An Aviation Chapter in Canadian History

Paul Campagna, P.Eng.

Photo: Department of National Defence

In 1958, the heroes of every Canadian boy (and probably quite a few girls) were the test pilots flying the CF-105, known as the Avro Arrow. Behind the test pilots were the engineers, creating what was to be the fastest, most powerful aircraft yet conceived. 1988 marks the 30th anniversary of its first flight, 1989 the last. Many articles have been written about the Arrow, some true, many false. Here, for the first time, are the engineering facts, painstakingly researched by a young Canadian engineer as a testament to the integrity of the team which created the Arrow.

"The biggest, most powerful, most expensive and potentially the fastest fighter that the world has yet seen . . ."

—Flight Magazine, 1958

Four years of excellence in Canadian engineering, research and design culminated in the maiden flight of the CF-105 Avro Arrow all-weather, supersonic jet interceptor from Malton, Ontario, on March 25, 1958. The world watched Canada's major contribution to aerospace engineering—but not for long. On Friday, February 20, 1959, the Canadian government ordered all work on the Arrow cancelled.

Some 14,000 employees were fired immediately. Within two months, five superb flying machines and a more powerful sixth, which had been within days of takeoff, were ordered reduced to scrap. Also, 31 others in various stages of assembly, along with all parts, drawings, accessories, blueprints and photographs were ordered destroyed.

Even today, some Canadians are unaware of the aircraft's existence, yet it still ranks as one of the most technically challenging projects ever undertaken in this country. Design of a supersonic interceptor with the parameters of the Avro Arrow presented colossal engineering problems which were systematically overcome. However, less than 30 years later, much misinformation exists about the Arrow, such as the number of aircraft that actually flew, what speeds were reached and technologically just how far ahead it really was.

The Company

A.V. Roe Canada Limited was established as a subsidiary of the British Hawker-Siddeley Group in 1945. On purchasing the Malton-based Victo-

Engineer as Problem Solver

John G. Howard, well known for the design of Colborne Lodge in High Park, the estate which he gave to the city of Toronto, appears in the patent record as No. 162: "Letters Patent to John G. Howard, of the city of Toronto, Architect and Civil Engineer, for the Invention of 'A New Method of Constructing Timber Bridges' issued 24 February, 1840." Here, the engineer emerges as problem solver. Canadian timber bridges were notoriously shortlived; violent spring floods with accumulated debris, but most particularly heavy ice buildup around cribs or piers, brought bridges down with discouraging regularity. John Howard thought he had an answer: "Bridges constructed in this manner are particularly adapted to rivers subject to freshets, and large accumulations of ice, as they are capable of being extended several hundred feet in one span, thus superceding the necessity of having either piers or cribs."

Patent number 142, a "Method of Constructing Bridges On Combined Principles, Called The Suspension Wood Bridge" issued July 14, 1831 to Nicol Hugh Baird, an engineer who worked on the Rideau Canal and resided in Nepean, tried to make use of the most plentiful building material of the day to solve the pressing problem of building cheap, reliable bridges over the innumerable rivers and streams of the new land.

World-renowned for his work on Standard Time Zones, civil engineer Sandford A. Fleming was issued patent number 232, "Invention of a New Method of Propelling Locomotives," on June 4, 1847. Insufficient traction was a global railroad problem made particularly acute in underdeveloped countries such as colonial Canada where cash-starved railroads wanted to minimize expensive cutting and filling, which of course was the way to deal with traction problems: reduce grade through construction. Fleming's was as follows:

"It consists in having the driving wheels of the locomotive placed horizontally, and pressed by springs against the sides of a central rail. The pressure of these springs can be increased or diminished at pleasure, so that the bite of the driving wheels can be increased when necessary, as when starting, or when going up or down steep gradients, and diminished when the train comes to a level. The central rail is raised above the side ones. The supporting wheels have no flanges on their tires, as the guide wheels prevent the locomotive from getting off the rails, and the pressure of the driving wheels, when they are made to revolve, draws the locomotive forward."

Not all inventions were so weighty. The skirt lifter was an ingenious answer to the demands of both fashion and decorum. Muddy or dusty streets and sidewalks made a device to lift long skirts out of the mud, particularly when mounting or dismounting sidewalks, eminently sensible and respectable—provided it lifted it only very slightly. One book claims a lady in Calgary invented one during the 1860s[4] but only two such patents appear during the decade, both issued to gentlemen.[5]

The Patent Lawyers

Canada is known worldwide for insulin, discovered at the University of Toronto in 1922 by Drs. Banting and Best. Patents on insulin were advised by a patent attorney called Charles Riches. In 1887, Charles Riches left his position as draftsman with the firm of Donald C. Ridout & Co., patent attorneys, to enter into partnership with W.J. Graham as Graham & Riches, Patent Solicitors, Civil Engineers and Draftsmen, in Toronto. Many years later, he advised his distinguished clients and the University of Toronto to patent the process of producing insulin, to maintain quality control and garner revenues for further research. Both parties were initially unwilling to do so because it seemed to run counter to the idea of medical knowledge being generated for all humanity. Patents were taken out, however—much to the benefit of both humanity and the University-owned Connaught Laboratories. The first commercial or large scale manufacturers of insulin, Eli Lilly of Indianapolis, did so under licence from the University of Toronto.[6]

Patent lawyers are an exceedingly important part of the patent process. Charles Legge, born near Gananoque in 1829, studied civil engineering at Queen's University before his training or apprenticeship with Samuel Keefer on the Welland Canal. Made famous by his work as Superintendent Engineer on the south half of Montreal's Victoria Bridge, and his book *A Glance at the Victoria Bridge and the Men Who Built It*, he was probably Canada's first patent solicitor. In 1859, the year the Victoria Bridge opened, he advertised as a patent solicitor. This information is found in a fascinating little book, *History of the Patent and Trade Mark Profession in Canada*[7]. It introduces just one of the many professions in which Canadian engineers have quietly made their mark and helped to create the modern engineering-dependent world.

Dr. Ball, chief of research at the National Museum of Science and Technology, is an engineering historian and author of *Mind, Heart, and Vision: Professional Engineering in Canada 1887 to 1987.*

References

1. See for example *Man The Tool-Maker*, 3rd ed., Chicago, University of Chicago Press, 1957, and Childe, V.G. *Man Makes Himself*, 4th ed., London, Watts, 1964.

2. The most readable introduction to Canadian inventions is Brown, J.J. *The Inventors. Great Ideas In Canadian Enterprise*, Toronto, McClelland and Stewart, 1967.

3. With the beginning of the *Canadian Patent Office Record* in 1873, new patents were listed in each issue. The *List of Canadian Patents, From The Beginning Of The Patent Office, June, 1824, To The 31st of August, 1872*, Ottawa, MacLean, Roger & Co., 1882, is the only comprehensive published record of earlier patents. Known as the "Blue Book" on account of its blue cover, it is scarce and expensive but has been reprinted as a labour of love by Gordon Phillips, P.Eng. and is available from Gordon Publications and Reproductions, 929 Alpine Avenue, Ottawa, Ont. K2B 5R9 for $7.50 postpaid. He has also produced an index organized by inventor, invention and location which is available for $6.00 postpaid; readers of **Engineering Dimensions** may obtain the two for $10.00 if prepaid.

4. Nostbakken, J., Humphrey, J. *The Canadian Inventions Book. Inventions, Discoveries and Firsts*, Toronto, Greey dePencier Publications, 1976, p.8.

5. Patent Number 1487, issued to George Campbell of the City of Toronto, for "A Ladies Skirt Lifter," January 22, 1863, and Patent Number 1607, issued to Marcel E. Lymburner of the City of Montreal, for "A New And Improved Skirtlifter," October 27, 1863.

6. Bliss, M. *The Discovery of Insulin.* Toronto, McClelland & Stewart, 1982, pp.131-133, 137-139, 174-176.

7. Maybee, G.E., Mitchell, R.E. *History Of The Patent And Trade Mark Profession in Canada.* Ottawa, Patent and Trademark Institute of Canada, 1985. I am indebted to John Singlehurst, P.Eng., of Meredith & Findlayson for bringing this book to my attention.

ry Aircraft Ltd., which was producing Lancaster bombers for the war effort, A.V. Roe turned its attention to commercial jet transports and military jet aircraft. On August 10, 1949, some two weeks after the British Comet made a short hop from its runway, Avro flew the C-102 Jetliner on its maiden flight to 13,000 feet, becoming the first commercial jet transport to fly in North America.

Unlike the Comet, the Jetliner was not plagued with catastrophic fatigue failure. Despite meeting the Trans-Canada Airlines specifications to which it was designed, the Jetliner never went into production. Instead, the company was told to focus on producing the CF-100 all-weather fighter, partly to support the Korean war effort. After flying for seven years, the lone Jetliner, a milestone in aviation, was cut to scrap, forcing Canada to depend on foreign markets for jet transport aircraft.

Although the CF-100 project was a success, it was decided that a new all-weather, supersonic jet interceptor would be required to meet Canada's expanding defence needs. In May, 1953, in response to an RCAF specification, A.V. Roe Canada submitted its report which examined five possible delta winged configurations, with varying wing sizes and engine types. In July, 1953, the Department of Defence Production chose the 1,200 square foot version, thus launching the CF-105 program.

Photo: Orenda Engines, Toronto

Flight tested in a B47 but never in an Arrow, the Iroquois engine was 19 feet long, four feet in diameter and composed of some 20% titanium alloys overall. With a 1:1 weight to thrust ratio, it would have given the Arrow better than Mach 2 speed.

The Aircraft

To set the record straight, the first production CF-105 aircraft, dubbed the Arrow, was rolled out on October 4, 1957, only four years after the start of the program—a major achievement in itself. Its first flight was March 25, 1958. On its third flight, the aircraft was flown supersonically at Mach 1.1. On its seventh flight, it exceeded 1,000 mph while climbing. Four more production aircraft were flown. Eventually, the Arrows would fly to Mach 1.98 (approximately 1,300 mph), although they were never pushed to their performance limit.

All five aircraft were equipped with two Pratt and Whitney J75 engines, each with approximately 18,000-lb static thrust and 26,000-lb with afterburner. A sixth aircraft was produced and ready for roll-out at the time of cancellation on February 20, 1959. This aircraft was equipped with the more powerful Iroquois engine, at 23,000-lb static thrust and 30,000-lb with afterburner.[1] Arrow number six was expected to break all speed records.

No "prototype" Arrow was ever built, only production aircraft. To move from drawing board to production line, one of the most extensive programs of wind tunnel, structural and systems testing ever undertaken on any aircraft was conducted. In addition, detailed mockups were built for checking system installation.

Part of the test program involved the use of fully instrumented one-eighth scale free-flight models launched on Nike rocket boosters. These models would telemeter information concerning various flight parameters including drag and stability. Today, those stainless steel models rest in Lake Ontario, approximately 13 miles off Point Petrie, waiting for some enterprising underwater enthusiasts to retrieve them.

The Wing

A striking feature of the Arrow was its large delta wing. It was determined that the delta was the most aerodynamically efficient platform for high speed and high altitude performance, while providing a large internal fuel capacity for the required range. To permit higher angles of attack and greater stability, the leading edge of the wing was extended, drooped and slotted, creating more favourable airflow conditions over the wing. These features had been used singly on other aircraft, such as the notch on the English Electric F-23, the leading edge on the Grumman

F-9 and the droop on the F-102, forerunner of the F-106 Delta Dart. Today, combinations of these are used on most fighters, including the Russian MIG series and the F/A-18 Hornet. An early prototype of the F/A 18 incorporated the notch. At the time, the combination of notch, droop and leading edge extensions made the Arrow unique and aerodynamically superior.

Another addition was negative camber, a slight concavity in the upper surface of the wing that helps to reduce the amount of elevator deflection required for stability and control (trim) during supersonic flight. This, in turn, reduces the amount of drag that would otherwise be created with greater elevator deflections.

The Fuselage

The aircraft was extensively "area ruled." This concept involves aerodynamic shaping of the cross-sectional area of the fuselage along its length, to reduce drag to a minimum. Also called the "Coke bottle" design, the fuselage is characteristically pinched at the waist at the wing joint, although this was not immediately noticeable on the Arrow.

Similarly, the cockpit was deigned as an extension of the fuselage rather than as a separate bubble, again for good aerodynamic performance. The cockpit canopy itself was of unusual design, opening and closing in clam-shell fashion due to its size and weight, as well as for ease of entry and exit. The canopy was made of a magnesium alloy with partly glazed glass. In back, drag was reduced by trailing the canopy off into a spine running the length of the aircraft to the tail. This also doubled as a conduit for controls and wire cabling. In short, everything possible was done to reduce aerodynamic drag, including the internal carriage of weapons.

The Weapons Carriage

The concept of internal weapons carriage has spawned several misguided criticisms about an aircraft that would destroy itself if the weapons package were lowered during supersonic flight. In fact, the weapons package was designed to be lowered and removed only while on the ground. In this way, a fully loaded package could be "snapped" into place, considerably reducing the turnaround time per aircraft. This concept also allowed easy reconfiguration for other roles, including reconnaissance and bomber. The pack was never designed to be lowered in flight; since it was 16 feet long and nine feet across, lowering in flight would have been ludicrous. At no time were any of the completed aircraft fitted with weapons.

Initially, the Arrow was to have carried the Hughes Falcon guided missile. The Falcons were to be replaced by Sparrow 2D missiles, with a sophisticated weapons control system known as ASTRA. However, Avro engineers judged the Sparrow missiles to be inferior for use in a high performance aircraft without further development.

Each missile was to be mounted on its own hydraulically activated retractable launching mechanism. Because of their large fins, Sparrows would sit partially within and partially outside the belly of the aircraft. (This is similar to the manner in which missiles are carried on the Tornado aircraft: they are recessed into the underbelly; however, no retractable launcher is required.) The smaller Falcon missiles would have been fully internal to the aircraft. Missiles would extend from their own individual bay doors. Aft missiles would be fired first, followed by forward missiles.[2] A sliding bay door arrangement was being considered for the Sparrows. Door opening or closing was to have been completed in 0.35 seconds; extension was to have taken another 1.25 seconds or less.

It has been argued that no other fighter has duplicated this internal weapons carriage. This is simply not the case. The CF-101 Voodoo aircraft, for example, employed a rotating platform, which carried some of the weapons internally and the remainder externally. The F-106 Delta Dart used an almost identical internal missile system to that of the Arrow. Internal weapons carriage may also become the future norm.

As calculated by Avro engineers, externally mounting four missiles could have increased drag by some 20% at Mach 1.5. Bill Gunston[3] states that the move towards faster, more agile fighters is slowly forcing the removal of externally mounted weapons in order to take every advantage of the resulting reduced drag. He states it will simply no longer be good enough to hang missiles on pylons. One solution is to use the recessed method of missile carriage and the other is to place weapons in an internal bay.

A recent article[4] describes stealth design techniques to reduce radar cross-sectional (RCS) area. These include using aerodynamic shapes such as delta wings, blending cockpit and wings into the fuselage and, of course, carrying weapons internally. Aerodynamic and stealth efficiency appear to be complementary design requirements. The Arrow was not a stealth aircraft, but obviously the

Photo: Department of National Defence

concept of a "clean" aircraft could have several inherent advantages.

The Landing Gear

The requirement for such a large weapons bay necessitated stowage of the main landing gear in the thin delta wings. This caused a number of engineering difficulties, overcome by Dowty Engineering Limited. On retraction, the main gear would be shortened, angled forward and then twisted in order to be accommodated. Given the 30-ton weight of the aircraft and resulting 200,000-lb compressive load on the main gear on landing, ultra-high-tensile steel with an ultimate tensile strength of 260,000-280,000 psi was required. Use of aluminum was obviously precluded, as was the use of butt and gas welding techniques. Instead, large forgings were made, using a die process. For example, the main outer leg was the largest forging, weighing 1,000 lb. After machining this would be reduced to 167 lb. Solutions to the problem put Dowty and Avro engineers at the forefront of metallurgical research.

Likewise, the engineers at Jarry Hydraulics were obtaining patents for their steering mechanism in the nose gear arrangement, among others. In fact, Avro engineers and their subcontractors made enormous strides in developing high temperature alloys, high pressure and high temperature systems, fuel technology for supersonic flight and human engineering, in terms of cockpit layout and design. These techniques pushed the world aircraft industry further ahead. In support of these advances, Avro maintained a huge metal-to-metal autoclave, a special heat treat furnace, a giant skin mill and a 15,000-ton rubber pad forming press (then the largest in the world).

Fly-by-wire

Early in the design, it was decided that some form of power assist would be required to help control and fly the aircraft during supersonic flight. The chosen result was fly-by-wire. In conventional systems, the pilot's stick and rudder controls are mechanically linked via steel cables or rods to valves which control high pressure fluid flow to the actuators. These powerful hydraulic actuators, in turn, operate the aircraft's control surfaces, such as elevators and ailerons. In military aircraft, automatic flight control systems, gyroscopes and position sensors are also mechanically linked to the actuators through the control rods.

In the Arrow automatic flight control system (AFCS), in automatic mode, the pilot's stick and positioning sensors were linked electrically to electro-hydraulic actuators. Hence, stability, command and control were effected almost instantaneously in all three axes. Analogue computers with a mix of vacuum tube and transistor technology were used, together with autostabilization of the tail fin and artificial feel, to give the pilot some sense of force on his control stick.

Not until the 1970s did fighter planes use a similar AFCS, although variations had been employed in experimental aircraft and the SR 71 Blackbird. The F-16 and Panavia Tornado both used analogue fly-by-wire.

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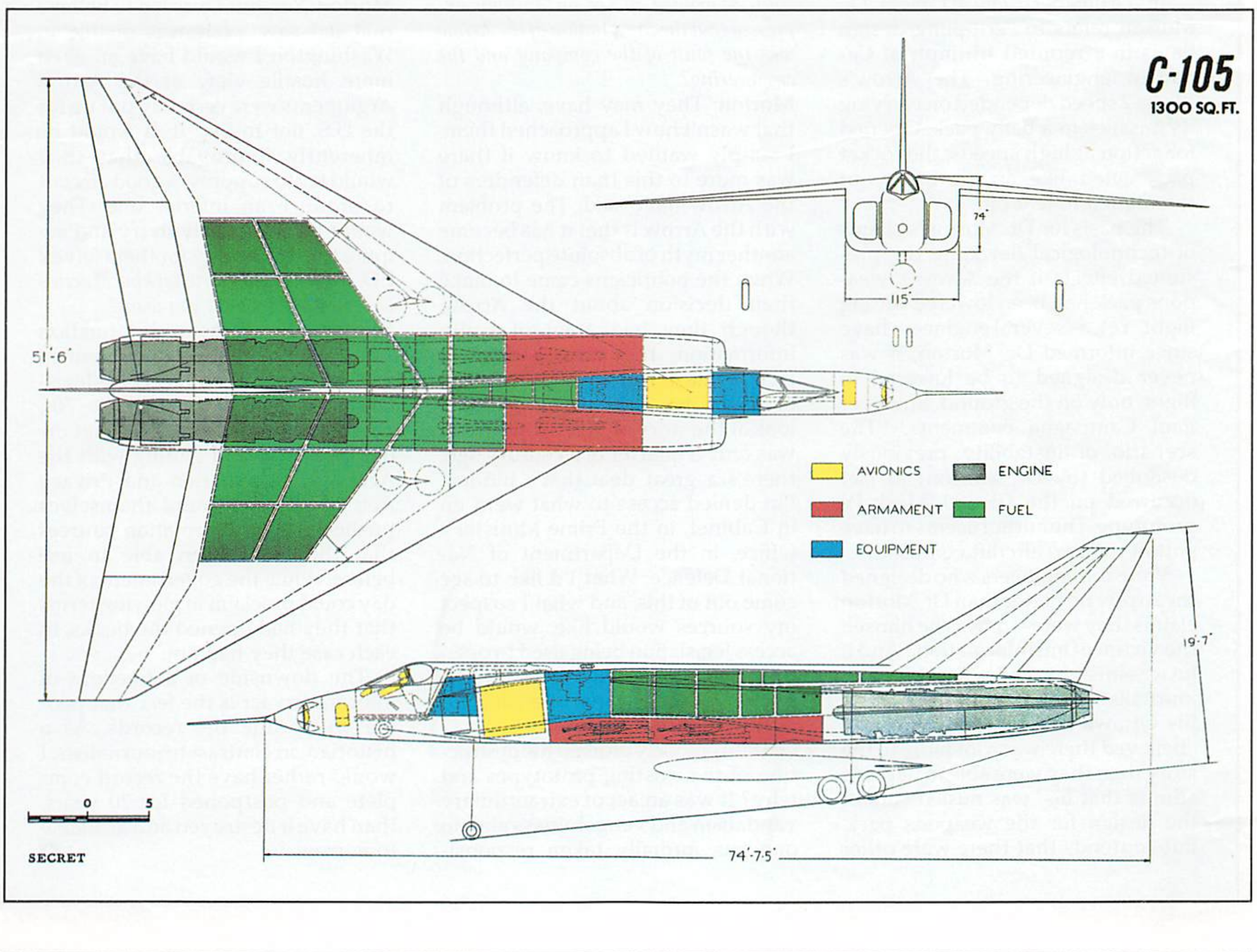

Drawing: Department of National Defence

"A Flawed Plane and an Inept Corporation"? The Historian's View

Margaret McCaffery

Thirty years ago, the Canadian public was cheering the launch of an aircraft that made headlines around the world. Three years ago, one of Canada's foremost historians, Dr. Desmond Morton, principal of Erindale College, University of Toronto, described the Avro Arrow as "a fatally flawed weapon, on a par with those earlier monuments to our military-industrial blundering, the Ross rifle or the MacAdam shovel." In an article in the *Toronto Star*, he said: "Politicians, our professional scapegoats, took the blame for aborting a design whose imperfections should have been obvious to a first-year engineering student."

In *The Illustrated History of Canada*, a text which most Canadian schoolchildren will read, Professor Morton claims that then Prime Minister John Diefenbaker cancelled the Avro Arrow, not because guided missiles had made it obsolete, but because it was "a flawed plane and an inept corporation."

In *A Military History of Canada*, Dr. Morton refers to "crippling design flaws in a reputed triumph of Canadian engineering. The Arrow's Mach-2 speed depended on carrying its missiles in a belly pack. Opened for action at high speeds, the rocket pack acted like an air brake—or threatened to tear off."

The basis for Dr. Morton's claims of technological flaws are the presumed effects if the Arrow's weapons pack had been lowered during flight. Yet, as several engineers have since informed Dr. Morton, it was never designed to be lowered in flight, only on the ground. Engineer Paul Campagna comments: "The scenario of instability previously described (by Dr. Morton) in fact occurred on the CF-100, Mark IV prototype. The author seems to have gotten the two aircraft confused."

Were the engineers who designed the Arrow no better than Dr. Morton claims they were—or was he himself the victim of misinformation? And if he was misinformed, why? Like any journalist, Dr. Morton won't name his Ottawa sources, who, he says, "believed there was a lot more to the story than they were able to tell." He admits that he "was misled" about the design for the weapons pack, but contends that there were other problems which would still justify the description of the Arrow as "a magnificent airplane that had major flaws." He maintains that since the plane's weapons and avionics systems "were being bought off the American shelf" and had not been tested in flight, their incorporation would have caused major problems "that would have involved considerable redesign."

In this interview with **Engineering Dimensions'** editor Margaret McCaffery, Professor Morton explains why the story of the Arrow is itself flawed.

ED: *Do you think you will change your account of the Avro Arrow in subsequent editions of your books?*

Morton: I may reflect on this controversy. Particularly when you're dealing with contemporary history, you've got a very partial access to sources. You have people alive with very strong feelings and knowledge, which they may or may not share.

ED: *Would it be fair to suggest that your sources wanted to see an opinion expressed that the cancellation of the Arrow was the fault of the company and the engineering?*

Morton: They may have, although that wasn't how I approached them. I simply wanted to know if there was more to this than defenders of the Arrow have said. The problem with the Arrow is that it has become another myth of absolute perfection. When the politicians came to make their decision about the Arrow, though they had a lot of faulty information, they also had some facts, some of which we know, some of which we don't know. When I look at the story of the Arrow, which was only a quarter of a century ago, there's a great deal that's hidden. I'm denied access to what went on in Cabinet, in the Prime Minister's Office, in the Department of National Defence. What I'd like to see come out of this, and what I suspect my sources would like, would be access legislation being used to open up all the records related to the Arrow, including the decision to destroy the prototypes.

Who precisely ordered the destruction of the existing prototypes and why? It was an act of extraordinary vandalism and vengefulness and no one has formally taken responsibility for it. I'm told there were American arguments that the aircraft was flawed—although that may be the same sour grapes attitude that you've suggested. I think it was a tragedy that the opportunity to perfect it was never achieved.

ED: *Did you ever speak with Mr. Floyd, who was vice-president of engineering at Avro during this time?*

Morton: No.

ED: *What do you think his response would have been?*

Morton: Oh I know what it is, because I've received a copy of the letter he and a group of engineers sent to the *Toronto Star*. That's one of the reasons why I wrote the *Star* article—to see what response I'd get, who was willing to talk. I've learned a great deal since then.

ED: *It's been suggested that there's more on file in Washington about the Avro Arrow than there is in Ottawa. With the U.S. Freedom of Information Act, wouldn't it be easier to get information from Washington?*

Morton: Yes, but I was led to believe that if I saw what was on file in Washington I would have an even more hostile view of the Arrow. Arguments were certainly put up for the U.S. not to buy it. It would be inherently improbable that they would try to suppress a good aircraft to produce an inferior one. They would be more likely to try and acquire the technology for themselves.

ED: *In an ideal world, what kind of access to information would you want?*

Morton: Our Access to Information Act is a very imperfect document; in fact, it's worse than no access legislation. At several points in the '70s, beginning with the first cabinet order on access and ending with the Access to Information and Privacy Act, researchers found themselves pushed out of information sources that they had been able to use before. While the government of the day could proclaim in glowing terms that they had opened the books, in each case they had not.

The downside of a freedom of information act is the fear that people will prune the records. As a historian, in contrast to journalists, I would rather have the record complete and postponed for 20 years, than have it destroyed and available tomorrow.

The first fighter to replace the analogue system with digital electronics was the F/A-18 Hornet.

How effective was the Arrow fly-by-wire automatic flight control system? According to test pilot Spud Potocki, in a 60-degree climb, with full afterburner, he would shut down one engine and experience no expected sideslip or roll. The AFCS would compensate instantaneously. Automatic approaches and takeoffs were also successfully completed. The Arrow was the most modern interceptor in the world, clearly over 20 years ahead of its time.

The Engines

Due to problems in acquiring a suitable engine, Avro decided to fit the first five aircraft with the Pratt and Whitney J75, which would give the Avro subsidiary, Orenda Engines, time to complete development of the lighter yet more powerful Iroquois engine. The Iroquois was approximately 19 feet long and four feet in diameter. To reduce weight, it employed fewer compressor stages and was composed of some 20% titanium alloys overall. In producing the rotor blades from titanium, Orenda's subcontractor, Canadian Steel Improvements, patented a process of precision casting.

At a combined 60,000-lb thrust for an approximate 60,000-lb aircraft, the Iroquois would have provided a 1:1 thrust to weight ratio. This would have given the Arrow a better than Mach 2 speed and perhaps Mach 3, limitations due to structural heating, not lack of power.[5] On November 1, 1957, dry thrust runs at over 20,000-lb were demonstrated. Twelve days later, the Iroquois was flight tested on a four-engined B47 and proved that it alone could have powered this aircraft. Like the airframe, the Iroquois pushed the state of the art in engine technology. Unfortunately, it was never flown in the Arrow.

The Problems

As good as it was, the Arrow was not without some problems. During the flight test program, two significant accidents occurred. The first, on flight number 11, involved failure of the left main landing gear to extend properly, causing the aircraft to veer off the runway. During an approach landing of the second Arrow, all wheels on the main gear skidded, with subsequent tire burst. The aircraft again veered off the runway. The resulting investigation showed that on this touchdown, the elevator had moved down, causing some backlift. This caused the pilot to overcorrect by applying too much braking pressure too soon, locking the wheels.

Other problems included failure of the nose gear door to retract and malfunctions with indicator lights and switches. Each was corrected in turn as the Arrow continued to meet and exceed specifications.

Jan Zurakowski, principal test pilot, stated that handling characteristics and performance agreed well with estimates. In flight number seven, he flew at 47,000 feet at Mach 1.52, while climbing. He indicated he was still accelerating and showing excess thrust available, and that handling was good. Pilot Jack Woodman, the only military pilot to fly the Arrow, said the aircraft was "...performing as predicted and meeting all guarantees."

The Consequences

In 1958, Canada had an aircraft industry that was among the best in the world. Many foreign engineers emigrated to Canada specifically to become part of "The Team." After cancellation, both Britain and the United States eagerly sought to get the Avro Arrow for research purposes.

In 1959, the brain drain reversed. Many Avro engineers went to NASA, including John Hodge who became associate flight director, Project Mercury, flight director, Gemini, and later flight director, Project Apollo. Likewise, Jim Chamberlin became head of the Space Task Group's Engineering Division. Jim Floyd, P.Eng., the man who largely conceived the overall program and who was vice-president of engineering at Avro, returned to Britain where he was consultant on the Concorde and other leading edge, high technology projects. Others went to McDonnell, Boeing and other aircraft manufacturers.

Back at Avro, the remaining 2,000 engineers continued on in various projects. One of these was the Avrocar, an experimental all-wing vertical take-off vehicle, completed for the U.S. Air Force. In 1962, Avro closed its doors, leaving a legacy of concepts and ideas, including a vertical take-off CF-100, a supersonic transatlantic transport, a spaceplane concept, and a monorail—testimony to the advanced thinking of one of the best engineering teams ever assembled.

Recently, some newspapers carried a story of one reporter's flight in an F/A 18. In it, he exclaims how far Canadians have come in aircraft technology, just 79 years after J.D. McCurdy's first flight in Nova Scotia. We were there 30 years ago—with a wholly Canadian product, the most powerful aircraft in the world.

Why Was the Arrow Cancelled?

A recently declassified U.S. Deputy Secretary of Defense memorandum dated June 1, 1960 says:

"Prior to the NSC (National Security Council) paper (December 1958) and following a visit of the President to Canada in July 1958, Canada took the following actions with the understanding that her defense industry depended largely upon the U.S. channelling defense business into Canada; cancelled the CF-105 and related systems contracts; decided to make maximum use of U.S. developed weapons, integrated into NORAD; worked with U.S. toward a fully integrated continental defence."

What exactly transpired at the July meeting with the President? The Defense Production Sharing Arrangements were signed at this time. Was the Arrow program, because of its rising costs, a bargaining chip for less expensive American goods? Was the program effectively cancelled shortly after this July, 1958 meeting?

Oddly enough, after its first successful flights, a media campaign attempted to discredit the aircraft.[7] Perhaps the reprieve until February 20, 1959, was to allow the flight test program to prove how poor the aircraft really was, making cancellation more palatable and logical. The opposite proved to be the case. Could this be why Arrow number six was never allowed to fly and break that speed record? Could this be why six of the most advanced aircraft ever built, along with all memory, had to be erased?

And how well did the defence sharing arrangements program work? The same memorandum continues:

"The last quarterly meeting of the Production Sharing Policy Group

was held on 25 May (1960). Despite all efforts, over the period 1 January 59 through 31 March 60, Canadian defense business in the United States almost doubled that placed in Canada. Canada is not satisfied with these results, nor do they appear acceptable from our view."

Whatever the reasons for cancellation, the loss to Canada's engineering community and aviation industry remains incalculable. It is clear from international reports of the day that the rest of the world was highly impressed with the Avro corps of engineers and the Arrow. Thirty years later, it is time for Canadians and Canadian engineers to look back and be proud of this magnificent engineering achievement.

Do you have any memories of the Arrow—facts, figures, reminiscences or photographs? If so, send them to The Editor, Engineering Dimensions, 1155 Yonge Street, Toronto, Ontario M4T 2Y5. We'll publish an Arrow Memorial in our January/February 1989 issue.

Paul Campagna, P.Eng., is the electromagnetic environmental effects (E^3) engineer for the Directorate of Avionics, Simulators and Photography of the Department of National Defence, Ottawa.

Acknowledgements

Jim Floyd, P.Eng., designer of the Avro Arrow, provided valuable as-

Setting the Record Straight: The Designer's View

Margaret McCaffery

"I feel for the youngsters. In our day you could get on with the job and not worry about going over the precipice." Those hardly sound like the words of a man who has known overwhelming disappointment in "getting on with the job," yet they capture the spirit of the man who designed the C-102 jetliner—which the New York press claimed "licks anything of ours"—was vice-president of engineering for Avro Aircraft when it was building the CF-105 (Avro Arrow), and ended up consulting on production of the Anglo-French Concorde.

James C. Floyd, P.Eng., epitomizes the cheery "mustn't grumble" attitude of his native Manchester, yet he's a proud Canadian, who retired to this country after spending 20 years working in Britain following cancellation of the Arrow and the crumbling of A.V. Roe Canada. His concern for "the youngsters" has led him on a concerted campaign to set the history books straight if possible, and if not, well, he's written one of his own.[1] He is currently helping to set up the Canadian Aerospace Heritage Foundation which aims to build a full-scale replica of the Arrow and other Canadian aircraft for permanent exhibit.

What does someone who was responsible for the design of the Avro Arrow think about the criticisms of its abilities? Jim Floyd and other Avro engineers have expressed themselves eloquently to the publishers of Professor Morton's books, but he sees this kind of misinformation as part of a larger picture:

"High technology is, by its very nature, difficult for the layman or voter to adequately assess, and its worth and impact can only be fully appreciated, even by those who have to ensure its survival, if it is properly and comprehensively presented. In the past, Canadian engineers have tended to adopt a low profile in the political arena and have rarely been consulted about the long-term effects of the decisions made by the 'captains of industry' or their political counterparts. As an example, I firmly believe that had Mr. Howe been exposed to a proper and full-scale engineering briefing on the Jetliner project, he would not have made the utterly erroneous statements about the alleged technical shortcomings of the aircraft, which must have influenced his decision to abandon the project and which later caused him considerable embarrassment, even within his own party."[1]

Although he refers to himself (with a twinkle in his eye) as "just a poor engineer" who doesn't know anything about politics, he was embroiled in the Cold War politics of the late 1950s by his involvement with the Arrow. In this interview with **Engineering Dimensions**' editor Margaret McCaffery, he relives those days at Malton.

ED: *Why do you think Diefenbaker cancelled the Arrow?*

Floyd: Diefenbaker had the worst advice possible. His main advice came from General Pearkes, who was a brave old soldier, but he didn't know anything about airplanes at all. He'd been hoodwinked by a visit to the States

Avro Arrow design team, left to right: Bob Lindley, chief engineer; Jim Floyd, vice president, engineering; Guest Hake, Arrow project engineer, and Jim Chamberlin, chief, technical design.

Photo: J.C. Floyd, P.Eng.

sistance in preparation of the article and supplied photographs of the Jetliner. Other photographs courtesy Department of National Defence and Arnold Rose, P.Eng.

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where he was told that airplanes are out and missiles are in and there'll never be another manned airplane bought by any air force.

ED: *Was it on the strength of that advice alone that Diefenbaker acted?*

Floyd: Oh no. It was such a complex picture, it was like a tree: even the leaves had something to do with it dying. There were four major reasons:

- Diefenbaker could see the costs of the Arrow rising. It isn't unusual for the costs on high technology to be going up all the time; one of the prime examples would be the Concorde, which by the time it flew cost more than double what it had been estimated at. The Arrow was going the same sort of way.
- General Pearkes had said we can only justify this sort of a cost if we could sell it to the Yanks or the Brits. So he went out, completely prematurely, because you never sell an aircraft to a foreign government before you've developed it yourself, and of course he came back with a no.
- Then there's this memorandum Paul Campagna brought back from Washington (see p. 51). It's obvious that the Americans had virtually insisted on the cancellation of the Arrow as part of this deal, long before Diefenbaker came out and said that the Arrow was cancelled. That's a new one to me.
- Then the Americans were cutting down on their development of manned airplanes. Although they'd put out a specification for the F-108, which was a very highly supersonic airplane, probably as near to the Arrow as you can get, they'd cancelled it, because they weren't too sure that manned aircraft would be needed. The British government had put out a White Paper saying that they didn't foresee that there'd be any fighter aircraft designed from that point on. So I really don't blame Diefenbaker for his uneasiness looking at the program. I would blame him, though, for the way he accomplished the cancellation.

ED: *Did you suspect that the program was going to be cancelled?*

Floyd: We suspected that there'd be some hiccup. In September 1958, we were told that the whole thing would be reviewed in March, so of course we were on tenterhooks. But the appraisal was done on February 20 and the cancellation came the same day. That was the biggest shock of the century. We were in a board meeting with John Plant (president of Avro Aircraft) trying to settle some very mundane union situation about seniority. Joe Morley (sales and service manager) came running down the corridor with a man from the DDP (Department of Defence Production) saying they'd heard on the radio that Diefenbaker had cancelled the Arrow.

ED: *So you heard about it at the same time as the general public?*

Floyd: Later than the general public—*they* heard it on the radio.

ED: *It sounds like the government had a gun to its head.*

Floyd: We were told to close everything down and that nothing would be paid as from that day. My first thought was to see if any of our other projects could be got into shape so I could keep my 1,500 engineers. I'd been pleading for years to get another project going at the same time as the Arrow, but Fred Smye (general manager), who was a most sincere man, felt we had a duty to do the best we could on that airplane.

ED: *I still find it very difficult to understand why it was ordered scrapped, especially when today we're all talking about technology transfer, joint ventures, etc.*

Floyd: You're in very good company. The first thing that I did was to get on to the RAE (Royal Aircraft Establishment) in the UK to see if they'd be interested in taking some of these airplanes and they said of course, provided we could back them up with parts. Well, we had 31 aircraft back through the plant in different stages of production, so we had plenty of parts. We'd even worked out a method of transportation over the northern route—and then the order to scrap came down. (This was mid-April 1959. Floyd had been ordered to scrap the Jetliner, his admitted favourite project, on November 23, 1956. Three years later, after setting up another first class design team at Hawker-Siddely, UK, where he led the feasibility study on the Concorde, Jim Floyd experienced the disappointment of seeing the design study for Concorde go to Bristol Aviation Corporation. Saying he didn't want to see another aircraft, he quit and took his family on vacation. On his return, his first call was from the minister in charge of the Concorde asking him to consult on the project. That one flew!)

ED: *What message would you have for today's engineers?*

Floyd: The best things I've learned have been about dealing with people to bring out the best in them. The old things I learned in England I rebelled against. I try to coax people rather than beat them over the head. Canadians are very flexible: treat them the right way and you can get anything out of them.

One of the things I'm trying to do with the Canadian Aerospace Heritage Foundation is to help young people get the incentive to do some of the things we tried to do. Today there seems to be an apathy, a sense of too many things in the way. I'd like to give the kids some hope. ✲

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BOOKS

Advice to Bring New Ideas to Market

Bringing Innovation To Market, *Jagish Sheth & S. Ram, John Wiley & Sons, New York.*

Sheth and Ram have done an excellent job of explaining why corporations and customers resist innovation, even though they realize that it is both necessary and desirable.

Bringing Innovation to Market consists of two parts: part one—Encountering the barriers; part two—Breaking the barriers. In part one, the socioeconomic framework and its dominating forces are examined in detail. These forces are also the driving forces behind innovation: changing customers, technological breakthroughs, new competition, and changing regulation. Key characteristics of each force are presented in association with substantiating examples that are present in our society.

After establishing a framework in which the socioeconomic forces can be evaluated for their usefulness to innovation, the authors identify the structural and psychological impediments, both corporate and customer, that prevent success; analyzing various marketing strategies, and giving readers potential solutions applicable to a variety of situations.

Part two focuses its attention on how to overcome the barriers brought about by the foregoing socioeconomic forces. Four attack strategies are being presented here: Slow and steady strategy; grab and grow strategy; migrate and maintain strategy, and pick and project strategy. These strategies are also evaluated for their usefulness and effectiveness under varying conditions through the use of a wealth of indepth case histories that illustrate actual application in the marketplace. In closing, the authors have put all of the above together in what may be called a handy reference package in Chapter nine. This package contains numerous tables and charts that summarize the highlights of the above topics; hence, it provides to the readers a quick cross section of barriers and solutions.

Although this book is aimed at professionals engaged in promoting innovation in the marketplace, its contents will undoubtedly attract the attention of executives, managers, and other decision-making officers, as well as experienced engineers who are involved with bringing innovative products or services to the marketplace. Nonetheless, this publication should be of interest to those with a profound interest in marketing technological products or services in general, as well.

Reviewed by Albert T'O, P.Eng. Mr. T'O is a plant engineer with AFG Inc. (formerly Ford Glass Ltd.).

A Useful Guide For Any Novice Inventor

The Book For Women Who Invent or Want To, *Elizabeth Wallace, The Women Inventors Project, 1987, 122 pages, $10.*

The title of this book is somewhat of a misnomer. Its content is not limited to the subject of inventing, nor should its readership be limited to its female target audience.

The first part of the book presents, in an orderly and readable manner, the entire process required to develop an idea into a true invention and get it to market. It covers such topics as confidentiality agreements, marketing law, business plans, market research, prototypes, intellectual property, manufacturing, packaging and others. A series of questions posed at each chapter's end provides an excellent mechanism for reconsidering and testing the merit of an invention and the commitment needed to get it to market.

The second part of the book provides information about networking as a woman inventor and is generally of limited value to those experienced in networking techniques.

The appendices contain valuable information about associations, organizations, journals, publications and government agencies of specific interest to the Canadian inventor.

Other books about the inventing process are readily available. In fact, entire sections of libraries are filled with books about the individual topics discussed in this book. However, it provides a succinct overview of the inventing process as it applies to Canadians; reading it will save an inventor time and help to avoid the aggravation of wading through non-specific material or masses of "legalese."

The language and references to job orientation are slanted towards women in traditional roles, resulting in a somewhat chatty style which may be offensive to professional men and women alike. However, the authors note in the introduction that the book's style specifically intends to encourage potential female inventors, regardless of their experience or educational background.

Image-conscious male inventors interested in reading *The Book For Women Who Invent or Want To* can hide the title by folding the book; it is spiral bound. Alternatively, they could buy the book for wives, daughters or sisters—and help to achieve the authors' real objectives.

Reviewed by Debra DiLeo, P.Eng. Ms. DiLeo is controller at Hi-Rise Communications Ltd., and represents the mining and geology field on APEO Council.

Engineering Dimensions will review books of general interest to engineers. Readers who would like to become book reviewers are invited to send the editor a list of their special interests. Books reviewed become the property of the reviewer. Comments made are the opinion of the reviewer and do not necessarily represent the views of the APEO.