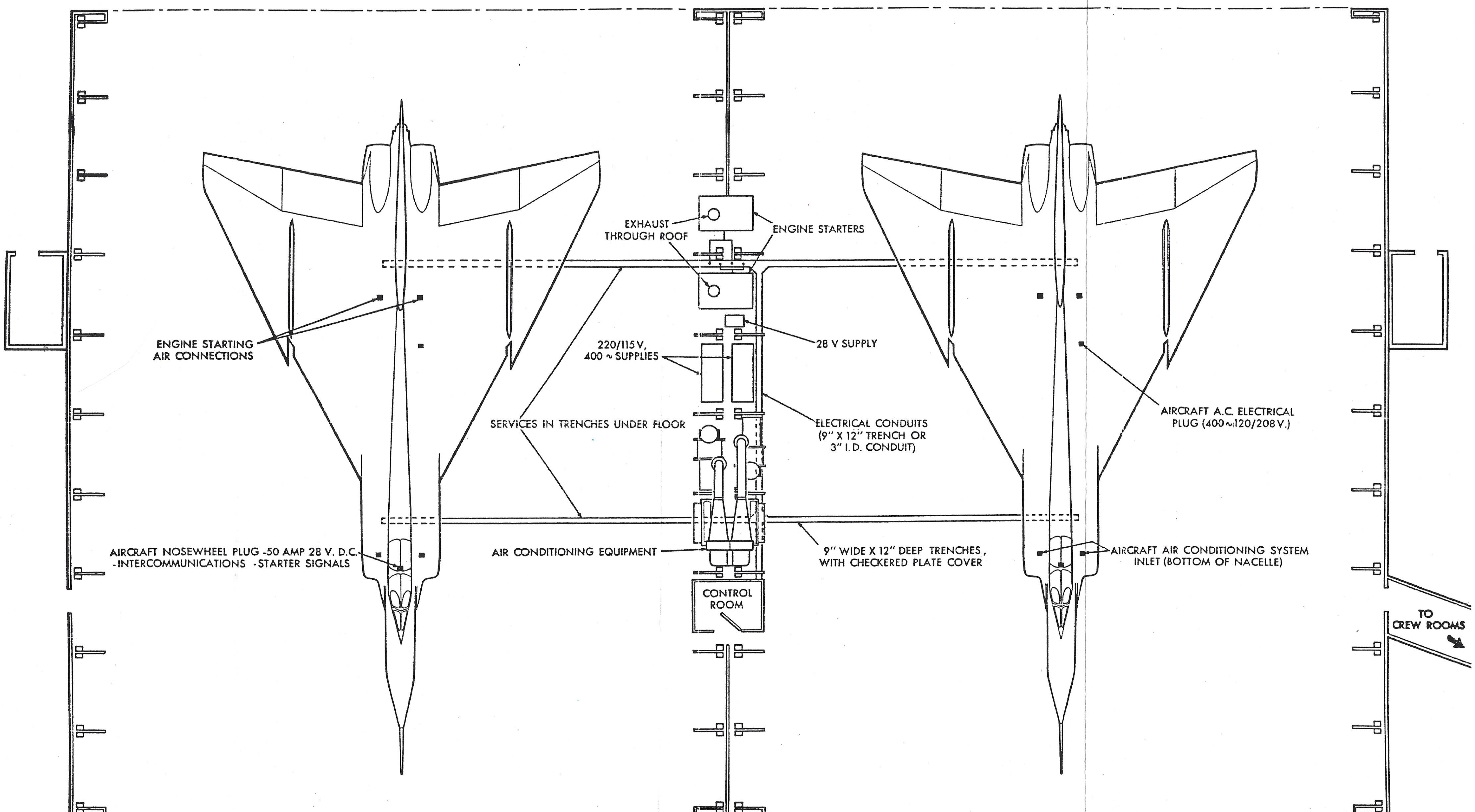
POSSIBLE LAYOUT FOR COMBINED TURNAROUND AND FIRST LINE MAINTENANCE FOR ONE SQUADRON



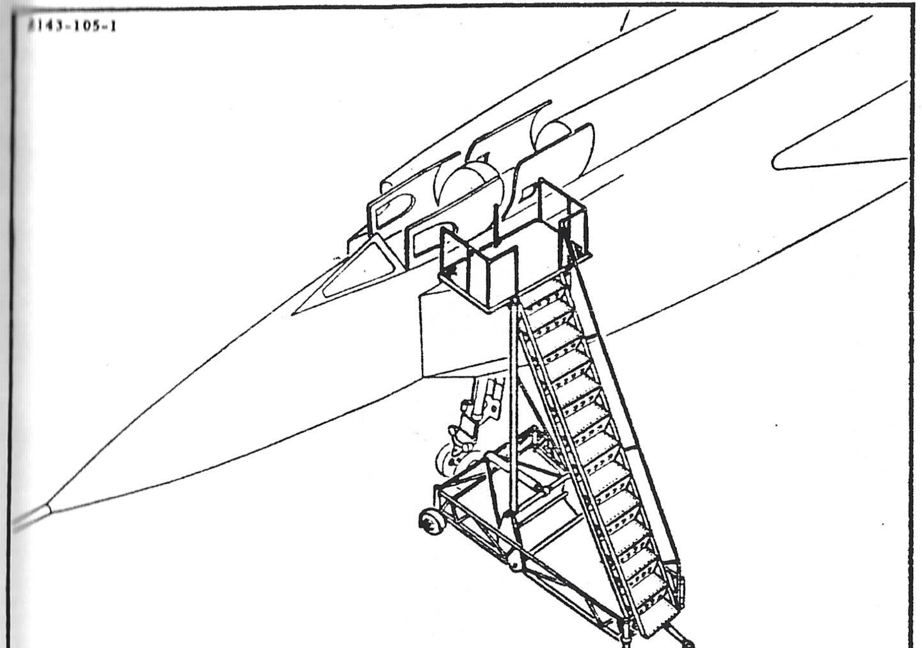
ESTIMATED ARROW 2 JET EXHAUST PATTERNS BASED ON J75 MILITARY THRUST



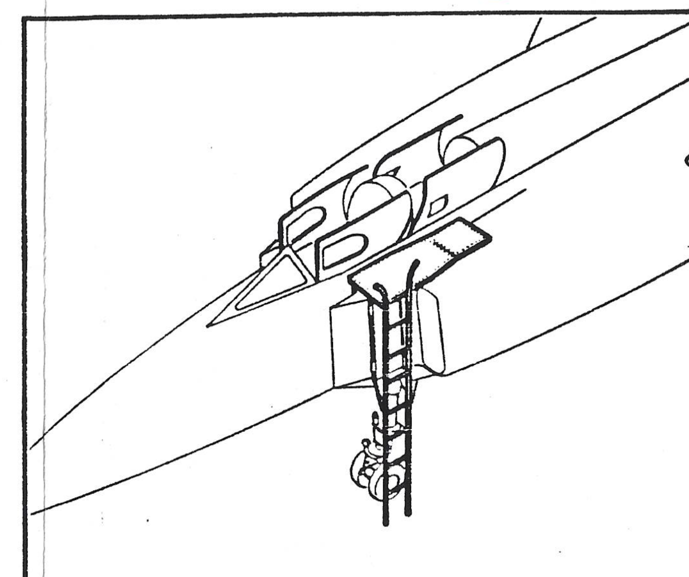
ALTERNATIVE LAYOUT FOR READINESS HANGERS



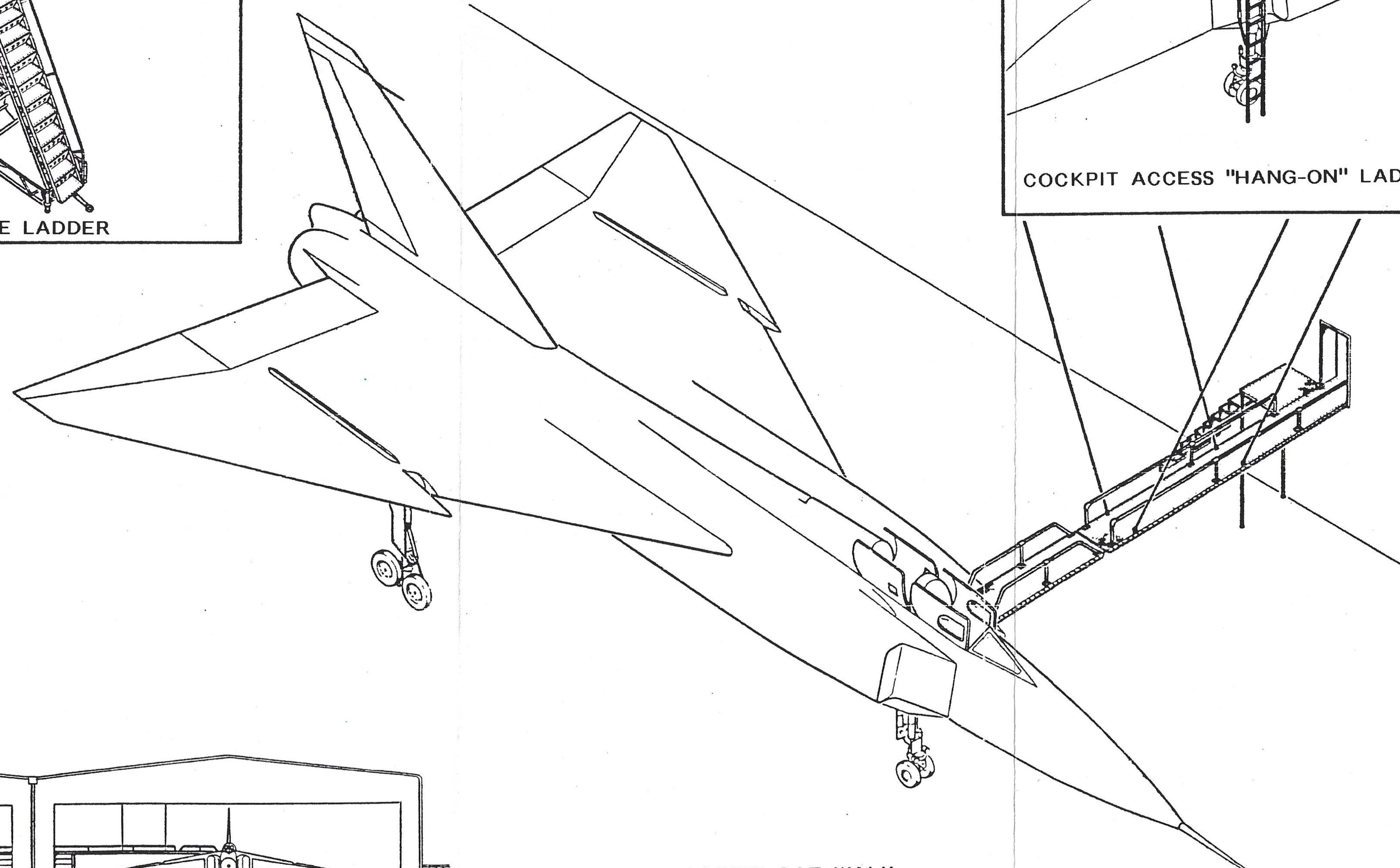
LAYOUT OF GROUND SUPPORT EQUIPMENT & SERVICES IN RCAF STANDARD READINESS HANGERS

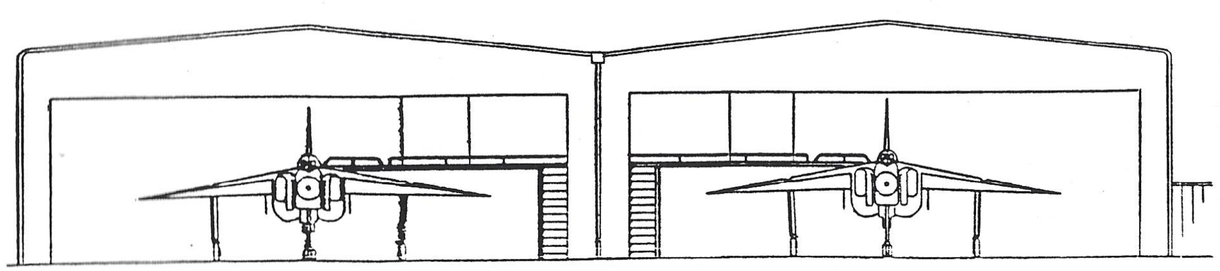


COCKPIT ACCESS MOBILE LADDER



COCKPIT ACCESS "HANG-ON" LADDER





COCKPIT ACCESS-CAT WALK

ARROW 2 COCKPIT ACCESS-CAT WALK

runway. With this siting arrangement at least 20 seconds were required to taxi from the hangers to the runway with the Arrow 2 aircraft, and a taxi strip from the maintenance area to the rear of the readiness hanger was recommended because with the (then) present arrangement the main approach to the runway could be blocked for periods of up to a minute while aircraft were being towed to and from the readiness hangers.

NOTES