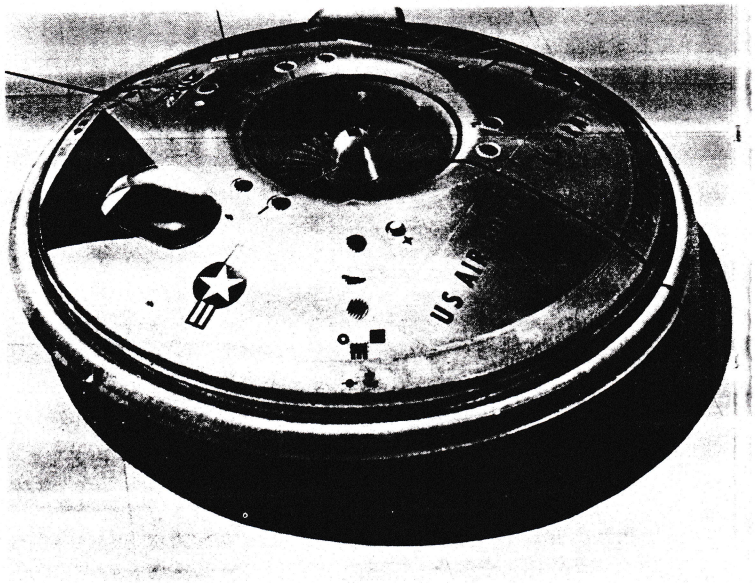
THE (ALMOST) FLYING SAUCER



Ernest Ball describes the Avro Canada Avrocar — a truly circular aircraft but one which achieved scant success.

IN 1955, Avro Aircraft Limited of Canada designed and built a research vehicle under the sponsorship of the United States Army and US Air Force. Originally given the official designation VZ-9V, it was intended to explore the potential of a new scientific and technical approach to vertical take-off and landing. The idea was for a machine which could be operated within ground effect as an air-cushion vehicle whilst accelerating to a point where it would function as an aircraft supported by aerodynamic forces generated by its forward speed. It was hoped that it would have a higher performance than other types employing this principle.

The leader of the design team which conceived the machine, named the Avrocar, was John Frost who had previously been project designer on the De Havilland D.H.110 in England. He joined Avro Aircraft in 1947 and became Chief Design Engineer VTOL, a position which he held until 1961 when he left for Australia.

The shape of the aircraft was dictated by the two extremes of its envisaged flight envelope — it was to be capable of hovercraft qualities, high forward speed in clear flight and high hover, outside ground effect. A circular planform was chosen, its thickness ratio derived from aerodynamics which were the precursors of those on which lifting bodies of more recent years have been designed.

A radical specification

In a paper presented to the Canadian Aeronautical Institute in 1961, John Frost commented on the fact that new ideas are often thought of and worked on at the same time in different parts of the world without one group having knowledge of the activities of the others.

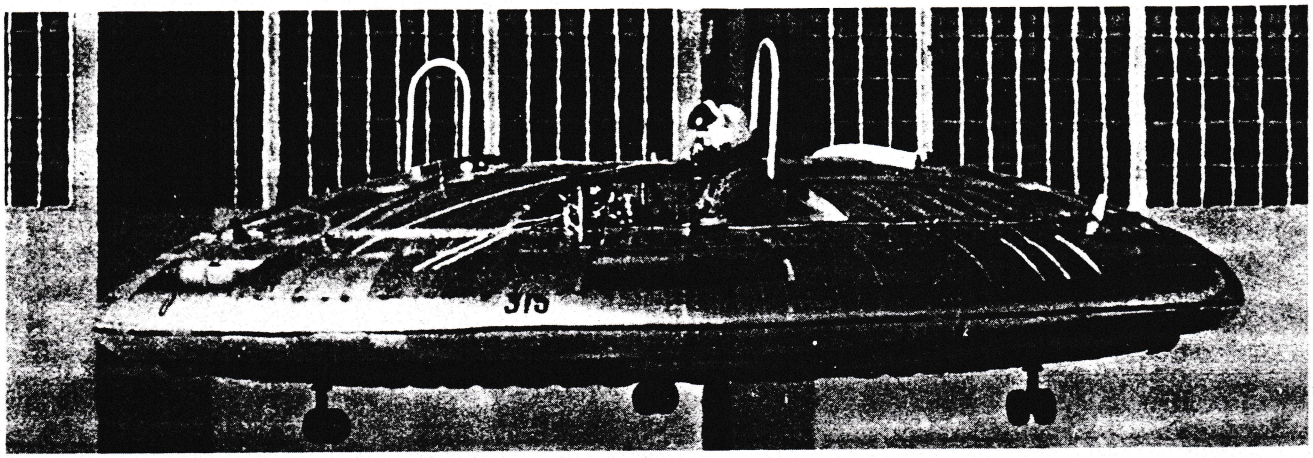
"In many cases", Frost said, "this is due to the state of the art, so that there are numbers of groups working who are all on the verge of taking the next step within the same period. In the case of the ground cushion, this was not so, since it was technically possible for the Wright Brothers to have built a ground cushion vehicle at the same time they flew the first aeroplane". Evidence suggests that he was correct in this assumption; it seems that Sir John Isaac Thorneycroft did, in fact, conduct air cushion experiments as long ago as the 1870's.

Not until the 1950's, however, did work on the ground cushion concept finally come to the fore. The Avro Special Projects group, under Frost's leadership, discovered the ground cushion effect in 1953 while studying a flat-rising vertical take-off aeroplane. Christopher Cockerell, working independently in England, came on it in 1955 — as had Thornycroft nearly a century before — while making efforts to reduce the drag on ship hulls. Carl Weiland of Switzerland was working on the same principle by 1956.

The outcome of the Avro Canada experiments was a circular vehicle which became known as the Avrocar and was designed, as already noted, for the US Army, the requirement being for a vehicle which could take off vertically and hover out of the influence of the ground. This, not surprisingly, involved the installation of considerably more power than would otherwise have been necessary. It would have been more economical in terms of horsepower to have it take off into aerodynamic flight from the ground cushion and to have dispensed with the "in-flight" hover characteristic. Two VZ-9V prototypes were built.

The Avrocar was 18-ft (5,48-m) in diameter and comprised a circular "wing" with a 20 per cent elliptical section and two per cent camber. The crew of two, a pilot and an observer, each sat in a separate cab situated on opposite sides of the craft and placed slightly forward of the centre line. The gross weight with a 2,000 lb (907 kg) payload was almost 6,000 lb (2 722 kg). Power was supplied by three Continental J69-T-9 turbojets which were used as gas generators to drive a centrally-located fan. The three engines, which together produced 3,000 shp,

The first VZ-9V prototype is shown below during one of its few free flights at Toronto in its original configuration. The illustration top right shows the later form, with a "focussing ring" right round the peripheral nozzle.



were arranged equidistant around the fan and tangentially to it, being mounted inside a triangular sub-frame assembly, on either side of the apex of which the cockpits were placed. Beside each engine was a separate fuel tank, a cross-feed system linking the three compartments. It was intended that the Avrocar should have a maximum forward speed of 300 mph (480 km/h) at high altitude and a range of 1,000 mls (1 600 km).

The fan measured 5 ft (5,486 m) in diameter and was designed to handle 550 lb (150 kg) of air per second at a pressure ratio of 1,07 to 1. The fan was driven by a tip turbine which used the exhaust gases from the J69 engines, the hot exhaust from the turbines being mixed with the cold air from the fan in a duct immediately below the fan. This duct passed from the bottom of the fan and extended below the cockpits, engine bays and cargo compartments to a peripheral nozzle around the entire circumference of the vehicle.

Because the Avrocar was required to loiter in ground effect and to be able to rise vertically and hover away from this influence, a stable ground cushion in pitch and roll was essential. This was achieved by the addition of a central jet through which part of the air could be passed during hovering and which could be closed for forward flight.

Stabilisation

The aerodynamic centre of the circular-planform vehicle was found to be 28 per cent of the root chord. The wing, therefore, had a negative static margin and was both statically and dynamically unstable in aerodynamic flight, thus requiring artificial stabilisation. This was achieved in a most interesting way. The turbine-fan combination (or turborotor) was allowed a small degree of freedom relative to the aircraft structure. This freedom was half a degree and a strong spring was used to restrict the movement. When the vehicle pitched or rolled, the fan, due to its gyroscopic couples, absorbed some of this freedom against the resistance of the spring. This small movement was then magnified about 20 times by a mechanical linkage and the resulting motion applied to the control system. This in turn directed the peripheral jet to produce corrective pitching and rolling moments from the jet reactions at the rim of the vehicle.

The mechanical control of the jet was originally achieved by the use of upper and lower spoilers forming a double ring around the periphery and projecting slightly from the sides of the radial duct. Outboard of the spoilers the duct was bifurcated with constant-radius walls to which the jet tended to adhere by coanda effect. Motion of the spoiler ring up or down resulted in the corresponding deflection of the jet.

To rise vertically, the spoilers were operated to deflect the air downwards, so forming a circular curtain of air beneath the vehicle. Transition to forward flight was effected by operating the spoilers to deflect the air backwards over the upper and lower wing surfaces to form a jet flap at the rear.

After some development, this system was modified in order to improve hovering lift. The upper nozzle and the spoilers were eliminated completely and control was achieved by a ring at the outboard edge of the lower nozzle. This "focussing ring" caused the jet to focus beneath the aircraft and flow downwards as a solid 'tree trunk'. When the control ring was moved aft, the jet was deflected rearwards, so resulting in forward thrust.

The prototype Avrocar began tethered flight trials, becoming airborne for the first time on 5 December 1959, at the Malton plant of Avro. After initial trials, it was taken to California for development tests under the auspices of the US Army, including an investigation in the Ames Research Center wind tunnels. It was returned to Toronto and began its first tests in forward flight on 17 May 1961. All was not well, however, and instability above an altitude of 4 ft (1,22 m) was so dangerous that final tests reverted to tethered conditions.

The development contract was completed in December 1961, and the project was abandoned. One of the two Avrocars was stripped and scrapped at Malton and the second machine was donated to the Smithsonian Institution in Washington and was subsequently placed on display at the US Army Transportation Museum at Fort Eustis, Va. The old Avro plant was sold off during the following year by De Havilland Aircraft of Canada who subsequently disposed of it to Douglas Aircraft of Canada.

1 Turborotor hub fairing
2 Multi-blade turborotor, diameter 5 ft (1,52 m)
3 Anti-ingestion grille
4 Circular air-intake duct
5 Three J69 turbojets (tangentially mounted)
6 Engine air intakes
7 Fuel tanks (adjacent to each engine)
8 Engine bearing frame
9 Observer's seat
10 Observer's bubble canopy
11 Oil tanks (each engine)
12 Forward apex of triangular sub-frame assembly
13 Accessories compartment
14 Pilot's instrument panel
15 Control column
16 Pilot's bubble canopy
17 Pilot's seat
18 Upper section of inner rim
19 Lower section of inner rim
20 Adjustable 'focussing ring'
21 Section of outer rim
22 Outer rim supporting struts
23 Focussing ring supporting struts
24 Focussing ring control rods
25 Guide vanes for airflow to peripheral nozzle
26 Sealing plates between inner and outer rims
27 Cargo compartments at rear