

The classic photo of the prototype CF-105 Arrow, 25201 was taken from a chase plane as it appeared on its maiden flight, 25 March 1958.  
AVRO AIRCRAFT LIMITED



# The McCarter Collection and the Avro Arrow

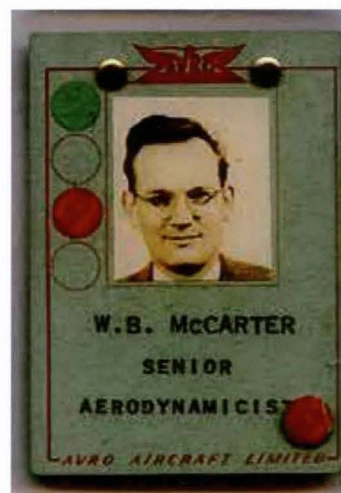
by Dr. David Waechter

**THIS VALUABLE COLLECTION... PROVIDES  
INSIGHT INTO THE CHALLENGES FACING AVRO  
AS IT DEVELOPED THE ARROW**

The William Beverly McCarter Collection, donated to the Canadian Warplane Heritage Museum, contains fascinating and relatively little-known details about the CF-105 Arrow and other Avro Canada programs. This valuable collection, an extensive compilation, provides insight into the challenges facing Avro as it developed the iconic Arrow. The documentation examines research into matters such as high-speed aircraft with delta wings, free-flight testing for the Arrow associated with the recovery in 2018 of a rocket-launched model from Lake Ontario, and the Martin-Baker ejection seat.

William Beverly McCarter (1925–2005) was an aeronautical engineer who worked at A.V. Roe Canada Limited from 1949 until 1959. Six months before he passed

away, McCarter donated a collection of his work material to the museum. The collection fills four large boxes and includes technical reports, brochures, conference proceedings, photographs, and correspondence. Most of the reports deal with the CF-105 Arrow or its engines, while a few items concern the C102 Jetliner, the CF-100 Canuck, and McCarter's post-Avro career at the Defence Research Board. This article discusses McCarter's background, his work for Avro, and the papers he left behind.



W.B. McCarter's Avro name badge, which is in The McCarter Collection.  
AUTHOR'S COLLECTION

JULY/AUGUST 2021

**FLIGHTLINES**







The 1948 graduating class in aeronautical engineering at the University of Toronto. Gerald Bull is farthest left in the second row and William Beverly McCarter is in the third row, directly up from Daisy Pon—the only woman in the class. Front and centre is Prof. T.R. (Tommy) Loudon who was head of both the Civil and Aeronautical Engineering departments. *AUTHOR'S COLLECTION*

Bev McCarter came from Hamilton, Ontario, and graduated from the University of Toronto with a degree in aeronautical engineering in 1948. He then took an additional year to complete a Master's degree at the university's new Institute of Aerophysics. A notable classmate of McCarter, who also did graduate studies at the institute, was Gerald Vincent Bull—best known for his work on the Velvet Glove missile and the Iraqi Supergun. Both students focussed their graduate work on equipment and methods for studying high-speed airflow. However, Bull stayed at the university two years longer than McCarter to acquire both a Master's degree and a Ph.D.

In 1952, Avro sponsored McCarter to take a diploma course at the College of Aeronautics in Cranfield, England. In June of the following year, he submitted a thesis on the longitudinal stability of high-speed aircraft with delta wings. His thesis was clearly related to the CF-105 program, which had just entered the project design phase in 1953. McCarter's thesis suggested that the damping of instabilities would be inadequate for a  $45^\circ$  delta wing in the transonic range, but under certain conditions, the damping

could be adequate for a  $60^\circ$  delta wing. In the end, Avro did use a sweep-back angle of about  $60^\circ$  for the Arrow's delta-shaped wings. The McCarter Collection includes reports on many tests with scale models carried out by Avro.

McCarter's Avro papers explained that because the Arrow was to operate over a broad range of speeds and altitudes, there was no single test method that could span the complete flight envelope and the corresponding range of Reynold's numbers. (The Reynold's number is a factor that takes into account the airspeed, atmospheric properties, and size of the aircraft or model under test.) An Avro report dated 2 July 1953, described tests planned for the Arrow program, including wind-tunnel tests and tests of rocket-launched free-flight models (FFMs). The report indicated that FFM tests should give more reliable results than wind tunnel tests because the Reynold's number for the FFM tests was larger and better matched that of the full-scale aircraft. Free-flight tests also removed the need for tunnel wall corrections and eliminated the possibility of interference from the model's mounting hardware. FFM tests were carried out at a Canadian Armament Research and



Development Establishment (CARDE) facility at Point Petre, located on Lake Ontario's northern shore. Two FFM tests were also carried out at a National Advisory Committee for Aeronautics (NACA) facility on Wallops Island, Virginia. Wind-tunnel facilities used for the Arrow program included those at the National Aeronautical Establishment (NAE) in Ottawa, Cornell Aeronautical Laboratories in Buffalo, as well as NACA Langley in Virginia and NACA Lewis in Cleveland.

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### THE EWART AND TAYLOR REPORT IS OF PARTICULAR INTEREST AT THIS TIME BECAUSE OF THE RECOVERY OF A ROCKET-LAUNCHED MODEL FROM LAKE ONTARIO

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A report in the McCarter Collection dated September 1956 summarized wind-tunnel test results obtained up to that time. Another report dated July 1957 summarized results of the first seven FFM tests—out of a total of eleven tests that were ultimately performed. The latter report was written by D. Ewart and W. Taylor and was approved by Jim Chamberlin, Avro's chief of

technical design.

The Ewart and Taylor report is of particular interest at this time because of the recovery of a rocket-launched model from Lake Ontario. Brought to shore by the "Raise the Arrow" team in August 2018, the model has a delta-wing configuration with a sweep-back angle of 70°. However, it was not one of the Arrow free-flight models, and this is confirmed by drawings in the Ewart and Taylor report, which show clear differences between the FFMs and the recovered model.

The recovered model precisely matches a delta test vehicle (DTV) known as DTV-3 that was tested under the auspices of Gerald Bull's Velvet Glove (VG) missile project. The test vehicle fuselage has a circular cross-section, like the VG missile, but the wing design is more akin to the Arrow. It is notable that W. Taylor was one of four Avro employees who attended the firing of this test vehicle on 20 October 1954. His attendance was quite possibly motivated by a need to see the firing and tracking procedures at CARDE in advance of the Arrow FFM firings. The Arrow FFM firings began only two months later. However, the flight performance of DTV-3 would have also been of interest to



The delta test vehicle that was recovered from Lake Ontario in 2018. Prior to the photo being taken, the nosecone section was removed and meticulous clean-up procedures were performed. The DTV was put on display at the Canadian Aviation and Space Museum in Ottawa on 1 July 2019. GOVERNMENT OF CANADA, CANADIAN CONSERVATION INSTITUTE





Free flight model (FFM) #1 and its booster rocket. This model was launched on 14 December 1954.  
CARDE NEGATIVE N° 8856

engineers working on the Arrow program because of its delta-wing design with relatively large sweep-back angle.

According to Ewart and Taylor, one of the challenges of FFM tracking was making sure the tracking radar followed the FFM after separation rather than following the spent booster rocket, which had a larger radar cross-section. This task was made easier by using a radar beacon inside the FFMs to transmit a strong response signal upon receiving an incoming radar signal.

Overall, the Arrow FFM tests were quite successful and were able to demonstrate the effect of various aircraft design modifications being considered by Avro at the time. In mid-September 2020, an object with geometry matching that of an Arrow FFM fuselage was detected by sonar at the bottom of Lake Ontario. But unfortunately, expedition leader John Burzynski and his team found that the object was in pieces, apparently having come apart on hitting the water. At the time of this writing, a recovery plan was not yet developed.

During the Arrow program, McCarter worked on a report with A.W.R. Gilchrist titled *The Escape Situation* in the C.105. The report was dated March 1954 and was quite

extensive. Topics covered included the Martin-Baker ejection seat and human tolerance limits for various conditions that would be encountered by ejecting from the aircraft. These conditions included high acceleration and deceleration, tumbling motion, wind blast, the impact forces of parachute deployment and ground contact, and the effects of low temperature and pressure. The report concluded that with a fully automatic ejection seat and partial pressure suit, the provisions made for pilot escape were adequate for all flight speeds, for all altitudes above 200 feet [61 m], and for G forces within specified limits.

Also during the Arrow program, McCarter led a group responsible for "internal aerodynamics"—the study of gas flow through the jet engines. As a result, many of the reports that he authored or coauthored himself had to do with different aspects of engine design. These included reports on intake and ejector design and reports comparing different engine types such as the Curtiss-Wright J67, the Pratt & Whitney J75, and the PS13 Iroquois.

Space limitations make it impossible to discuss all of the documents contained within The McCarter Collection. Nevertheless, here are some additional items that are worth mentioning:

- an early draft of a C102 Jetliner brochure, hand-written by McCarter and dated January 1950
- a CF-105 booklet prepared for a sales presentation to the U.S. Air Force in August 1954
- a 1954 report on the lift distribution on supersonic wings by B. Etkin and F. Woodward
- reports by Jim Chamberlin on CF-105 stability, dated in February and September of 1955
- Arrow Periodic Performance Report numbers 11, 13, and 15, dated Oct 1957, Jan 1958, and Nov 1958, respectively
- a report by Rodney Rose titled *An Initial Study of the Supersonic Trans-Atlantic Airliner*, dated February 1959—the same month the Arrow was cancelled

Bernard Etkin, mentioned in the third item above, was a well-known aeronautical engineering professor from the University of Toronto who often did consulting work in the aviation industry. The last item by Avro engineer Rodney Rose concluded that a supersonic aircraft carrying 150 passengers "is not only technically feasible, and within the current 'state of the art,' but has much to recommend it." The report further suggested that a serious design study on such a concept could consider using eight non-afterburning Iroquois engines paired in four pods or possibly four non-A/B Iroquois engines of twice the size. The possibility of a 75-passenger version using four standard non-A/B Iroquois engines was also discussed. The wing design required would be similar to that of the Arrow.

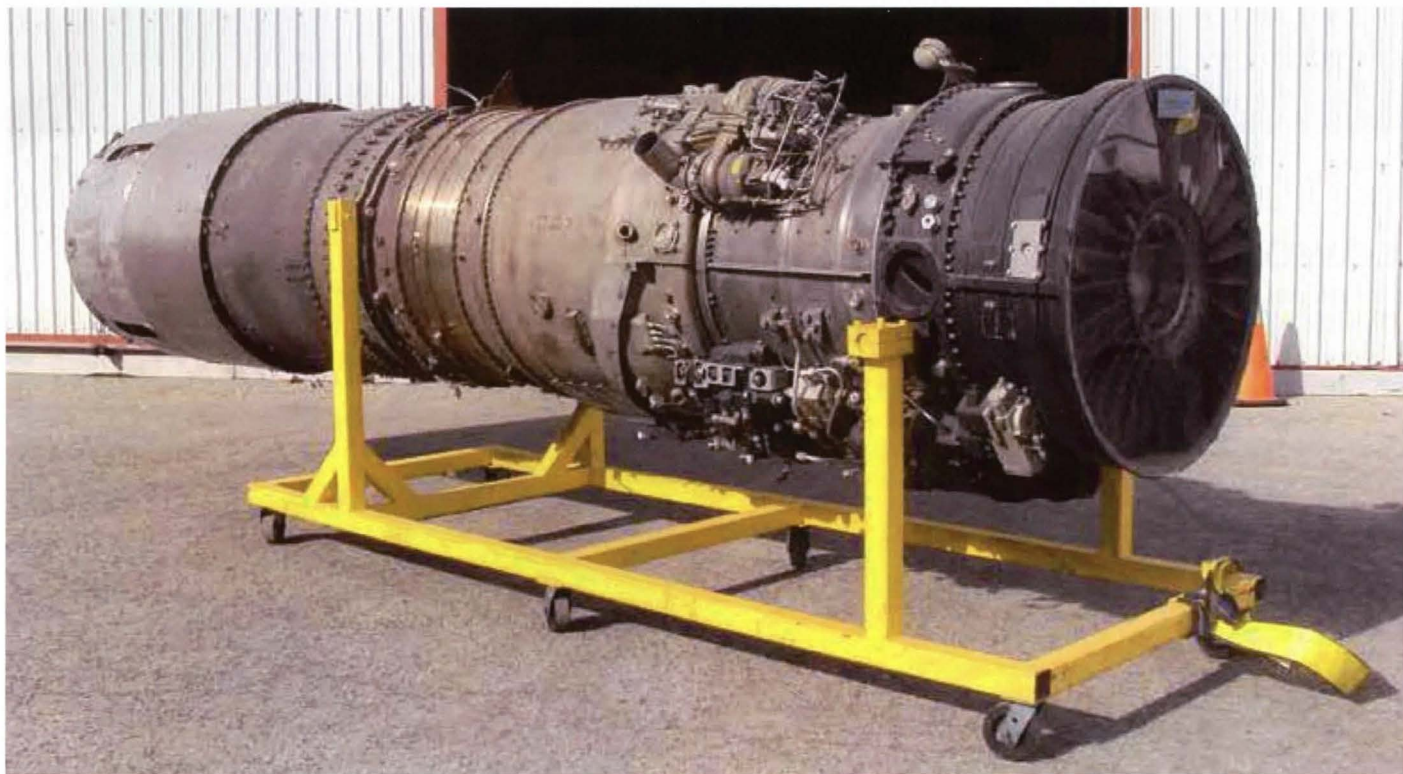
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**IN MID-SEPTEMBER 2020, AN OBJECT WITH GEOMETRY MATCHING THAT OF AN ARROW FFM FUSELAGE WAS DETECTED BY SONAR AT THE BOTTOM OF LAKE ONTARIO. BUT UNFORTUNATELY... THE OBJECT WAS IN PIECES, APPARENTLY HAVING COME APART ON HITTING THE WATER.**

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A PS13 Iroquois engine at the Canadian Warplane Heritage Museum. This engine type was never flown in an Arrow aircraft but was slated for use in the sixth Arrow and beyond. The only Arrows that ever flew used J75 engines by Pratt & Whitney. Much of W.B. McCarter's work during the Arrow program was concerned with the engines and their performance. *AUTHOR'S PHOTO*

Finally, it is worth mentioning that two of Bev McCarter's university classmates, Ralph Waechter and William Kuzyk, also retained original Avro reports from their time at the company. The Ralph Waechter Fonds and the William Kuzyk Fonds were both acquired by Library and Archives Canada in the past several years. Collectively, the documents retained by the three former classmates—McCarter, Waechter, and Kuzyk—provide a tremendous amount of primary-source information about the products of A.V. Roe Canada Limited and the company's development programs. 🍁

#### **Acknowledgements**

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The fifth CF-105 Arrow produced, 25205. This Arrow only made one short test flight before the project was cancelled on Black Friday, 20 February 1959. *AVRO AIRCRAFT LIMITED*