~~Aero~~

AVRO CF-105 ARROW

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MANUFACTURER:- Avro Aircraft Limited, Malton, Ontario.

TYPE:- Twin-engine, all-weather interceptor.

DEVELOPMENT:- Serious studies for a successor to the Avro CF-100 began in 1951 and in March 1952 the RCAF "Final Report of the All-Weather Interceptor Requirements Team" was submitted to Avro outlining basic RCAF requirements for a supersonic all-weather interceptor. Avro replied in June 1952 with two proposals, C104/1, single engine and C104/2 twin engine, both Delta wing configurations. During the following months intensive discussions between Avro and RCAF representatives examined a wide range of possible sizes and configurations culminating in RCAF Specification AIR7-3 in April 1953, confirming their preference for a twin engine aircraft with a crew of two. In May 1953, Avro submitted Report No. P/C-105/1 "Design Study of Supersonic All-Weather Interceptor Aircraft". A Tailless High Delta wing configuration was selected on grounds of weight and efficiency, the Delta providing by far the lightest wing for a low thickness/chord ratio, and due to its large root chord, still providing adequate thickness for fuel and undercarriage stowage. The high wing configuration promised lowest weight and best access to engines, armament, electronics, etc. Five aircraft sizes were considered with wing areas from 1000 sq.ft. to 1400 sq.ft., 1200 sq.ft. was selected as the best compromise between minimum weight and maximum performance. Three powerplants considered were Rolls-Royce RB106, Bristol B.OL.4 and Curtiss-Wright J67, all with afterburners, all three were then in the early development stage and had not yet run. The most promising potential armament system was considered to be the Hughes MX1179 system with six Falcon guided missiles. For purposes of comparison, the report outlined three additional proposals, two 900 sq.ft. area, twin engine aircraft, one with engines located outboard, and a 750 sq.ft. wing area, single engine design. All three were considered impractical from the point of view of meeting RCAF requirements.

In July 1953, a Ministerial directive issued from the Department of Defence Production authorized a design study to meet RCAF Specification AIR7-3 and during the next 12 months preliminary design work established loads, sizes and aerodynamic parameters. Manufacturing techniques were established and some wind tunnel work was carried out during the same period. The aircraft was to have a wing area of 1200 sq.ft., a crew of two, pilot and systems operator, armament was to consist of guided missiles and 2.75" unguided air-to-air rockets. Engines selected were to be Rolls-Royce RB106 with afterburners, however early in 1954 Rolls-Royce abandoned development of the RB106 and the Curtiss-Wright J67 was selected with a new Orenda design, subsequently designated Iroquois, slated for later versions. By mid-1954 the first production drawings were issued to manufacturing and intensive wind tunnel work began. The considerable aerodynamic advance represented by the CF-105 required extensive tunnel work, particularly to assess stability and control problems. In 1955 engines again became a problem, the USAF abandoned the J67. As a temporary alternative the Pratt & Whitney J75 was selected for Mark I aircraft. Armament was determined as Sparrow II guided missiles developed by Canadair Limited and Douglas Aircraft from the basic U.S. design. The fire control system was to be "ASTRA" developed in Canada by RCA Victor, Honeywell Controls and Computing Devices of Canada.

Design and construction work proceeded at a remarkable pace considering the complexity of the problems involved and on 23 March 1958 the first prototype flew, piloted by Avro Chief Experimental Pilot, Jan Zurakowski.

Flight characteristics proved excellent and the program proceeded rapidly with five J75 powered aircraft flying by early 1959 and construction of the first Iroquois powered aircraft well advanced.

Mk.2A and Mk.3 versions were projected, Mk.2A with variable geometry jet pipe nozzles, additional internal fuel and redesigned wing leading edge as well as changes to landing gear, structure and systems to cope with increased weight. The Mk.3 was to have more powerful Iroquois 3 engines, variable geometry intakes, variable geometry jet pipe nozzles and insulated structure.

At this time, however, a number of serious questions became apparent. In the U.K. and U.S.A. the validity of manned fighter aircraft was being questioned; costs of the Arrow, its fire control system and armament were reaching astronomical proportions; the specification had so closely tailored the aircraft to RCAF requirements that sales to other countries were doubtful; Canada was experiencing a difficult economic period and in 1957 the newly elected Progressive Conservative Government began searching for areas to reduce government spending, the Arrow naturally came under close scrutiny. On 23 September 1958, the Sparrow Missile and ASTRA fire control systems were cancelled and Arrow production was postponed, test and development work continued, however on 20 February 1959, the entire project was cancelled. All completed aircraft were destroyed and disposed of as scrap although the nose section of 25206 is now part of the National Aeronautical Collection in Ottawa as are a few other items such as wing tips, landing gear, components, etc.

CONFIGURATION DECISIONS:-

2 Crew
- complexity of fire control systems
- requirement to perform manual controlled attack in event of automatic system failure

2 Engines
- dual engine safety
- large weapon payload and fuel load dictated aircraft size too large for any single engine

Fuselage Configuration
- two seats
- large armament bay

Delta Wing
- very thin wing required for supersonic speed
- structural and aeroelastic efficiency of Delta wing made achievement of very thin wing with low thickness/chord ratio possible
- large internal fuel capacity and room for undercarriage

Tailless Configuration
- problem of mounting horizontal tail on very thin fin
- stalling characteristics objectionable with horizontal tail
- tailless Delta information available from Avro in U.K.

Wing Notch and Leading Edge Extension
- to cure anticipated pitch-up problems

Leading Edge Droop
- to increase buffet boundary by preventing leading edge aerodynamic breakaway at high angles of attack

Anhedral (4°) - to reduce landing gear length
- no appreciable aerodynamic effect

High Wing - lowest structural weight
- straight through wing structure and simple wing/fin attachment
- good access to engines and armament

Area Rule - from computer data, radar nose sharpened, intake lips thinned, fuselage cross section area reduced below cockpit, extension fairing added at rear

Engine Installation
- Iroquois finally selected for Mk.2 production and service aircraft
- fixed geometry intake therefore excess ram air to engines at supersonic speed; to eliminate spill and related high drag penalty, gills opened automatically at high speed and allowed excess air to pass over engine, cooling engine and afterburner, then passed into ejector annulus providing small additional thrust

Air Intakes
- fixed geometry with boundary layer bleed diverting 2/3 of boundary layer over and under wing, remaining 1/3 to heat exchangers of air conditioning system; intake ramp to create oblique shock wave at supersonic speed and allow optimum pressure recovery inside intake as well as prevent turbulence in intake at most of Mach number range
- perforations of intake ramp to suck off boundary layer air and prevent intake "buzz"

WINGS:- High Delta wing monoplane aerofoil section NACA 0004-6-3.7 Mod.; inner wing, four spar main torsion box, ribs parallel to fuselage, aluminum alloy machined skins with integral stiffeners (box formed integral fuel tank); outer wings joined to inner by a peripheral bolted joint, multi-spar box beam, machined tapered skins, trailing edge consisted of control boxes housing aileron linkage system, aileron attached with continuous piano hinge; ribs normal to main spars.

FUSELAGE:- Aluminum alloy stressed skin construction designed around two engines and associated intakes; fuselage sides attached to wings chordwise by continuous piano hinge, heavy formers attach wing to fuselage; cockpit between intakes; removable armament pack below intakes at centre section; titanium skin in jet pipe area.

EMPENNAGE:- No horizontal tailplane, large vertical fin and rudder, machined skins.

LANDING GEAR:- Tricycle type, nose wheel and strut retracting forward into fuselage, main wheels retracting inward into wings, twisting during retraction. Dual nose wheels, two wheel "tandem bogie" main wheel units track 30'2.5" (9.21 m).

POWER PLANT:- Mk.1, two Pratt & Whitney J75 P3 (1st a/c) P5 (a/c 2 - 5) turbojet engines, 12,500 lb.(5670 kg) static thrust dry, 18,500 lb. (8392 kg) static thrust with afterburning.

Mk.2, two Orenda PS-13 Iroquois turbojet engines, 19,250 lb. (8732 kg) static thrust dry, 26,000 lb. (11794 kg) static thrust with afterburning.

FUEL:- Two rubber cell type tanks in fuselage, six integral tanks in each wing, total fuel capacity 2897 Imp.Gal.(13170 litres), total useable fuel 2508 Imp. Gal.(11502 litres), provision on Mk.2 aircraft for one 500 Imp.Gal.(2273 litres) external drop tank.

Projected Mk.2A and Mk.3 versions with additional internal fuel.

ACCOMMODATION:- Crew of two, pilot and systems operator in tandem pressurized, air conditioned cockpits, electrically actuated clamshell canopies with emergency explosive opening devices; Martin Baker C5 ejection seats.

ARMAMENT:- Mk.1, no armament, weapons bay occupied with test instrumentation. Mk.2, **four** Sparrow IID microwave homing guided missiles in enclosed weapons bay. Quickly interchangeable armament pack, ASTRA I fire control system.

DIMENSIONS:- Wing span 50'(15.24 m); length Mk.1 73'4"(22.35 m), 80'10"(24.64 m) including probe; Mk.2 78'(23.77 m), 85'6"(26.06 m) including probe; height 21'3"(6.48 m); wing sweepback L.E.61°27', T.E.11°12'; anhedral 4°; wing area 1225 sq.ft.(113.8 sq.m); root chord at centre line of aircraft 45'(13.72 m), tip chord 52.98"(1.35 m).

WEIGHTS:-	Mk.1	Mk.2
Empty	49,040 lb.(22245 kg)	
Gross(Norm)	57,000 lb.(25855 kg)	62,431 lb.(28319 kg)
(Max)	68,602 lb.(31118 kg)	68,847 lb.(31229 kg)

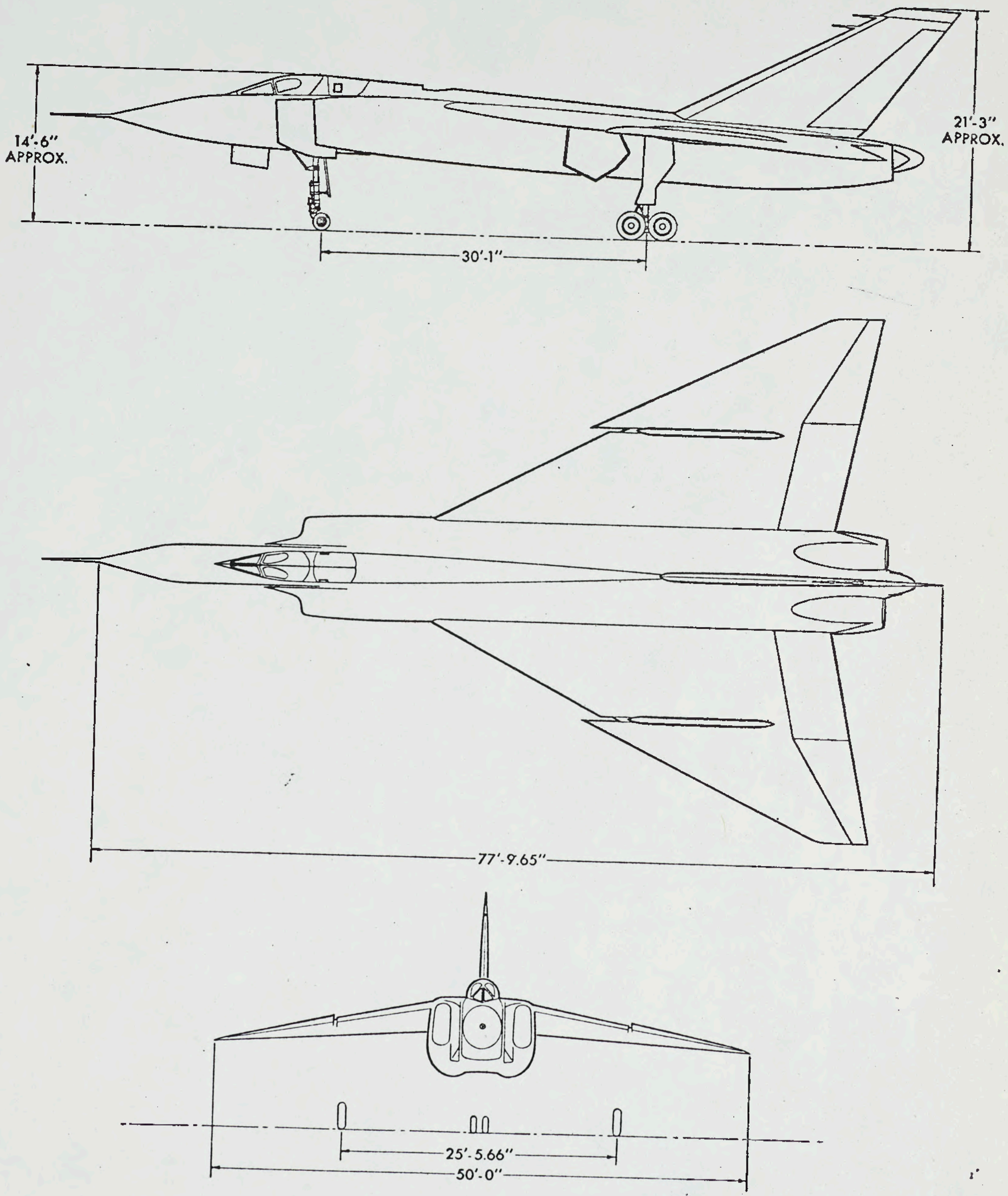
PERFORMANCE:-	Mk.1	Mk.2
Max.Speed (@ 40,000'(12192 m))	Mach 2.0 (1325 mph(2132 km/hr)	Mach 2.0 (1325 mph(2132 km/hr)
Combat Speed	Mach 1.5	Mach 1.5
Cruise Speed	Mach 0.92	Mach 0.92
Acceleration from Cruise @ 30,000'(9144 m)		1.23 min. to Mach 1.5 2.30 min. to Mach 2.0
Acceleration from Cruise @ 40,000'(12192 m)		1.95 min. to Mach 1.5 3.10 min. to Mach 2.0
Acceleration from Cruise @ 45,000'(13716 m)		3.17 min. to Mach 1.5 4.65 min. to Mach 2.0
Combat Ceiling	53,000'(16154 m)	58,500'(17830 m)
Climb	38,450 ft/min. (11720 m/min)@ S.L. 16,500 ft/min. (5029 m/min)@ 40,000' (12192 m)	3 min. to 31,250'(9525 m) 4.4 min. to 50,000'(15240 m)
Combat Radius,		
High Speed		264 miles (425 km)
Max. Range		408 miles (657 km)

PERFORMANCE:-	Mk.2A	Mk.3
Combat Speed	Mach 1.5	Mach 2.5
Combat Ceiling	58,600'(17861 m)	68,600'(20909 m)
Combat Radius,		
High Speed	575 miles (925 km)	487 miles (784 km)
Max. Range	787 miles (1267 km)	593 miles (954 km)

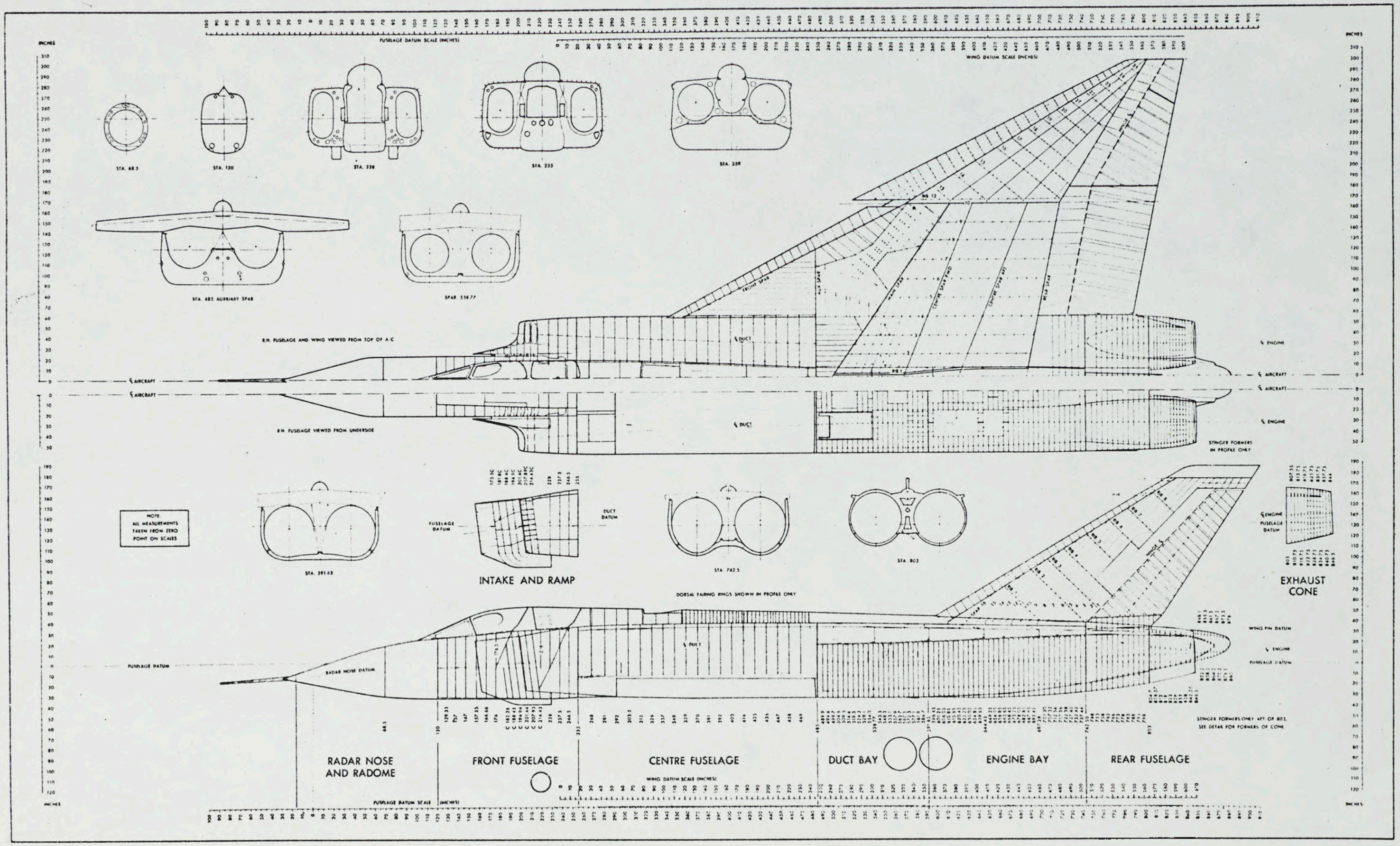
PRODUCTION:- Total of 5 Mk.1 aircraft completed and flying when project cancelled 20 February 59, first flight a/c 25201, 25 March 58. First Mk.2 a/c 25206 scheduled to fly March 1959. Total of 37 aircraft scheduled to fly by January 1961.

REFERENCE:- Avro CF-105 Arrow, Preliminary Aircraft Operating Instructions; The Avro Arrow 2, 2A & 3, Avro Aircraft; Avro Arrow Service Data, 1 Aug 58; Initial Air Force Evaluation of Mk.1 Arrow; Avro CF-105 Program Proposal (AD-44) Dec. 56; Avro Aircraft Model Specification AAMS-105/1 Nov.55; The Canadian Approach to All-Weather Interceptor Development, J.C. Floyd to R.AeS., 9 Oct 58; Air Pictorial, Feb.65.

A.J. Shortt 23.3.77

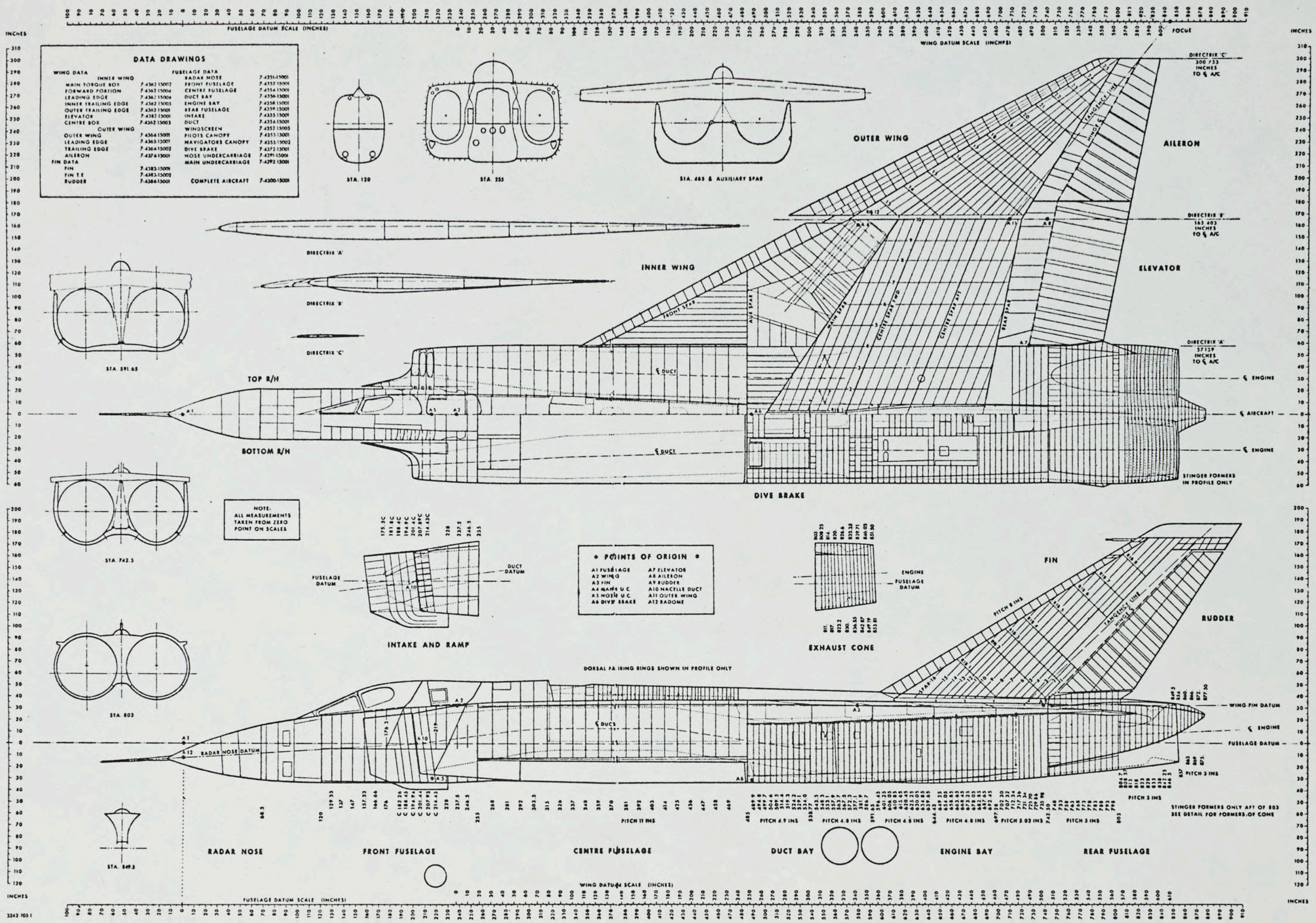


AVRO ARROW MK 1



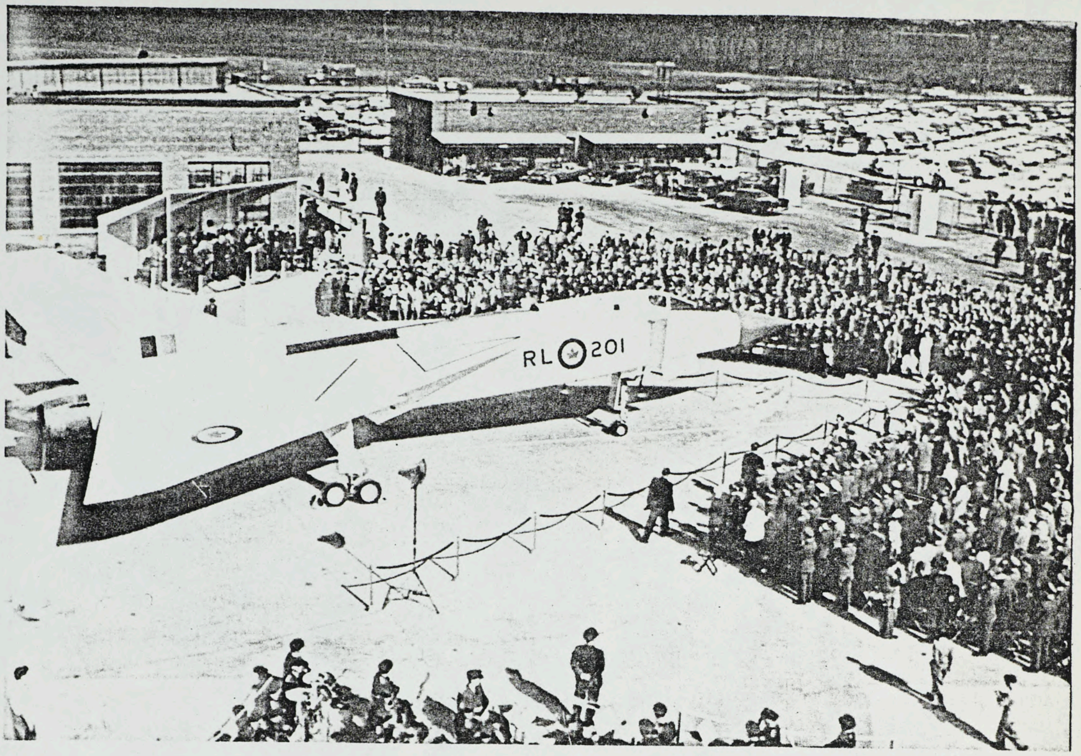
STATION DIAGRAM

CONFIDENTIAL

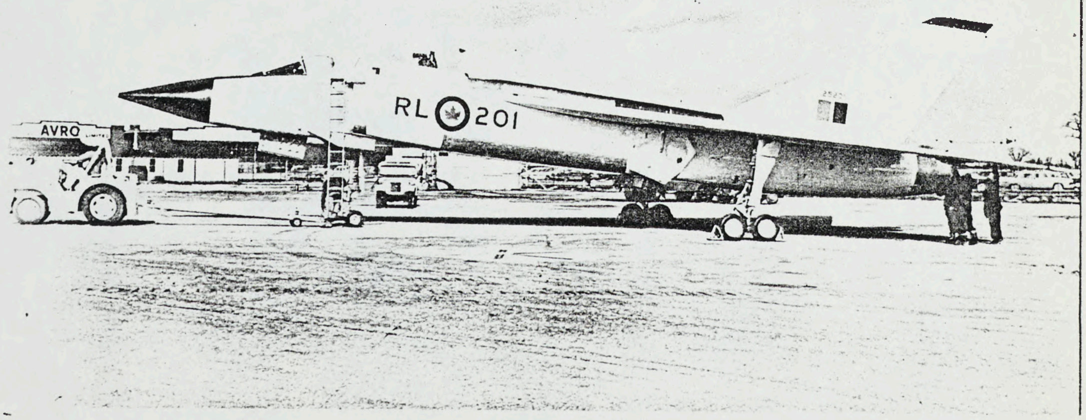


ARROW 2 (IROQUOIS ENGINE) STATION AND DATUM LINES 3 VIEW GENERAL ARRANGEMENT

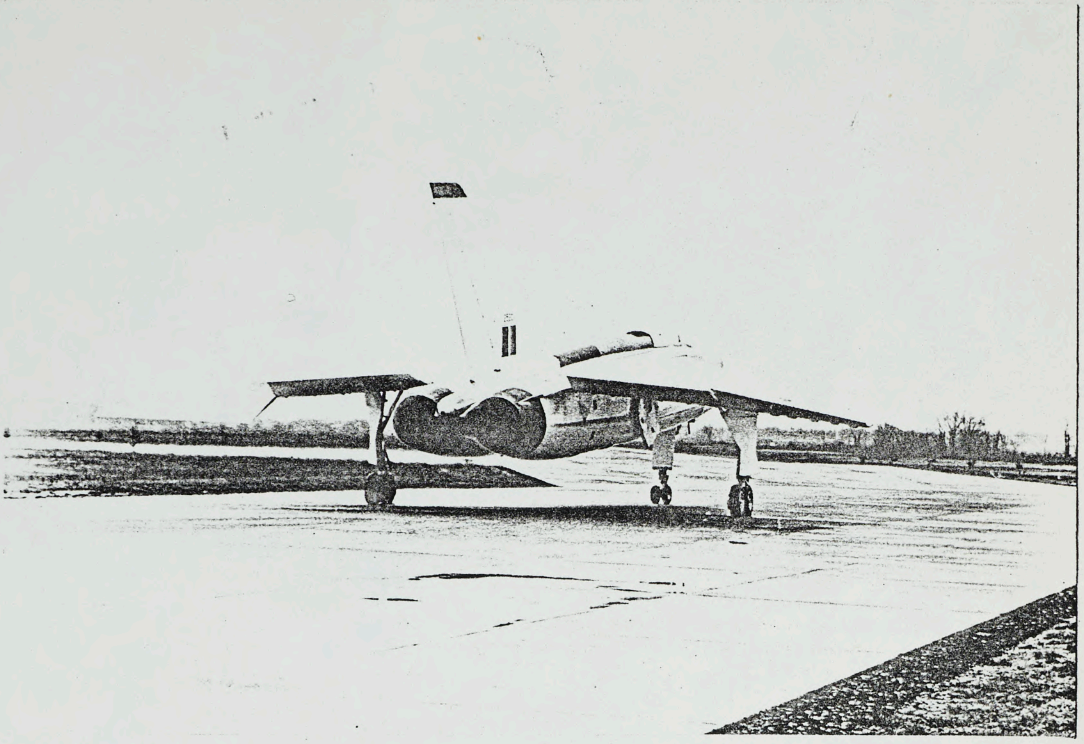
Produced by
ILLUSTRATION SECTION
SALES AND SERVICE DIVISION
AVRO AIRCRAFT LIMITED



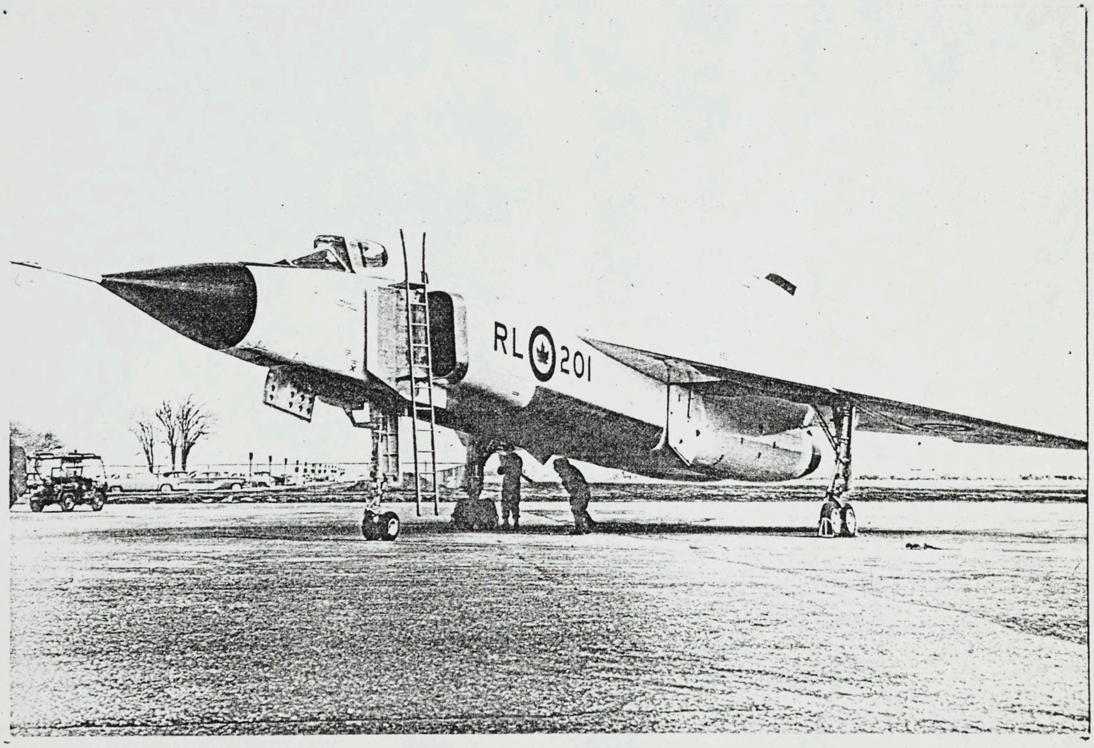
Arrow 25201, Roll-out ceremony, Malton, 4 October 1957 #1763



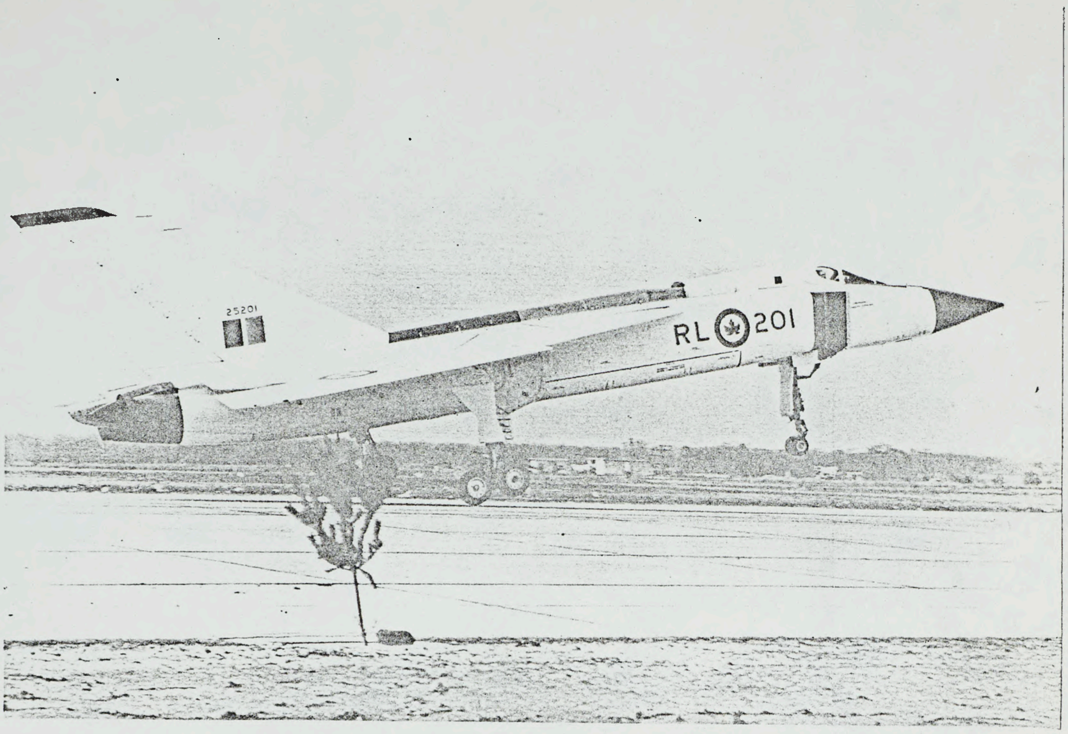
Ground handling trials, November 1957 #4084



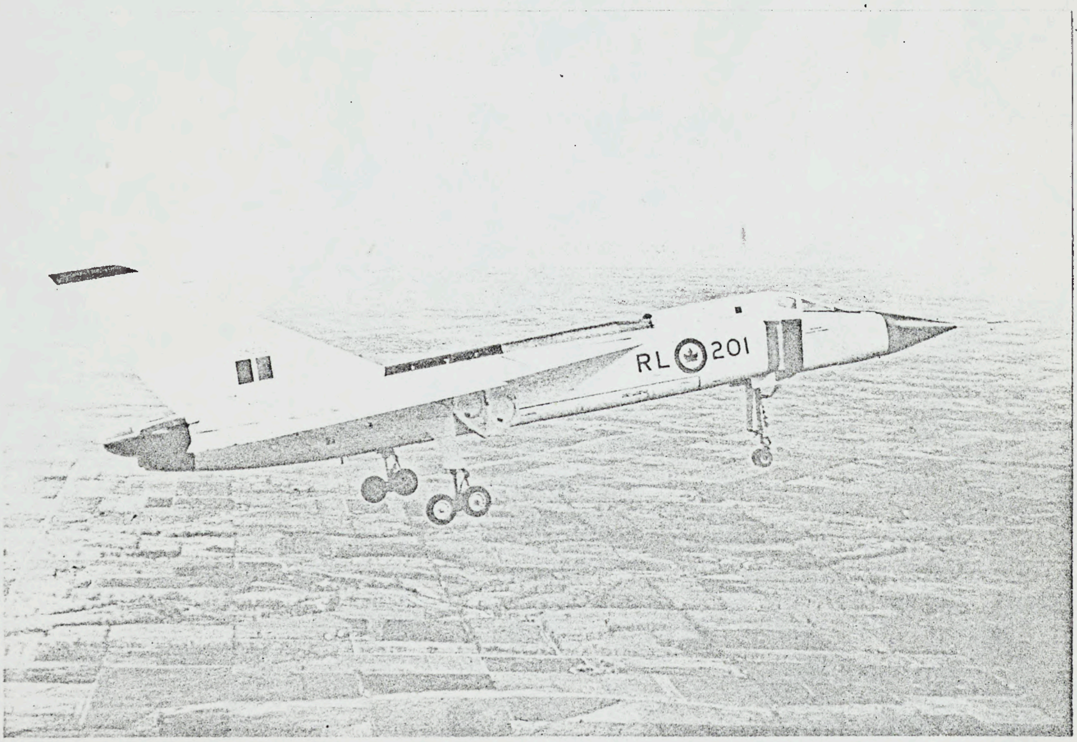
Arrow 25201, low speed taxi trials #4085



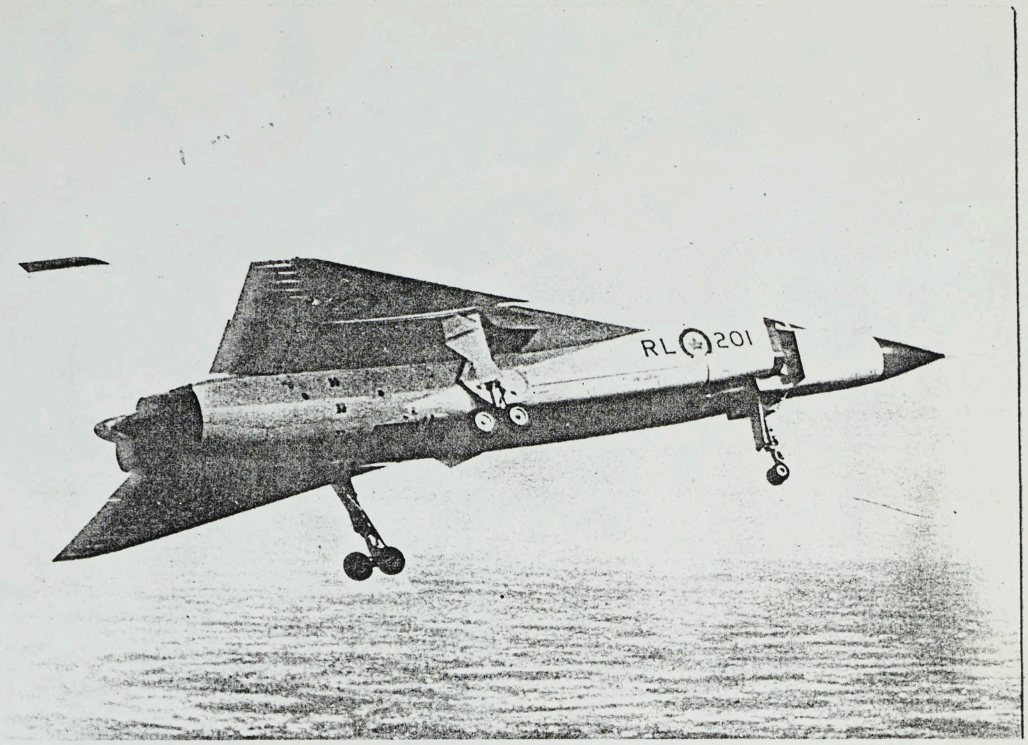
Ground handling trials, November 1957 #A1437



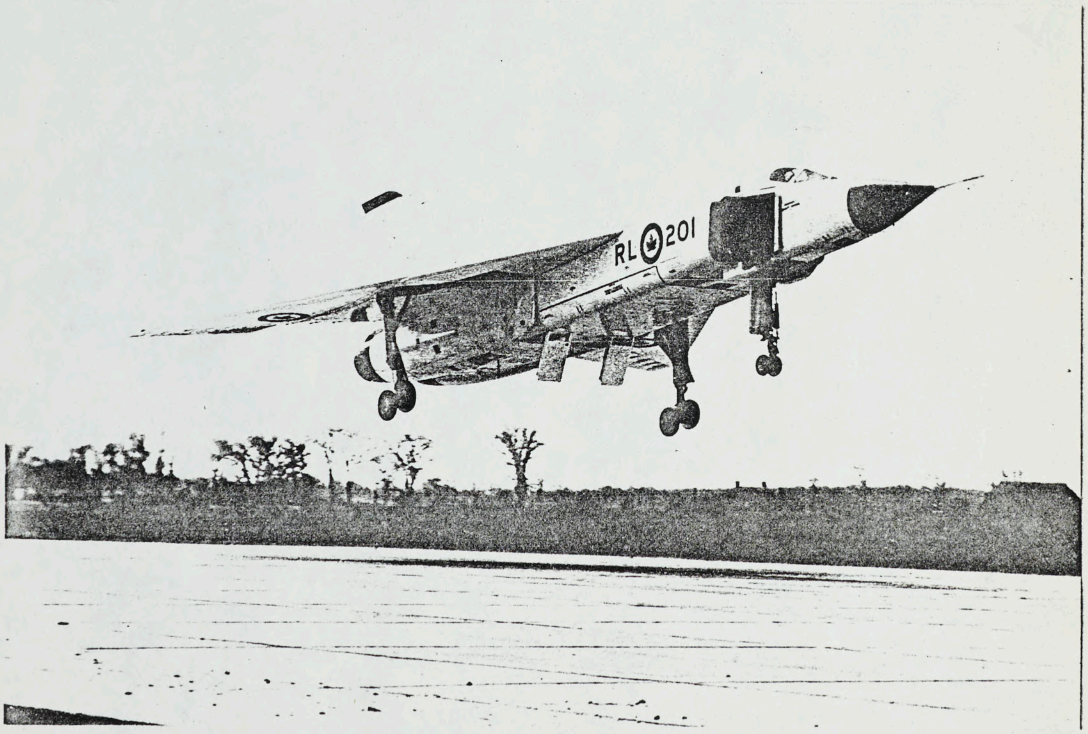
Take-off, first flight, 9:51 AM, 25 March 1958 #4081



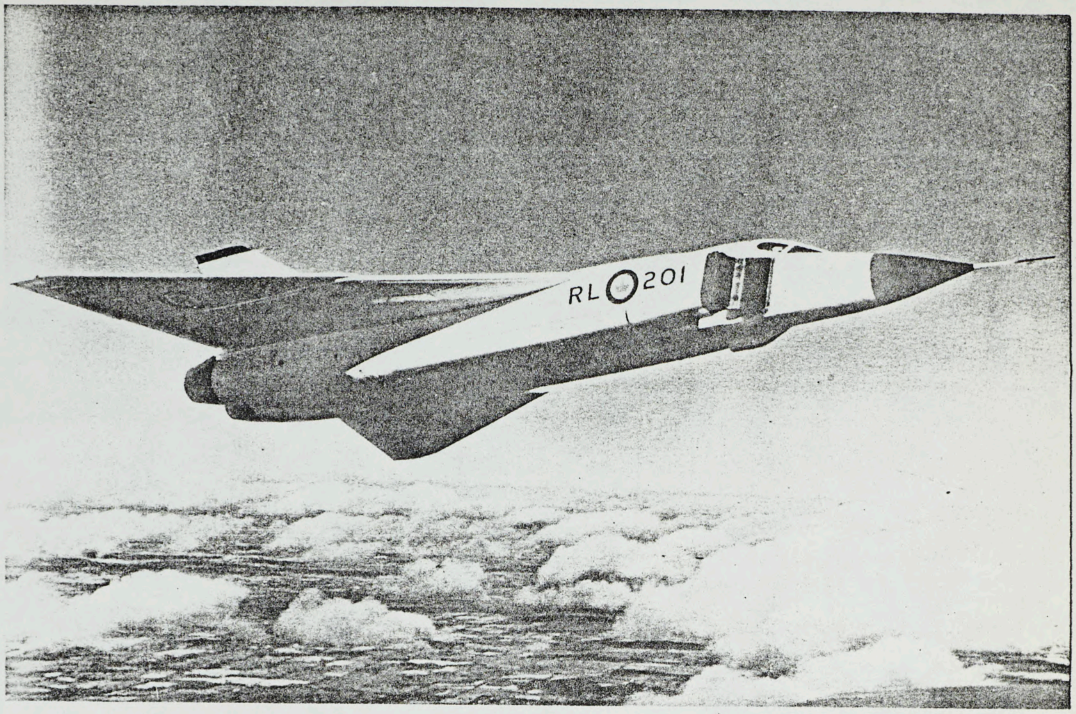
First flight, over Malton area #A1331



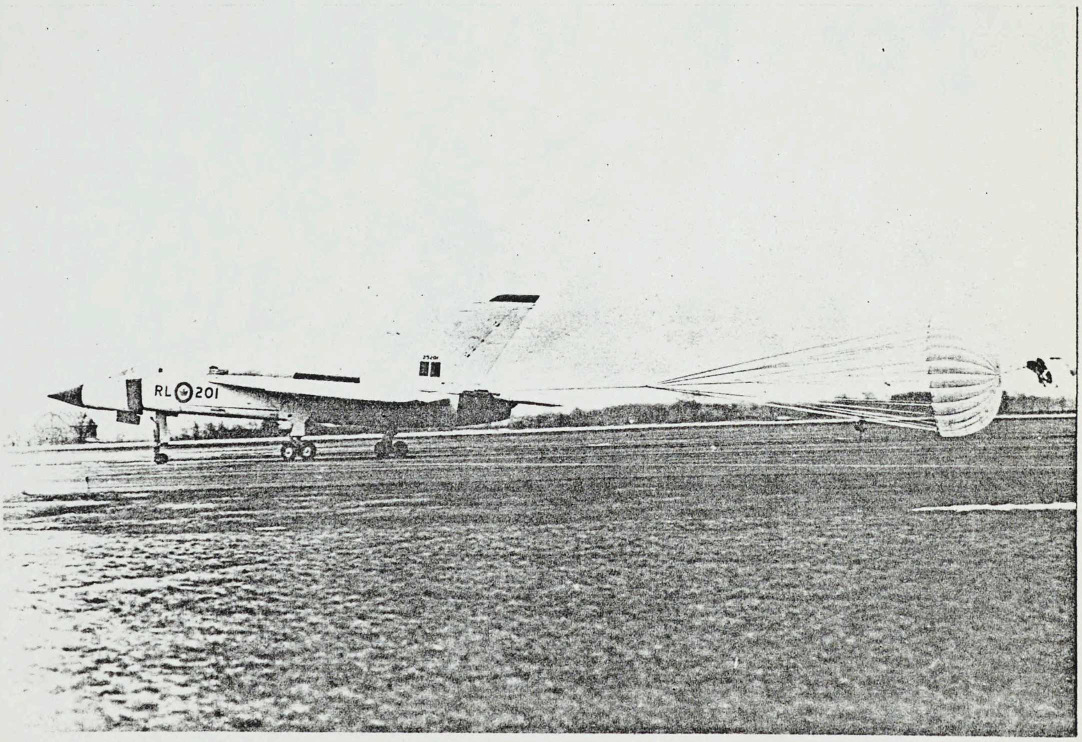
First flight, large weapons bay visible. #4076



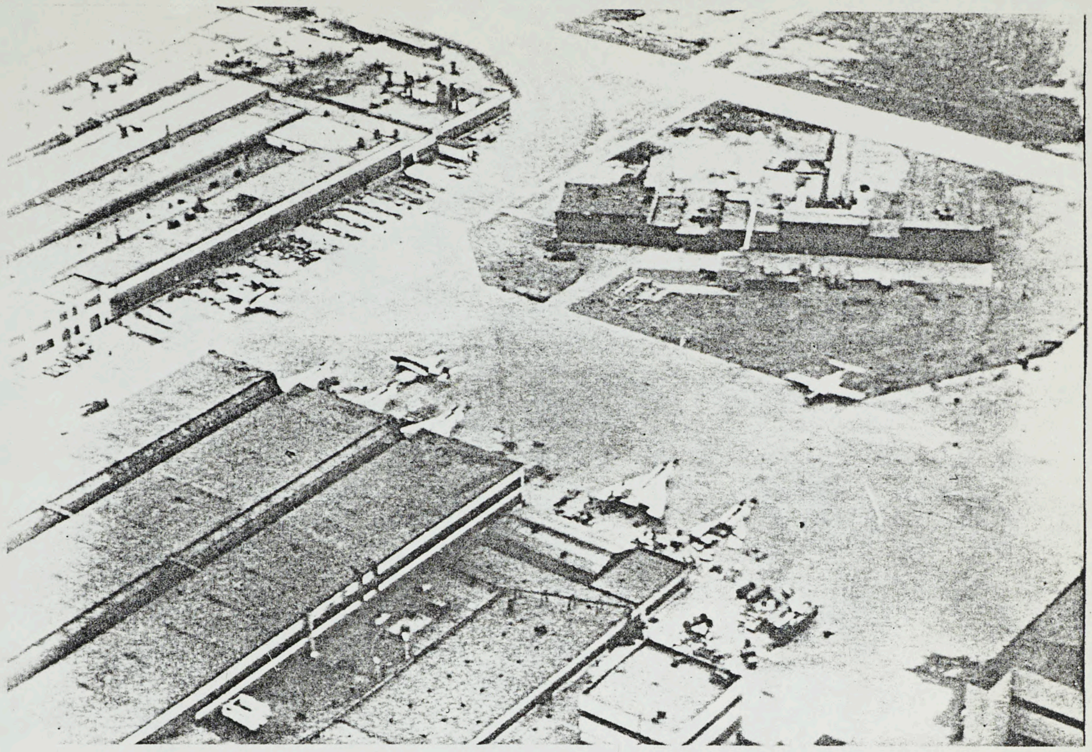
Landing, first flight, speed brakes extended #A1435



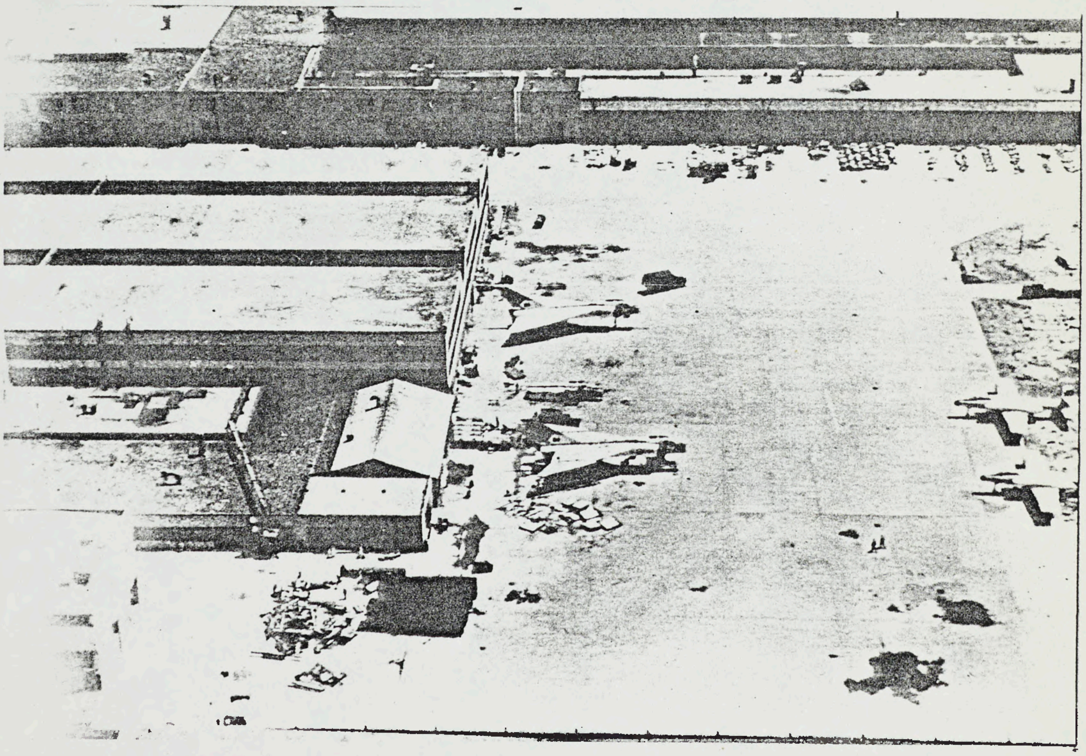
On test over Southern Ontario, April 1958 #6891



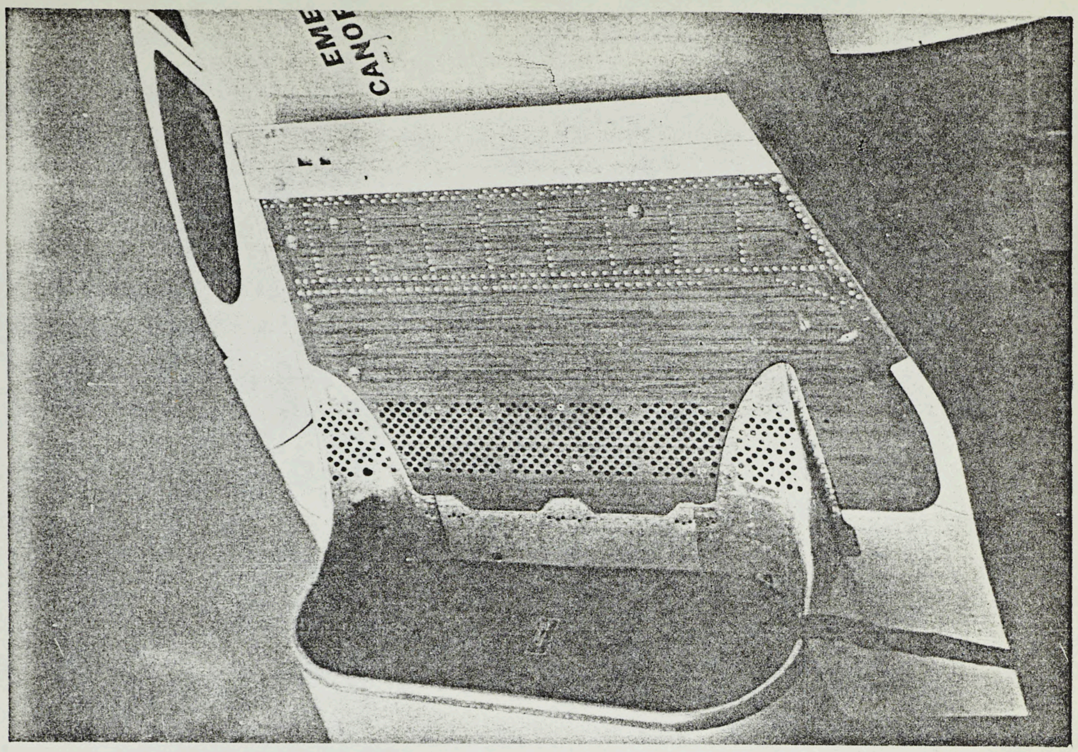
Landing, April 1958, brake parachute deployed. #4082



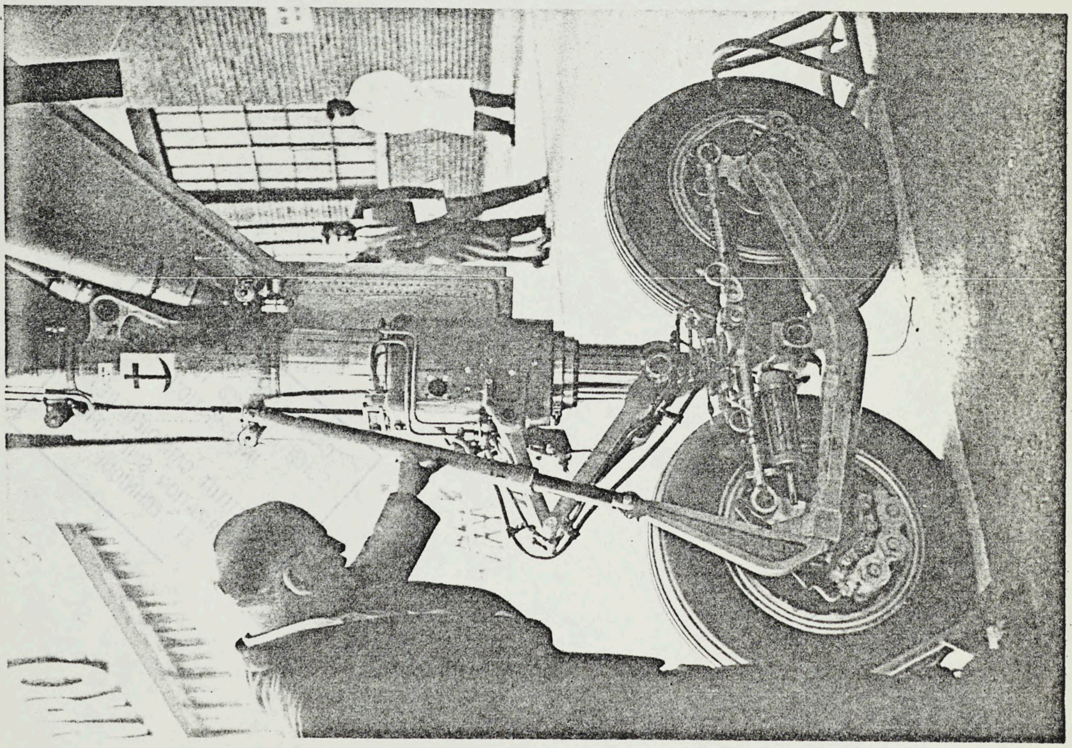
Arrows being broken up at Malton #4078
Spring 1959



Arrow 25204, nearest camera, Spring 1959 #4079



Detail, air intake #1778



Detail, main landing gear #1776