# FLYING THE AVRO ARROW†

**by Jack Woodman***

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## INTRODUCTION

It has been more than 19 years since the Arrow program was cancelled. The Avro Arrow is still, however, a subject of great interest among Canadian aviators, and the program is still being talked about. I am sure that many people are still wondering whether the decision to cancel the Arrow program was the right decision. However, I am not here to discuss politics, but rather to describe for you as best I can remember and from the limited material available, the design of the Arrow, the flight test program, and handling and performance qualities.

The go-ahead for the design and development of the Arrow was first authorized by the Canadian Government in July of 1953 and was assigned the project number CF-105. Preliminary design was complete the summer of 1954; the first engine-runs December 4, 1957; first taxi trials Christmas Eve, 1957; and the first flight March 25, 1958. Jan Zurakowski, Project Pilot and Chief Development Pilot for Avro, made the first flight, which lasted 35 minutes, and reported good flying qualities, no surprises, no trouble, and made the general comment, "It handled very nicely". John Plante, Executive Vice-President and General Manager, said "The first flight on any aircraft is a tremendous achievement, but we have a lot of work to do yet". It was a proud moment in Canadian aviation.

Unfortunately, less than one year later, on February 20, 1959, the Arrow program was cancelled. The Canadian Government elected to go with the Bomarc missile rather than to develop and produce the Arrow. Five airplanes had been built and flown; the sixth, and the first to have production Iroquois engines, was on the line and ready to go. The aircraft, the reports, and the paperwork were all destroyed. Approximately 68 hours of flight time had been accumulated, and 95% of the flight envelope partially explored. However, the capability and potential of the aircraft and its weapons system were never realized. When it was all over and done with, only four pilots could say they had flown the Avro Arrow – Jan Zurakowski, Spud Potocki, Peter Cope and myself.

### BRIEF HISTORY OF PROGRAM

| | | |
|---|---|---|
| Program Go-Ahead | – | July 1953 |
| Project No. | – | CF-105 |
| Preliminary Design Complete | – | Summer 1954 |
| First Engine Runs | – | Dec 4, 1957 |
| First Taxi Trials | – | Dec 24, 1957 |
| First Flight | – | Mar 25, 1958 |
| No. of Aircraft Flown | – | 5 |
| Flight Hours (Total) | – | 68 hrs, 45 min |
| Pilots Checked Out | – | 4 |
| Program Cancelled | – | Feb 10, 1959 |

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† Presented at the Flight Test Symposium, May 16, 1978 in Winnipeg.
* Director of Flying Operations.

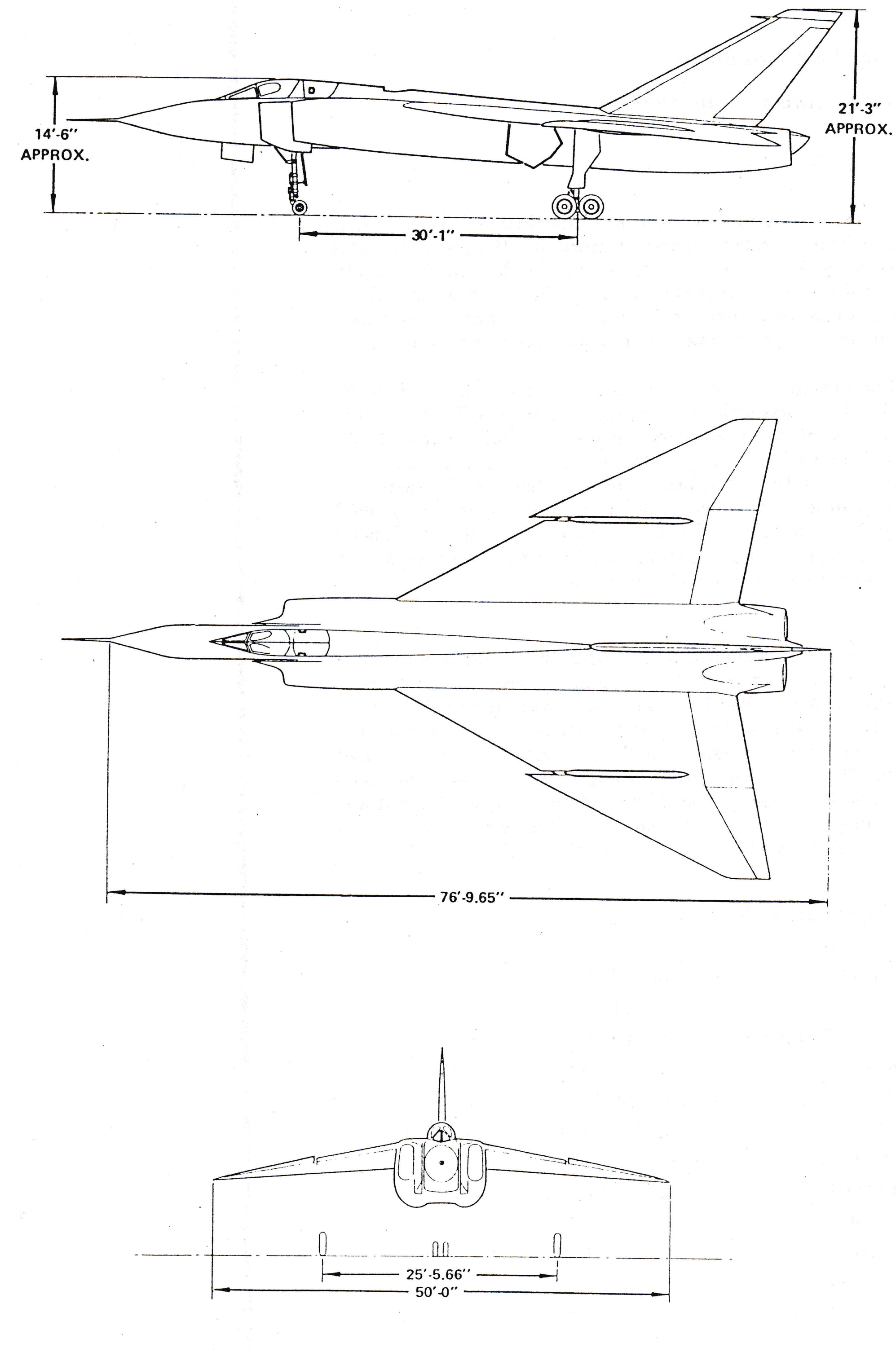



Figure 1

## AIRCRAFT CONFIGURATION

The Avro Arrow Mk 1 was a twin engine, two-seat, delta wing, all-weather interceptor designed specifically to meet the peculiar Canadian defence requirements. There were a number of relatively unconventional features on the Arrow, and aerodynamically the CF-105 was, I believe, a considerable advance over contemporary aircraft. The Arrow program was a very ambitious project for Avro and for the RCAF, but seemingly well within reach and most likely attainable. Some of the design features are worth mentioning, as detailed in the following descriptions.

## DESIGN FEATURES

The dimensions and general configuration of the aircraft are shown in Figures 1, 2 and 3. The crew consisted of a pilot and a radar operator. The advantage of a two-seat airplane as compared to a single-seat airplane lay in the complexity of the fire control system, even though the system was intended to be entirely automatic. The choice of two engines was a combination of circumstances, with the main advantage being reduced attrition. Perhaps the main factor, however, was the very large weapons package required as payload and the large amount of fuel required to meet the range requirements. In the early design, the range requirements pretty well sized the airplane, and at that time there was must no single engine large enough to provide the required power. The Arrow Mk 1 was powered by two Pratt and Whitney J75-P3 engines, each of which produced 18,500 lbs of thrust at sea level, with afterburner.

### Flight Limitations – Arrow Mk 1

| | |
|---|---|
| – Max Takeoff Weight | 69,000 lbs |
| – Normal Combat Weight | 64,000 lbs |
| – Max Landing Weight | 65,000 lbs |
| – Max Speed | 700 kts EAS<br>Mach 2.0 |
| – Max Altitude | 60,000 ft |
| – G-limits | 7.33/–3.0 |
| – Landing Gear | 250 kts EAS |
| – Escape System – Max Speed | No limit |
| Min Speed | 80 knots |
| – Max Angle of Attack | 15° |

### The Wing

The choice of a delta wing design versus a straight or sweptback wing was, I believe, a compromise to achieve structural and aeroelastic efficiency with a very thin wing and at the same time to achieve the large internal fuel capacity required for the specified range. The structural advantages of the delta design made achievement of this thin wing section possible. (CF-105 thickness/chord ratio = 3.5%; CF-100 Mk 1 was 10%.) Some characteristics of a delta wing include:

*No Stall* – There is no well-defined stall for a tailless delta and this is perhaps the outstanding feature. It permits flying the airplane to much lower speeds compared to straight or sweptback wings. Minimum speed is usually determined by sink rate and/or minimum control.

*Ground Effect* – Since ground effect is a function of chord length, not wing span, the effect with a delta wing can be very pronounced. This simplifies the flare and landing problem. Landing the CF-105 was quite straightforward.

*Light Wing Loading* – CF-105 wing area was 1225 sq ft, and at normal combat weight, wing loading was approximately 50 lbs per sq ft. This gave good manoeuvrability at high altitude, high speed, and was also structurally strong.

*Attitude* – The delta wing will have a higher angle of attack for any given $C_L$, which means an increase in pitch attitude and possibly flying on the back side of the power-required curve during approach to landing. Attitude was the limiting factor with the CF-105 during landing; handling qualities remained good throughout.

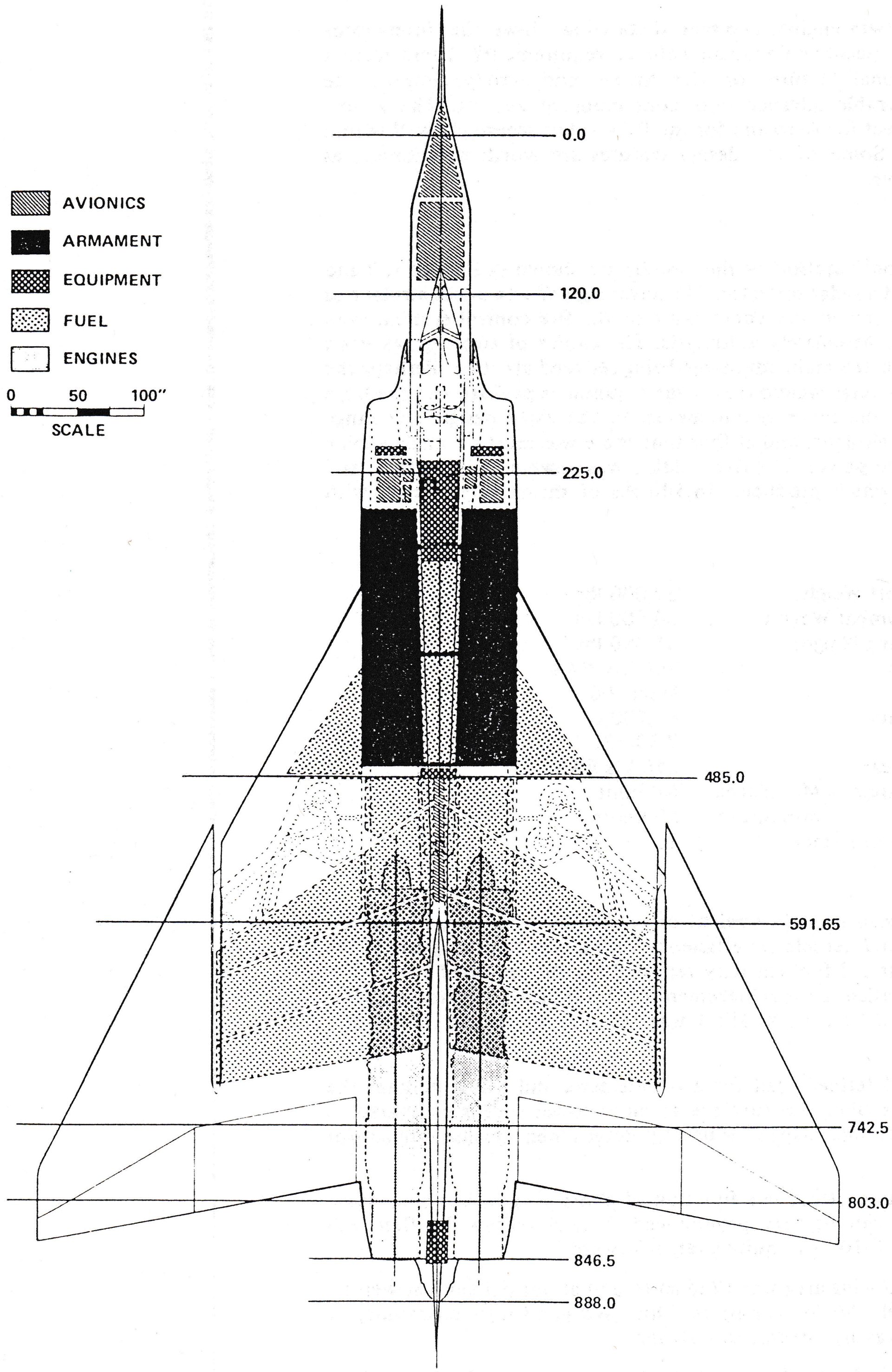

AVIONICS
ARMAMENT
EQUIPMENT
FUEL
ENGINES
0
50
100"
SCALE
0.0
120.0
225.0
485.0
591.65
742.5
803.0
846.5
888.0

Figure 2

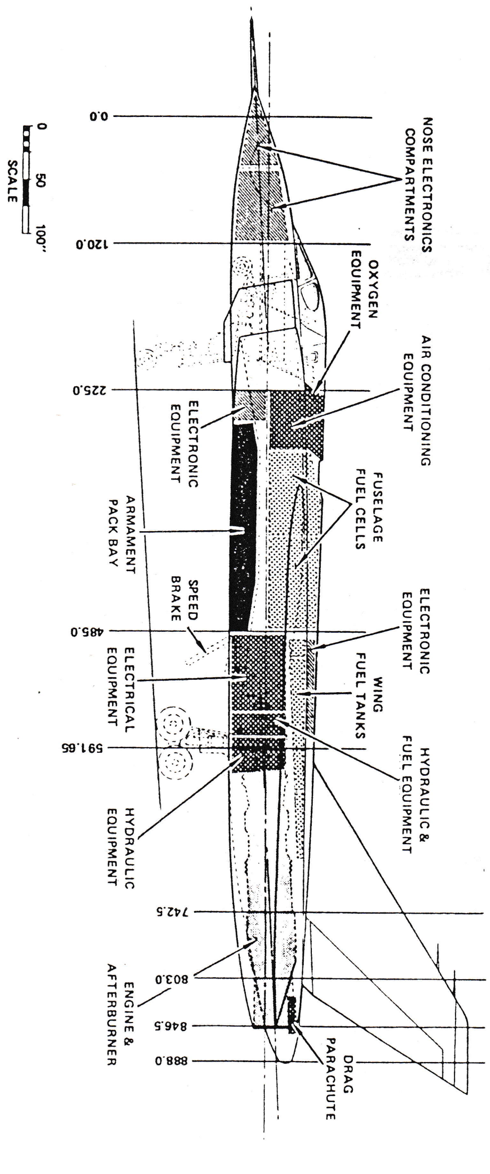



Figure 3

Analysis showed that, due to a short elevator arm, high elevator angle would be required to trim at high altitude, which would create excessive trim drag. To compensate for this, approximately 0.75 percent negative camber was built into the wing, which had the effect of building in elevator angle without the excessive control surface drag.

The CF-105 had a leading edge notch and a leading edge extension about midspan on the wing. The purpose of the notch and the extension was to control the spanwise flow of the boundary layer air, characteristic of all swept wing aircraft, not just deltas. This is necessary to eliminate early flow separation, stalling of the wingtips, and the aerodynamic centre shifting forward and giving pitchup, which is embarrassing to any pilot. The notch is similar to a wing fence, but it produces its desired effects by airflow rather than by a physical barrier, and it was Avro's opinion that the effects of the notch were present over the entire speed range of the aircraft rather than just a portion of it. Also, the notch was expected to increase drag by a smaller amount than a fence.

The leading edge of the Arrow wing was drooped approximately $8^{\circ}$ inboard and $4^{\circ}$ outboard. This was done to increase the manoeuvre margins and the buffet boundary by preventing leading edge breakaway at high angles of attack. Determination of $C_{L max}$ was never accomplished in flight test; however, wind tunnel results showed that at Mach 0.92, the $C_L$ was increased from 0.26 to 0.41 due to leading edge droop.

Another peculiarity of the CF-105 wing was $4^{\circ}$ anhedral. This was on the airplane strictly to reduce the length of the landing gear, and had no appreciable aerodynamic effect or significance.

A high wing arrangement was adopted because of the flexibility this permitted. For example, this allowed a relatively simple engine installation. Also, any changes in engines or armament could be made without affecting the basic wing structure. This is not always the case with an integrated wing/fuselage structure.

## Structure

A great deal of theoretical work was done on the application of area rule to the CF-105, and during the early design stages

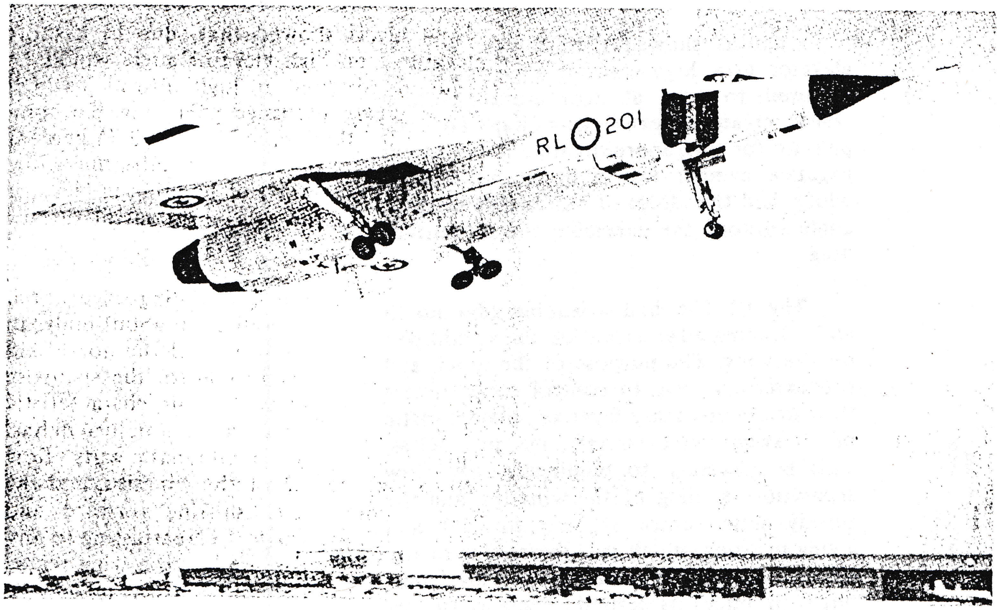



Figure 4

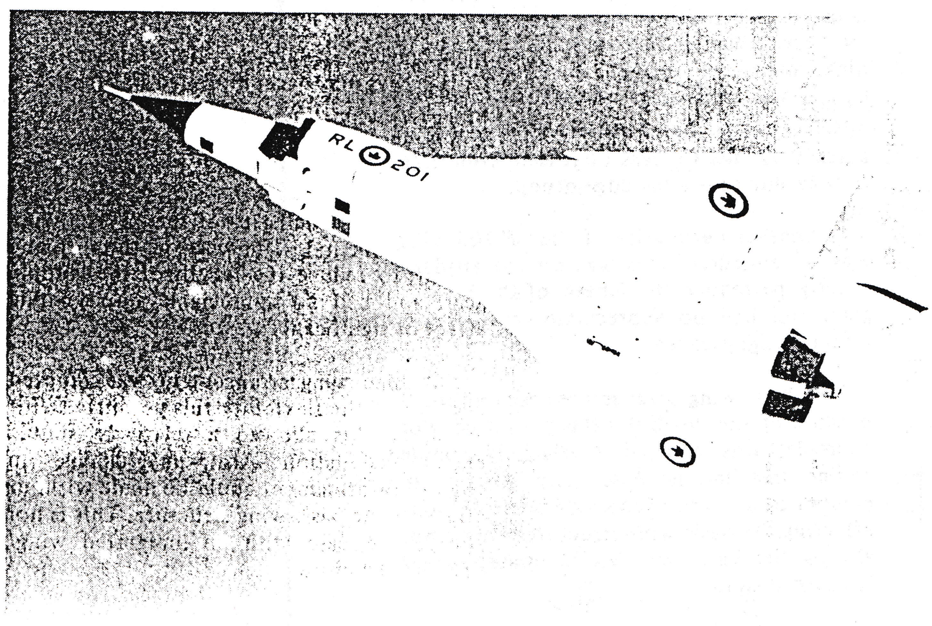



Figure 5

certain changes were incorporated. For example, the radar nose was sharpened, the intake lips thinned down, cross section area of the fuselage reduced below the canopy, and an extension fairing was added at the rear of the fuselage.

*Engine Intake*

The CF-105 air intake was a fixed geometry intake. Intake gills immediately adjacent to the compressor inlet opened automatically at Mach 0.5 and allowed air to bypass the engine for cooling purposes and to alleviate spillage at high Mach numbers. It is interesting to note the similarity between the Arrow inlet and the McDonnell F-4 inlet. The arrangement of the intakes consisted basically of the following:

- A boundary layer bleed that diverted air in the boundary layer over the top and bottom of the wing, as well as air being taken into the heat exchangers in the air conditioning system.

- An intake ramp used to create an oblique shock wave at supersonic speeds in order to achieve optimum pressure recovery characteristics inside the intake and, combined with the normal standing shock, to prevent inlet instability and inlet "unstart" over the Mach number range.

The angle of the intake ramp was $12^{\circ}$. The face of the ramp was perforated to prevent "intake buzz", caused by the interaction between the inlet shock and the boundary layer from the ramp.

*Wing and Fuselage*

The structure of the CF-105 was relatively conventional. The outer wing consisted of multispar, boxbeam, heavily tapered skins and ribs running to the main spars. The outer wing was bolted to the inner wing by a peripheral joint covered by a fairing. The inner wing consisted of a main torsion box containing spars, ribs, and machined skins.

The fuselage was designed basically around the two engines, with the cockpit in between the intakes. The engines were suspended from the inner wing.

Materials used were mainly aluminum and magnesium alloys, although titanium was used extensively in the area of the jet pipe, where low weight and high strength were required at temperatures up to $800^{\circ}$F.

Avro manufacturing capability included a big metal-to-metal autoclave, a special heat-treat furnace, a giant skin mill, heavy machining equipment, and a 15,000-ton rubber pad forming press, which at the time was the largest of its kind in the world.

The fuselage, wings vertical stabilizer, and control surfaces were all of metal construction. The tandem bogey main wheels were attached to the inner wing main torquebox. Speedbrakes were fitted below the fuselage, and a drag chute was installed in the aft end of the fuselage. Space in the radar nose and armament bay was utilized for test equipment and instrumentation.

Systems

The aircraft systems (the fuel system, hydraulic system, electrical system, pneumatic system, etc.) were all relatively conventional except, perhaps, for the landing gear and the flying control system. *(Systems being developed for Arrow Mk 2 were far more advanced. Ed.)*

*Landing Gear*

The tricycle landing gear consisted of a forward retracting nose gear with dual wheels, and main gear with two-wheeled bogeys, which retracted inboard and forward into the wing. Cockpit control was by means of a lever in the shape of a wheel, located on the LH forward panel. and it was operated by a simple up or down motion. Emergency lowering of the landing gear was by a 5000-psi nitrogen bottle, which, when activated, released the door and gear uplocks, and the gear then fell in a normal manner by gravity, aided by air loads.

The problem with the CF-105 landing gear was one of stowage. Because of the high, thin wing the gear was relatively long. In order to stow the gear, it had to be shortened and twisted as it retracted. On the eleventh of June on the eleventh flight of the first airplane, the gear failed to extend completely, even though cockpit indicators showed it down and locked. The landing was made with the left main gear cocked approximately 30° to one side. In other words, it had not fully untwisted. The landing roll was about 4000 ft, and, of course, with the port leg twisted it pulled the aircraft to one side. As the aircraft left the runway and came in contact with soft ground, the undercarriage snapped. The aircraft came to rest on its RH gear and LH wingtip. Because of the excellent photographic coverage, the cause of the accident was quickly determined. Avro had the airplane flying again approximately 4 months later, and flight procedure from that time was to have a chase-plane check gear extension prior to landing. Zurakowski was the pilot, and I know that if he had only had some indication of a problem, the accident would never have occurred.

*Flying Controls*

The CF-105 flying controls were a fully powered, irreversible, artificial feel control system. There were three modes of operations: a normal mode, an automatic mode, and an emergency mode. The automatic mode was not installed in the early aircraft. Two independent hydraulic systems provided the muscle, each with two engine driven pumps. The supply was 4000 psi. Also, a ram air turbine was to have been installed on later aircraft for use in the event of a two-engine flameout.

In the normal mode, a damping system provided stability augmentation for all three axes, and co-ordinated rudder movement with movement of the ailerons and elevators. Artificial feel was provided by an electrical system in such a way that stick force required was made to feel proportional to the amount of g's pulled. Stick force per g was constant, irrespective of speed or altitude.

When the pilot exerted a force on the control column to move the elevators, a force transducer on the control column transmitted electrical signals to a series of servos, which converted the electrical signals into mechanical movement by means of hydraulic pressure. The electrical output at the transducer was directly proportional to the force exerted at the grip. The control column would move as the force was exerted, as with a conventional flying control system, but it was not moved directly by the pilot. Movement of the control column followed the movement of the elevators. The response of the system was virtually instantaneous, and it therefore appeared as if the control column were moved by the pilot.

In the emergency mode, the force transducer was taken out of the loop. The control column was linked by cable directly to the hydraulic actuators, which controlled the elevators. Artificial feel was provided by a spring-loaded assembly along with a bob-weight, which induced loads on the control column and made control column movement progressively heavy as g's were applied.

Operation of the ailerons and the rudder by means of electrical signals, or by cables, was very similar to operation of the elevators. Components in the systems differed slightly, but from the pilot's point of view, the systems operated in a similar manner. The damping system was duplicated in yaw, however, as this was the critical axis and of major importance to the safety of the airplane in the high speed range. The airplane in the lateral-directional axis was naturally unstable. It was designed that way, by necessity, to meet performance requirements specified by the RCAF.

The flying control system was anything but developed at the time the program was cancelled, and if I remember correctly, it had No. 1 priority in the flight test program. The airplane, at certain speeds and altitudes, flew as well as any I have ever flown; at other points control was very sensitive and the airplane difficult to fly accurately. However, I know it was just a matter of optimizing the controls, the damping system, and the feel throughout the complete flight envelope. And it *would* have been accomplished.

I know the control system sounds sophisticated and perhaps overly complicated, and maybe it was for its time. But the Arrow flight control system was very similar to the systems being used now in today's most advanced aircraft. If the automatic mode had been installed, we would have had what is known today as Control Wheel Steering (CWS), i.e., flying the airplane through an autopilot. The Arrow control system was the same as a "fly-by-wire" system except for the mechanical linkage provided in the emergency mode.

I cannot help but feel that if Avro had been permitted to develop the Arrow, both Avro and Canada would have been recognized as leaders in the field of high performance airplanes.

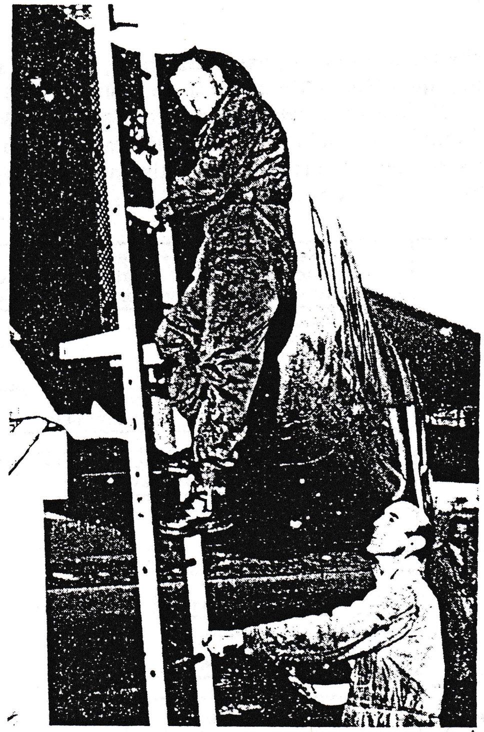
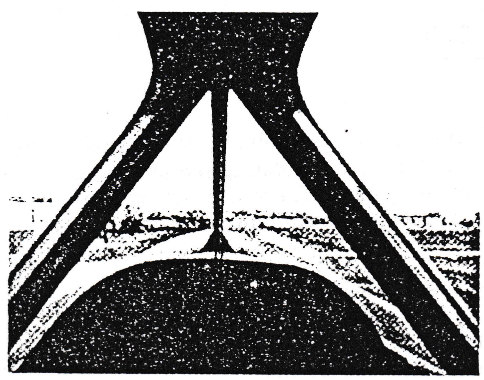


Figure 6 KEN LARMOUR

### Cockpit

The cockpit was generally comfortable and well arranged. It was a bit small, and with a pressure suit some of the controls and switches on the side consoles were difficult to see or operate. There were only 2 or 3 inches of clearance between the canopy and the pilot's helmet, and I remember hitting the canopy with my helmet on several occasions with normal head movement and look-around.

Entry and exit to the cockpit was by means of a vertical ladder, 9 to 10 steps high (see Figure 6), hooked over the engine intake ramp. From the ladder, you stepped to the top of the engine intake, over the canopy, and down into the cockpit. This was a little awkward. Also, I think it would have been a source of trouble in squadron service, with people stepping on the side railing and air conditioning ducts with dirty or snow-covered boots. Generally, however, I think the cockpit was quite comfortable.



Pilots' view from the cockpit of the Arrow shows excellent visibility despite slight nose-up attitude while taxiing. Photo was taken from mobile cockpit mock-up.

Figure 7

The parachute harness and the seat harness were combined, and strapping in was relatively simple. Leg restraints were used to pull and hold pilots' legs back against the front of the seat pan during emergency ejection. A Martin-Baker C.5 automatic ejection seat was used, which provided an escape envelope from ground level up.

Figure 7 gives you an idea of the pilot's forward view from the cockpit. The Arrow had a V-shaped windshield and vision splitter. This is not, in my opinion, the best kind of windshield to fly behind, but it was obviously satisfactory, and Avro did a good job with forward visibility.

## FLIGHT TEST PROGRAM

The flight test program was scheduled for eight phases. Basically, the first series of tests were to evaluate the general handling qualities of the aircraft, to evaluate the flying control system and damping system, to check instrumentation and telemetry techniques, and to check safety under adverse conditions. The eight phases of the program are shown in Figure 8. The initial series of flights entailed preproduction testing and development, using the first five aircraft with the J75 engines. This was the Arrow Mk 1.

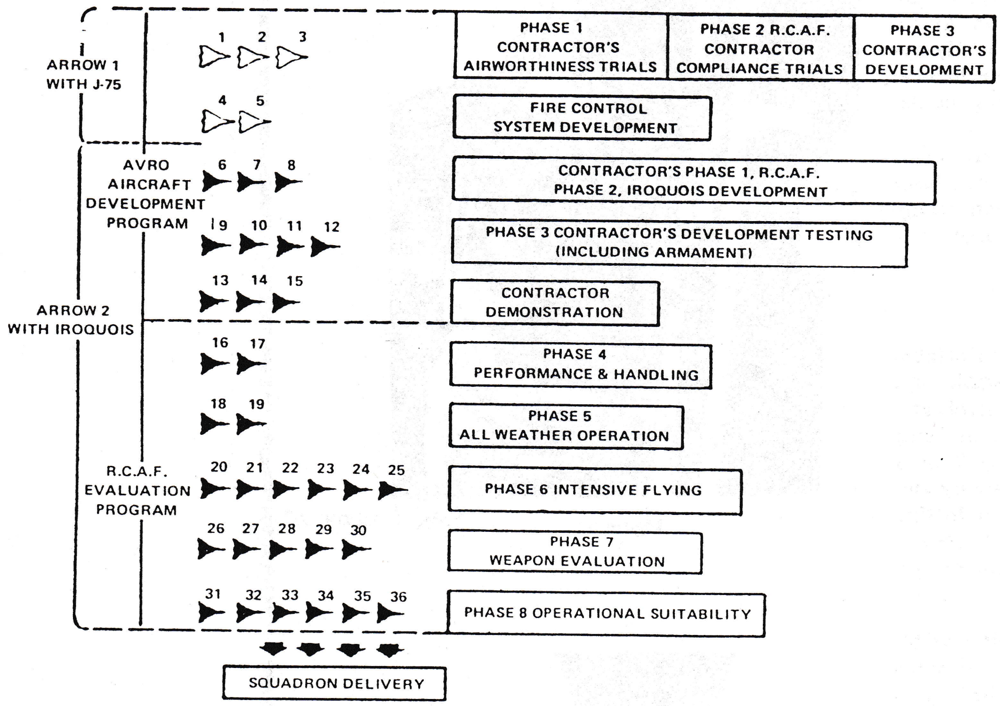



Figure 8

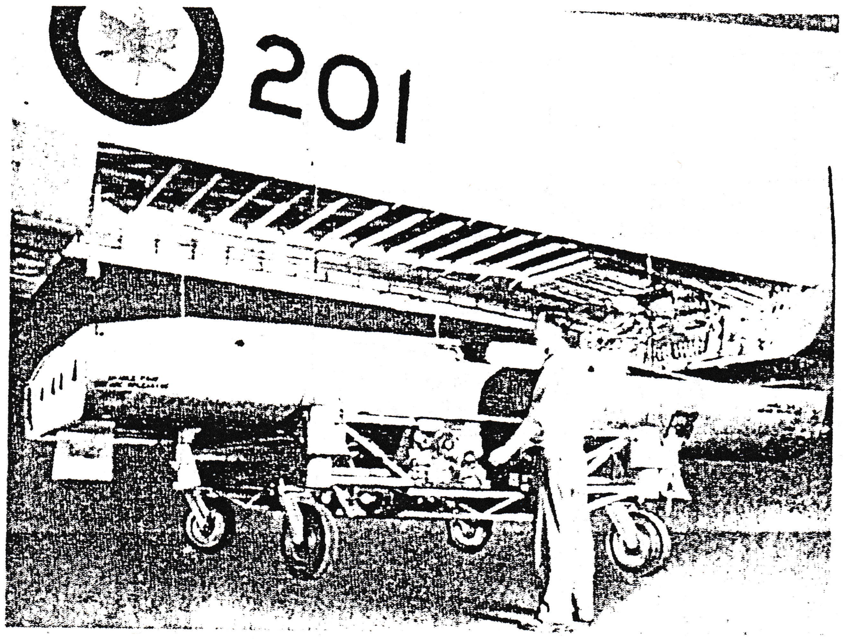
The Arrow Mk 2 started with the 6th airplane, with production Iroquois engines. Phases 1 through 3 were to have involved contractor testing and development, and phases 4 through 8 were slated for Air Force testing and evaluation. Obviously only a portion of the initial Phase 1 preproduction testing was accomplished; however, some significant milestones were reached:

- First two flights were familiarization flights.
- On the third flight, the aircraft flew supersonically (M 1.1 - M 1.2).
- On the seventh flight, the aircraft flew to Mach 1.5 (1000 mph) at 50,000 ft.
- Maximum speed attained was Mach 1.97 - 1.98.
- Four pilots were checked out.

According to my records, the five aircraft flew 64 flights for a total of 68 hours and 45 minutes. The breakdown by aircraft is as follows:

| First Flight Date | Flights | Hours |
|---|---|---|
| 25201 – Mar 25, 1958 | 24 | 25:05 |
| 25202 – Aug 1, 1958 | 22 | 23:40 |
| 25203 – Sep 22, 1958 | 11 | 12:20 |
| 25204 – Oct 27, 1958 | 6 | 7:00 |
| 25205 – Jan 11, 1959 | 1 | 0:40 |
| | 64 | 68:45 |

On Feb 17, 1959, aircraft No. 1 and No. 4 both flew. This was the last day any of the Arrow aircraft left the ground. As I mentioned, Zurakowski made the first flight; he also did most of the early flying.




The complete weapon pack can be hoisted into position under the Arrow in a matter of minutes.

Figure 9

## DATA ACQUISITION

The Arrow data acquisition and handling system was composed of an airborne multi-channel recorder (magnetic tape), phono panel, oscillograph, an airborne radio telemetry link, a mobile telemetry receiving station, and a mobile data reduction unit. The aircraft armament bay, which was a removable self-contained unit, was used to house all the airborne instrumentation. For visual monitoring of flight conditions on the ground, a special operations room was set up, which contained recording oscillographs that gave instantaneous visual records of data during actual flight. Personnel in the room were in constant radio contact with the pilot by means of the conventional radio link, so instructions and/or comments could be exchanged at any time.

The instrumentation used during the Arrow program was the same as that being used in today's flight test programs – refined a little today, but basically the same. The system was a constant source of trouble during the Arrow program, however. During the first series of flights, the system was plagued with a number of problems that were probably due to the thousands of wires and connections running to the instrument pack. As I remember, these problems were never really resolved, and many a flight was delayed because of them. Chase aircraft, either a CF-100 or F-86 Sabre, were used on almost every flight.

## PERFORMANCE – ARROW MK 2

The performance specifications for the Arrow Mk 2 under ICAO standard atmospheric conditions were as follows:

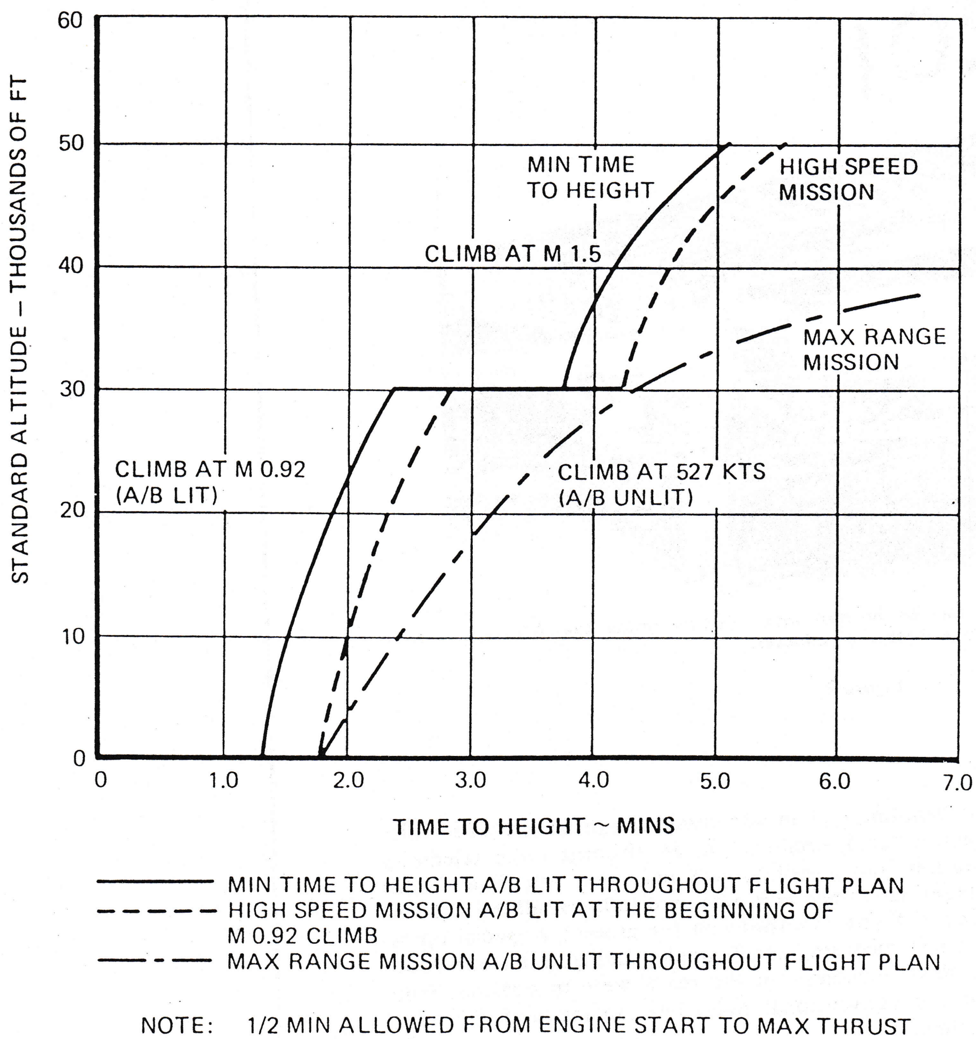



**Figure 10**
**Arrow 2 – time to height**

From engine start, at normal takeoff weight, max thrust time to 50,000 ft & M 1.5 – 5.13 min

| | | | |
|---|---|---|---|
| **Weight** | Normal takeoff weight | – | 62,431 lbs |
| | Combat weight | – | 53,796 lbs |
| | Design landing weight | – | 47,743 lbs |
| | Wing loading at takeoff weight | – | 50.9 lb/sq ft |
| **Speed (Sea Level)** | Maximum thrust (TAS) | – | 700 knots |
| | Military thrust (TAS) | – | 665 knots |
| | Max thrust— 50,000 ft – combat wt | – | Mach 2.0 |
| **Ceiling** | Combat ceiling at combat weight | – | 60,500 ft |

**Rate of Climb**
**(Steady State – S.L. – Combat Wt)**

| | | |
|---|---|---|
| Max thrust at M 0.92 | – | 44,500 ft/min |
| Mil thrust at 527 kts | – | 20,300 ft/min |
| At 50,000 ft with A/B | – | 10,700 ft/min |

Arrow Mk 1 never did quite reach max speed of M 2.0, but there is no reason to believe that the production aircraft with Iroquois engines would not have reached Mach 2.0 quite easily. The Iroquois engine had approximately 30% more thrust than the J75, and the airplane would have weighed about 5000 lbs less. I believe the Arrow Mk 2 had sufficient performance capability to set a new world speed and altitude record, which was held at that time by the United States. The first Arrow Mk 2 was scheduled to fly at the end of February, and I believe it would easily have met all performance guarantees. Performance curves and a typical mission profile are shown in Figures 10, 11, 12 and 13.

## HANDLING

Reading from some of my old flight reports, on my first flight I reported that at low and high indicated airspeeds the airplane behaved reasonably well, the controls being effective, with good response, and the aircraft demonstrated positive stability. However, due to the sensitivity of the controls the aircraft was difficult to fly accurately. At high Mach numbers, I reported the transition from subsonic to supersonic speed to be very smooth, compressibility effects negligible, and the sensitive control problem experienced at lower speeds and altitudes eliminated. The aircraft, at supersonic speeds, was pleasant and easy to fly. During approach and landing, the handling characteristics were considered good; approach speed was 190 knots, touchdown was at 165 knots, drag chute was deployed at 155 knots, and the aircraft rolled the full length of the runway. Attitude during approach was approximately 10°, with good forward visibility.

On my second flight, I reported that the general handling characteristics of the Arrow Mk 1 were much improved. The yaw damper was now performing quite reliably, although turn co-ordination was questionable in some areas. The roll damper was not yet optimized, and longitudinal control was sensitive at high IAS.

On my sixth and last flight, I reported longitudinal control to be positive with good response, and breakout force and stick gradients to be very good. Lateral control was good, forces and gradients very good, and the erratic control in the rolling plane, encountered on the previous flight, no longer there. Directionally, slip and skid were held to a minimum. At no time during the flight was there more than 1° of sideslip, and the problem of turn co-ordination appeared to have been eliminated at this point. Final approach to landing was at 175 knots and a 3° glideslope; attitude was approximately 12°, touchdown was at 160 knots, and the landing roll was estimated at 6000 to 6500 ft, with little or no braking.

To me, it appears obvious that excellent progress was being made in the development of the Arrow.

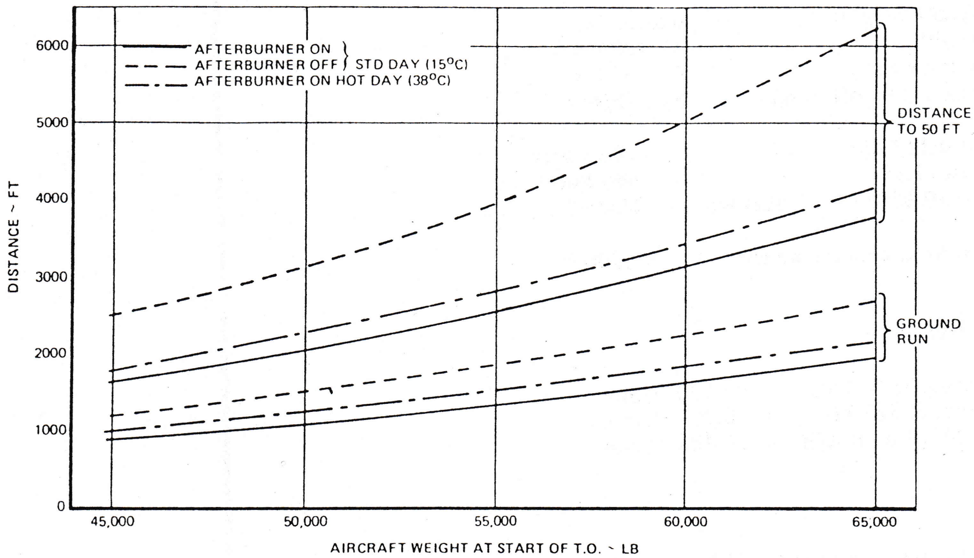



**Figure 11**
**Arrow 2 – takeoff distance at sea level**

Normal takeoff weight, at S.L., to 50 ft: Max thrust – 3430 ft; Mil thrust – 5600 ft

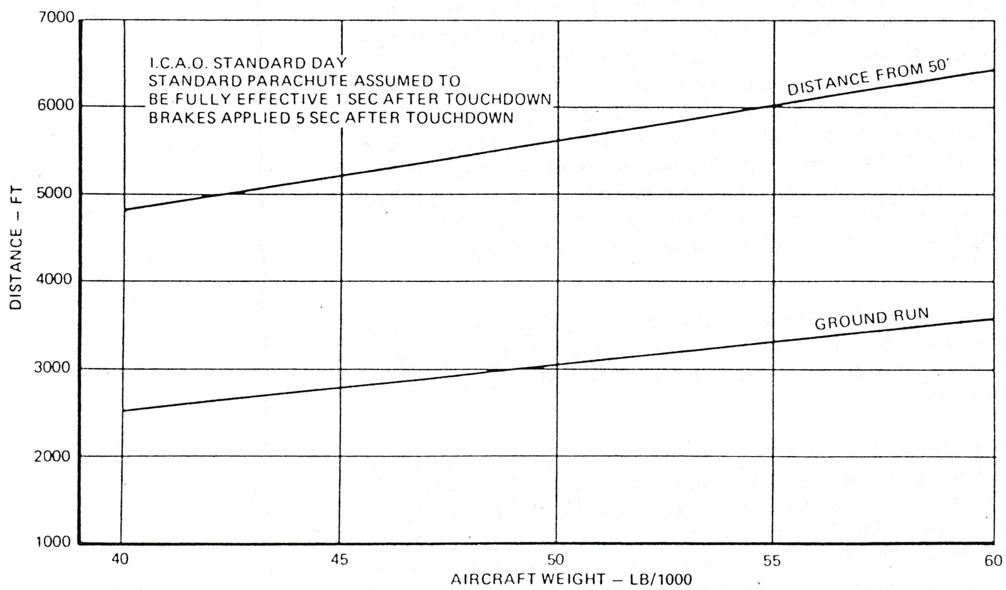
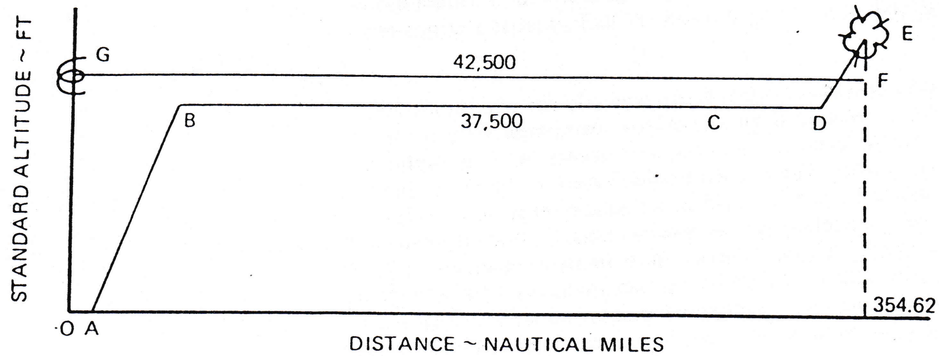



Figure 12
**Arrow 2 – landing distance at sea level – Iroquois series 2 engines at ground idling**

Design landing weight, at S.L., from 50 ft – 5450 ft




| | CONDITION | DISTANCE N. M. | TIME MIN | FUEL LB | A/C WT. LB |
|---|---|---|---|---|---|
| | Start Weight | – | – | – | 64,599 |
| 0 | Engine Start | – | .5 | 100 | 64,499 |
| 0 | Takeoff to unstick at S.L. Max Thrust A/B unlit | – | .34 | 210 | 64,289 |
| 0-A | Acc. to 527 kts at S.L. max thrust A/B unlit | 5.92 | .97 | 712 | 63,577 |
| A-B | Climb at 527 kts to 37,500′ max thrust A/B unlit | 46.5 | 5.32 | 2015 | 61,562 |
| B-C | Cruise out at M 0.92 at optimum cruise altitude (37,500′) | 266 | 30.3 | 4108 | 57,454 |
| C-D | Acc. to M 1.5 at 37,500′ maxthrust A/B lit t | 21.5 | 1.83 | 1490 | 55,964 |
| D-E | Climb at M 1.5 to 50,000′ max thrust A/B lit | 14.7 | 1.04 | 835 | 55,129 |
| E | Combat at M 1.5 at 50,000′ max thrust A/B B lit | – | 5.0 | 3042 | 50,359 * |
| E-F | Descend to 42,500′ at idle thrust | – | 1.5 | 113 | 50,246 |
| F-G | Cruise back at M 0.92 at optimum cruise altitude (42,500′) | 354.62 | 40.4 | 4400 | 45,846 |
| G | Loiter over base at 42,500′ at max endurance speed | – | 15.0 | 1330 | 44,516 |
| G-0 | Descend to S.L. at idle thrust | – | 7.35 | 383 | 44,133 |
| 0 | Loiter at S.L. at max endurance speed | – | 5.0 | 700 | 43,433 |
| | TOTAL | 709.24 | 114.55 | 19,438 | |

*1728 lb. missiles fired during combat.
Fuel density 7.8 lb/gallon.

Figure 13
**Arrow 2 – maximum range mission full internal fuel**

Combat radius: High-speed mission – 249 nm; Max range mission – 355 nm;
Ferry mission – 1254 nm

## CONCLUSION

The handling and performance characteristics of the Avro Arrow were shaping up very nicely. There were many problems still to be resolved at the time of cancellation, but from where I sat the Arrow was performing as predicted and was meeting all guarantees. The decision to cancel the Arrow program was, in my opinion, very poorly founded. Nothing has happened since 1959 to support that decision as being correct. In fact, just the opposite happened.

Several months before the cancellation announcement, there was a lot of bad publicity in Toronto newspapers about the Arrow. It was as if an anti-Arrow campaign were being waged. Retired Army officers, self-proclaimed aviation experts, and others, were implying that the day of the manned interceptor was over. They said missiles would be the first line of defence, and the Arrow would be obsolete before it could enter squadron service. Ironically, not too long after the program was cancelled, an announcement had to be made concerning the decision to scrap the Bomarc missile program due to obsolescence. The Bomarc just never got off the launching pad, and the Canadian Government had been "led down the garden path". Ground-to-air missiles can be effective weapons, and a combination of missiles and manned aircraft is probably a good way to go, but one certainly does not replace the other.

The decision to scrap the Arrow program could not logically have been based on money, because since the cancellation, the Air Force has purchased at least 400 new aircraft, if not more. This includes the F-101, the F-104, the F-5, and the present-day evaluation of the F-14 and F-15 as a replacement fighter for use in the 1980's, which run about 15 to 20 million dollars per copy. This new manned interceptor is intended for the 1980's, some 30 years after the Arrow was cancelled and the idea of the manned interceptor declared obsolete.

Cancelling the program was one thing, but to make matters worse, everything was destroyed – all the aircraft, the records, and all the work that was accomplished, almost as if to hide all the evidence. I think one of the aircraft, at least, should have been assigned to the NAE and kept as a research vehicle. Also, I'm sure other aircraft manufacturers could have benefitted from Avro's experience – makers of the Concorde, for example. Cancelling the Arrow program denied Avro, and Canada, the opportunity of developing their technological expertise and becoming world competitors in the field of high performance aircraft.

The years 1957, 1958, and 1959 were exciting years in Canadian aviation, and for myself, I just wish they had lasted a little longer.

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## NOTE

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