The Arrow Revealed

AVRO AIRCRAFT'S SUPERSONIC FIGHTER MAY BE AIRBORNE BY YEAR'S END

THE CF-105 ARROW, Avro Aircraft's major tour de force of the aeronautical art, was exposed to the public gaze for the first time on October 4, when a ceremonial roll-out was held at Avro's Malton, Ont., plant.

Although the configuration of the Arrow was well known in broad terms prior to this roll-out, few onlookers present were prepared for the sight of swiftness embodied.

Advance publicity on the Arrow indicated that it was a big airplane, grossing approximately 68,000 pounds. At no time is this more evident than when in close proximity.

Fine Lines: Yet the designers have achieved such a fineness of aerodynamic line, that when one moves far enough away to get the whole aircraft into proper perspective, it doesn't seem unduly large.

The Arrow has been designed as a true supersonic airplane; that is, it will be able to cruise at supersonic speeds. Maximum design speed is understood to be in the order of Mach 2.0. Operational ceiling has been quoted at "over 60,000 ft." and is probably about 65,000 ft. Range is equal to that of the CF-100, which is approximately 1,500 miles (without tip tanks).

It has been said that the Arrow will be able to reach 60,000 feet in four minutes, a figure that on consideration does not appear unreasonable in view of the fact that when the Arrow 2 comes along, its two Orenda Iroquois, with reheat in operation, will produce a thrust at sea level of some 54,000 lbs., about enough to give a power/weight ratio of 0.8/1.0 . . . . sufficient to make possible near vertical flight during the first several thousand feet of the climb.

Short Take-Off: It has been emphasized by Avro that the Arrow will be able to operate from existing runways; a feature that is also attributable to the great power available. However, landing presents somewhat more of a problem, and in order to stop the aircraft within the limits of existing runways, it will be necessary to have recourse to a drag chute as part of normal landing routine. So far, no mention has been made of the possibility of incorporating thrust reversal, but it may be confidently assumed that such a development is being studied by Orenda engineers.

First flight of the Arrow may take place before the end of the year, though Avro is not committing itself definitely on this deadline. Following the roll-out from the production bay, the aircraft was moved to flight test where it has since been undergoing a series of ground tests covering engine run-up, fuel, electrics, hydraulics, and other systems. These will be followed by runway trials, which will eventually lead to the historic first flight.

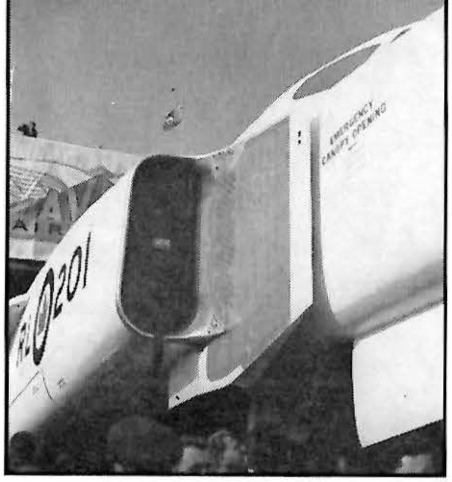
At the controls the first time the Arrow breaks ground, and throughout the initial stages of the test program, will be Jan Zurakowski, Avro's chief experimental pilot.

Double Sweep

FOR GENERAL purposes, the Arrow has been described as having a delta planform; however, it would be more accurate terminology to call it a "modified delta", having two slightly different angles of sweep to the leading edge of the wing, as well as a moderately swept trailing edge. The leading edge is interrupted by a sawtooth jag. From the wing root out to the sawtooth, the sweep is some 61°; from the sawtooth to the tip the sweep is a slightly greater 63°. The trailing edge is swept back about 11°.

The wing is extremely thin, in the physical as well as the aerodynamic sense (in the latter case, it is probably about 4% at the root), and has pro-

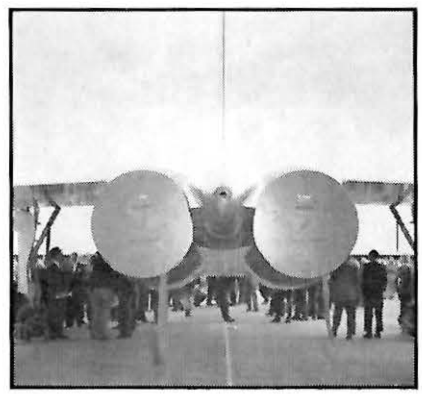
Avro Aircraft workers and guests at the unveiling ceremony swarm around the Arrow for a detailed inspection.



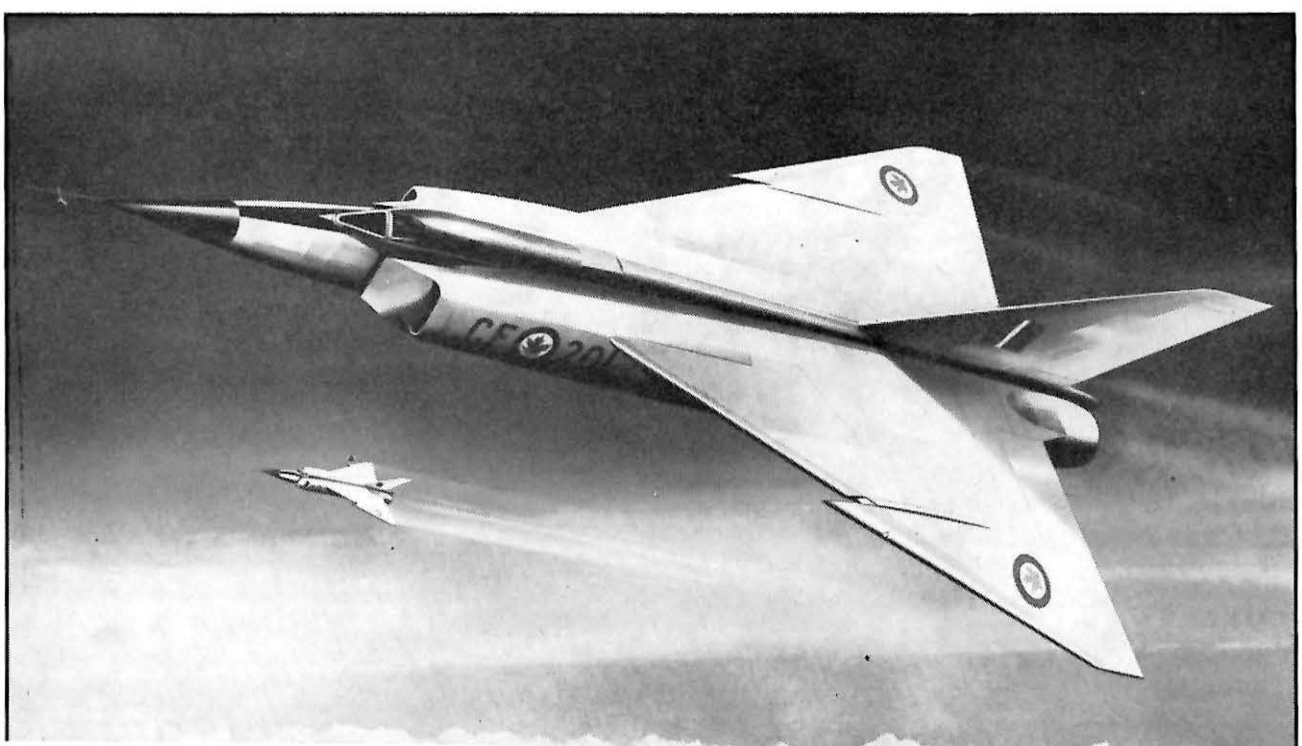
Chisel-edged intake ramp has multitude of approximately ½ in. diameter holes at inlet's lip, probably comprising some form of boundary layer bleed.

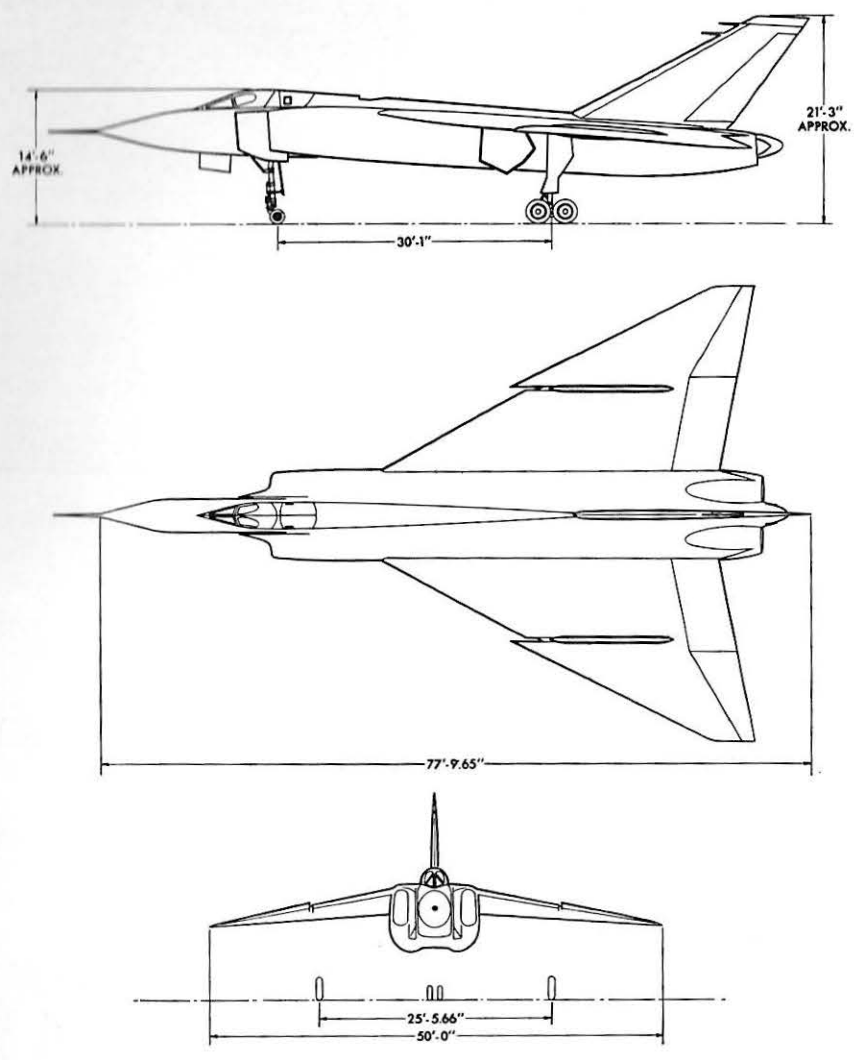
Main undercariage twists and shortens when retracting. Main gear is by Dowty; nose gear by Jarry. Note extended and notched leading edge. Depth of wheel well is indication of wing's extreme thinness.

Leading edge camber can be seen in this photo. Also evident is fine workmanship, as typified by smooth skinning. Tires, wheels and brakes are by Goodyear Tire.



Skinning around tailcone and jet pipes is stainless and/or titanium. Drawing below is artist's impression of how Arrow will look when airborne.





AVRO ARROW MK 1

nounced anhedral. The fine leading edge has an easily discernible droop, fixed. The trailing edge is quite thick — about three-quarters of an inch — and is very abrupt. That is, the edge is not tapered to a thin edge, or even rounded off; it is simply machined flat. The wing tip ends are similarly straight and flat.

The control surfaces are very large, the elevators in particular. The considerable elevator area makes it easily understandable why the elevator power control jacks had to be designed for an output load of over 70,000 lb.

Notched Edge: At the point where the sawtooth of the leading edge occurs, there is also a notch which extends back to the point where what appears to be a rather thick fence begins. This apparent fence — in cross-section it seemed a half round bulge — reaches almost to the hinge line of the control surfaces.

The purpose of previous applications to subsonic aircraft of the sawtooth leading edge has been to reduce the thickness/chord ratio, delaying compressibility stall, thereby maintaining smooth airflow over the ailerons at high Mach numbers.

In the case of the leading edge notches, they are also to be found on the English Electric P.1A and B, where their vortex-generating capability does away with the need for wing fences. However, the Arrow has what appears to be fences in addition to the notches.

This first aircraft is one of a production batch of unspecified quantity. It is powered by two Pratt & Whitney J-75's rated at some 20,000 lb./th. for take-off with reheat. This powerplant will go into the initial few aircraft off the line (understood to be five), while the Orenda Iroquois of 27,000 lb./th. (with reheat) will be installed in succeeding aircraft. The J-75 aircraft have been designated the Arrow 1, while the Iroquois-powered versions will be known as the Arrow 2.

Production Tooling: It has been underscored that the first Arrow is not a protoype in the usual sense of the word. It is not a hand-made model produced in an experimental shop. Instead, it has been built with the same production tooling as is being used for the following aircraft in the pre-production batch. All these aircraft will, of course, be used for development work in its many phases and in this way the development program will be greatly accelerated, enabling the Arrow to get into operational service that much sooner.

The wing forms the envelope for integral fuel tanks, the flow from which is automatically controlled through a crossfeed system. The automatic control (Honeywell Centre of Gravity Control System) ensures that the fuel is selectively fed from the various tanks to the engines in such a way that the longitudinal trim is not disturbed. This is especially important in an airplane such as the Arrow where the rate of fuel consumption is so high that to take all the fuel from one source could cause serious disruptions of trim balance faster than a crew man could counter them.

The first Arrow lacks armament and probably important components of the electronic system — especially in connection with fire control — currently under development by Radio Corp. of America and associated Canadian subcontractors.

Although there is no actual armament in this initial aircraft, provision has been made for the weapons bay. The armament will, it is anticipated, comprise air-to-air guided weapons. The Sparrow 2 has been mentioned in this connection, but it seems likely that something more advanced than this weapon will be available by the time the Arrow is ready for operational service.

Bomb Carrier: Other roles that the Arrow will be able to fill, besides that of an all-weather interceptor, include those of photo reconnaissance and attack. Avro says it can even carry a nuclear weapon, thus giving it a bomber capability not hitherto publicized.

The electronic system which RCA is charged with developing includes that for fire control, navigation and communication, and an integrated automatic flight control system. In connection with the latter, Minneapolis Honeywell's Aeronautical Div. is responsible for development on an associate basis. Canadian companies working on the electronics system under subcontract to RCA and M-H are Honeywell Controls Ltd., RCA Victor Ltd., and Computing Devices of Canada Ltd.

The effects of aerodynamic heating had to be considered in the design of the Arrow, for elevated temperatures significantly reduce the allowable stresses and elasticity of all metals, as well as other materials. In this regard, it will be noted that the Arrow does not have the blown clearview plastic canopy that has come to be accepted as more or less standard equipment for modern high speed aircraft. This is because the skin temperatures which are likely to be encountered are such that a plastic canopy would soften to the extent that, because of the effects of pressure differential, it would blow up like a bubble to point of failure.

As a result, the Arrow's windscreen and sideview panels for the pilot are made of tempered glass about an inch thick.

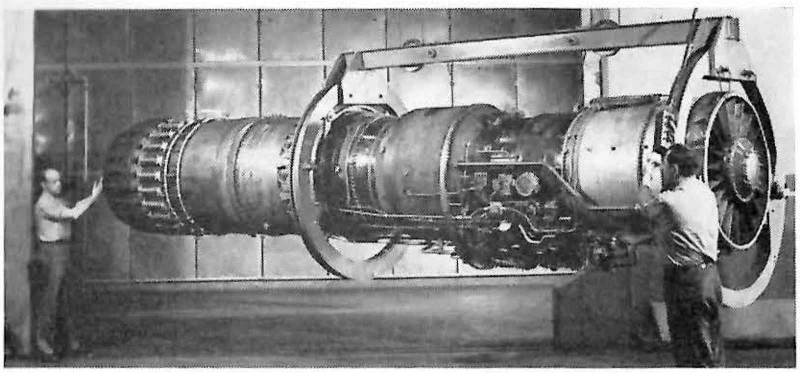
And although aerodynamic heating has caused some serious problems in the development of the Arrow, the effect of this phenomenon is apparently not considered critical. Says Avro: "The present Arrow is on the threshold of the heat barrier, popularly called the 'Thermal Thicket', and studies are now under way to adapt the aircraft for even higher speeds to pierce this barrier."

Not the Last: The Arrow has frequently been described, often by authoritative voices, as being the last manned fighter aircraft that Canada will develop. However, more and more often it is being opined, with equal authority, that this isn't necessarily so.

And on the occasion of the Arrow roll-out, Avro Aircraft President Fred Smye added his voice to those disagreeing with the "end of the manned fighter" school of thought. Then Minister of National Defence George Pearkes summed up the thinking of the dissenters by noting that . . . "Much has been said of late about the coming missile age, and there have been suggestions from well-intentioned people that the era of the manned airplane is over, and that we should not be wasting our time and energy producing an aircraft of the performance, complexity and cost of the Arrow.

"They suggest that we should put our faith in missiles and launch straight into the era of push-button war. I do not feel that missiles and manned aircraft have, as yet, reached the point where they should be considered competitive. They will, in fact, become complementary. Each can do things which the other cannot do, and for some years to come both will be required in the inventory of any nation seeking to maintain an adequate 'deterrent' to war. However, the aircraft has this one great advantage over the missile. It can bring the judgment of a man into the battle and closer to the target where human judgment, combined with the technology of the aircraft, will provide the most sophisticated and effective defence that human ingenuity can devise."

POWER FOR THE ARROW 1



The engine that powers the Arrow 1, the Pratt & Whitney J-75, has been described by its maker as "the most powerful production turbojet known to exist in the world".

As installed in the Arrow, with afterburner, the J-75 is rated at some 20,000 lb./th. for take-off. The Orenda Iroquois, which is scheduled for the Arrow 2, is currently rated at 27,000 lb./th. for take-off, with reheat.

Comparative weights of the two engines (both as fitted with afterburners) are 5,500 lb. for the J-75, and 4,000 lb. for the Iroquois. Specific fuel consumptions (without reheat) are 0.80 lb. per lb./th./hr. for the J-75 and 0.85 lb. per lb./th./hr. for the Iroquois.

The Pratt & Whitney J-75 has been designed for speeds of up to Mach 2.0. It features a 16-stage two-spool axial compressor, cannular combustor and a three-stage turbine.

The engine has a diameter of 45 in. for a frontal area of 11 sq. ft. The length with afterburner is not available, but it is probably approximately the same as that of the Iroquois, i.e., 264 in. The Iroquois has a diameter of 42 in. and a frontal area of 9.6 sq. ft. The comparative dimensions of the two engines are such that the planned switch from J-75 to Iroquois will not affect the external geometry of the airframe, though there will inevitably be some internal structural modifications.

The J-75 has an annular magnesium alloy air intake casing, with six radial struts supporting the front main bearing. There are 18 fixed incidence steel inlet guide vanes. Anti-icing is effected with hot bleed air.

The J-75's two spool compressor comprises a low-pressure unit and a high-pressure unit. The low-pressure compressor is a nine-stage axial flow type enclosed in a two-piece drum type steel casing, with steel stator blades. The drum type rotor, which has steel blades, has stub shafts supported in one ball bearing at the front end and in two ball thrust bearings at the rear end, where it is connected to the splined inner drive shaft from the second and third-stage turbine wheels.

The high-pressure compressor is a seven-stage axial flow type with a drum type steel casing which is fitted with steel blades. The drum type rotor also has steel blades and is supported in the front by a single ball bearing and at the rear by two ball thrust bearings. At the rear end it is spline-connected with the outer drive shaft from the first-stage turbine wheel.

Pressure ratio of the HP compressor is 12:1, and air mass flow 300 lb./sec. at take-off rpm.

The cannular type combustor has a steel outer shell and eight interconnected Inconel alloy flame tubes. There are six fuel burners in each tube, with downstream injection.

The three-stage axial turbine is encased in steel. The casing has hollow nozzle vanes and solid stator blades. The turbine wheels are of Timken 17-22-A (S) alloy, with solid "Waspaloy" blades. The first-stage HP turbine wheel is flange-bolted to the drive shaft, supported in one ball bearing. The second and third-stage LP wheels are flange-bolted to a stub shaft supported in a single ball bearing ahead of the wheels and a single ball bearing behind the wheels.

The afterburner is fitted with a variable area iris-type nozzle, and has a Chandler-Evans AR-7 afterburner fuel control.