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# AVRO ARROW

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Design

## Design

June 24, 1999

*The Arrow 206 on the assembly line.*

The Arrow was primarily a triumph of innovative design. Here we glance at a few of the aircraft's design features.

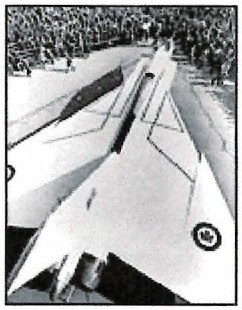
*For a more in-depth treatment of the Arrow's design, see* Technical Aspects of the Avro CF-105 Arrow *by Stephen R. Payne and A.J. Shortt of the National Aviation Museum.*

*For detailed drawings and plans of the Arrow, visit exn.ca's* The Arrow Diagrams*. a collection of 17 technical drawings of the Arrow.*

### RCAF specifications

*From left to right, Robert Lindley, Cheif designer, Jim Floyd, Vice President of Engineering, Guest Hake, Arrow Project Designer, and Jim Chamberlin, Cheif Aerodynamist.*

In April 1953 the RCAF released their demanding specifications for a new supersonic interceptor, known as Air-7-3, "Design Studies of a Prototype Supersonic All-Weather Aircraft", which called for a craft that could function in the uniquely Canadian context of a vast northern wasteland. They were without parallel in the world of aviation. The twin-engined, two-seat fighter should be able to operate from a 6000 ft runway, have a range of 600 nautical miles (11000km). It was to cruise and combat at Mach 1.5 at an altitude of 50,000 feet and be capable of pulling 2g in maneuvers with no loss of speed or altitude. It was to be equipped with a sophisticated fire control system, and to have an all-missile weapon system which would operate either independently or as part of an integrated defence system. The high speed mission radius was to be at least 200 nautical miles. The time from a signal to start the engines to the aircraft's reaching an altitude of 50,000 feet and a speed of Mach 1.5 was to be less than five minutes. The turn around time on the ground was to be less than ten minutes.



**Airframe Design**

The choice of a twin-engined, two seat design was typical of the uniquely Canadian challenges – the vast emptiness of the Northern wastes. Unlike the USAF, which selected a single seat, single engine design for its modern interceptor, the RCAF felt the workload for a single pilot in bad weather or at night would be too high. The CF-105 was to operate in very cold weather, but to remain resistant to the superheating which came with sustained high-speed flight. Titanium was extensively used, and an environmental control system capable of producing 23 tons of ice per day was installed to protect the crew and instruments.

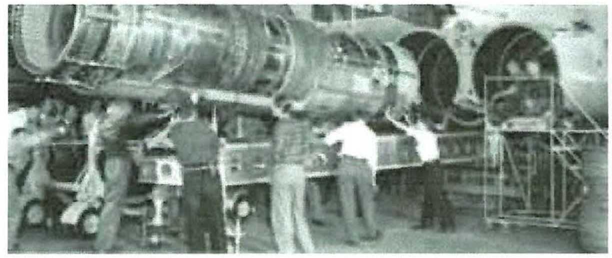
Because of the immediate need to counter the Soviet threat of the day, there was to be no prototype. This meant that an unprecedented amount of testing would have to take place, involving wind tunnels, models, elaborate rigs and an early version of computer simulation. The result was that time-consuming and costly custom-manufactured prototypes were eliminated, and instead an assembly line was set up from the first model onward. This meant the initial development price would be higher, but the cost would more than be defrayed once the plane went into production. This is important to consider when deciding whether the Arrow would have been an economically feasible project or not. As it turned out, the price of producing the first Arrow in terms of man-hours to weight ratio cost significantly less than previous aircraft.

The fuselage had a subtly pinched, wasp-waisted "Coke-bottle" shape that wasn't immediately noticeable. This was an aerodynamic concept known as the Area Rule, which reduces drag to a minimum. The aircraft also used a then-revolutionary control system known as "fly-by-wire", where instead of using rods and cables to link the pilot's controls with actuators on the airplane, electronic signals sent through wires did the job instead, faster and with less effort on the part of the pilot. This is in common use now, but it was pretty hot back in the late 50s.

**Iroquois Engine**

The Arrow Mk.2 was to

be powered by two Orenda PS-13 Iroquois engines, the development of which was begun in 1953. It was designed to deliver 8,720kg dry thrust and 11,800kg with afterburner. These engines consumed enormous amounts of fuel when flying at supersonic speeds, close to a quarter ton per minute. Engine weight was important in such a large plane, and to keep the weight down, expensive and rare metals like titanium were used. Of a total weight of about 2000kg, 30% of the weight of the Iroquois was accounted for by titanium parts. The final Arrow Mk.3, with even better engines, was expected to fly at Mach 2.5.



*The Iroquois engine getting ready to be placed into the engine cavity*

Because the Iroquois would not be available for the first prototypes, it was decided to use the Pratt & Whitney J75 to power the Mark 1 prototypes and pre-series aircraft. The thrust of the J75-P-3 with full afterburner was 8390kg, equivalent to the maximal dry thrust of the Iroquois.

Noise from the Iroquois was said to permanently deafen a human at 100 metres, and perhaps kill at closer ranges. The engines were installed at the extremities of the aft fuselage, with the engine nozzles projecting well beyond the wing trailing edge and the tail. They could be changed in 30 minutes, by extracting them backwards. The Iroquois' weight-to-thrust ratio made it the most powerful engine of the American continent, and it was said to be fuel efficient. Development costs had not amounted to more than 90 million dollars, considered inexpensive even in the 1950's.

**Armament**

The Arrow's complex and expensive radar and fire control system ended up being one of its major Achilles heels, and its story is indicative of the processes that brought down the project.

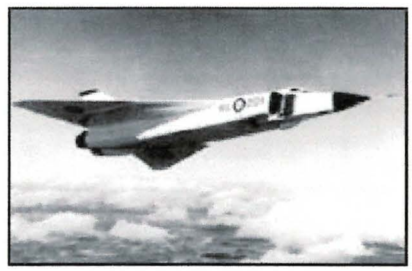
A search for an alternative weapons system began after it was determined that the Canadian-grown Velvet Glove air-to-air missile developed for the CF-100 would be inadequate for supersonic combat.

The original idea was to fit the Arrow with Falcon guided missiles built by Hughes Aircraft, along with a Hughes guidance system. However the RCAF, against the advice of Avro and the USAF, decided to adopt the more-complex Sparrow II missile, then under development for the U.S. Navy. They ordered a new Canadian-built guidance system called the Astra, designed by weapons-newcomers RCA-Victor, to marry the missile to the Arrow.

Unfortunately, the U.S. Navy cancelled the Sparrow development in 1956, calling it too ambitious. The project was taken over by Canadair and Westinghouse Canada. The cost of assuming this development was to prove too much in the end, as was the expensive Astra fire control system. Both were cancelled in September 1958, some six months before the Arrow's cancellation, ostensibly to be replaced with the original Hughes-built Falcon system that Avro had recommended. This vacillating and overspending was to contribute greatly to the image of the Arrow as a money loser.

The Arrow was intended to use only missiles as armament, and they were to be stored in a huge internal missile bay larger than that of a B-29. The internal bay not only protected the missiles from the weather but also reduced drag. Maintenance access was simplified by adopting a high, shoulder wing structure.

### Wings



Though quite a few wing designs were examined, the high delta wing was decided upon as the most aerodynamically efficient for a high-altitude, high-speed interceptor. The wings were placed high, over top of the fuselage as opposed to under it, allowing the engines and armament packages to be changed more easily and without requiring any modification of the wing structure. The large delta wings provided an opportunity to stow away other elements such as fuel tanks and, in the thicker wing root, the landing gear. The leading edges were drooped, more strongly on the outboard wing sections.

A tail wing placed on the thin tail fin would be strongly affected by air currents called wing downwash, or else would have to be placed so low that landing angles would be compromised. The resulting tailless configuration gave the Arrow its distinctive look.

Characteristic dogtooth notches along the front of each wing controlled airflow across the wingspan of the large delta wings. This allowed higher angles of attack and made the craft aerodynamically superior. Variations of these are quite common on modern aircraft such as MiGs, which have posts that serve the same purpose.

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