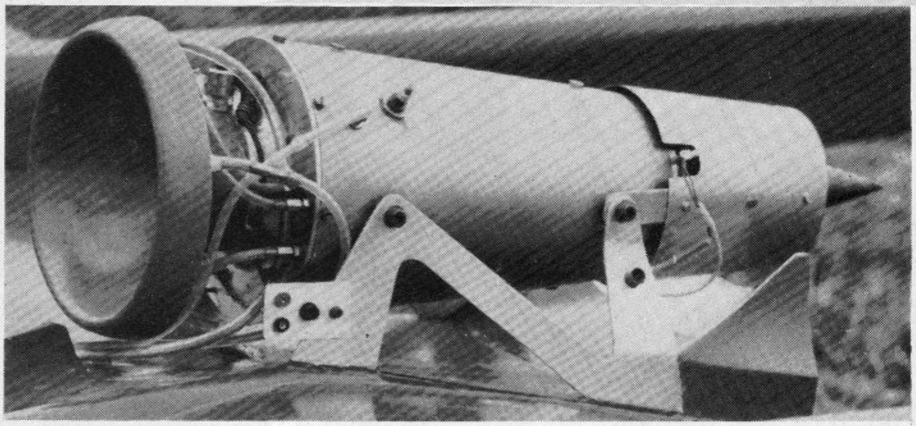
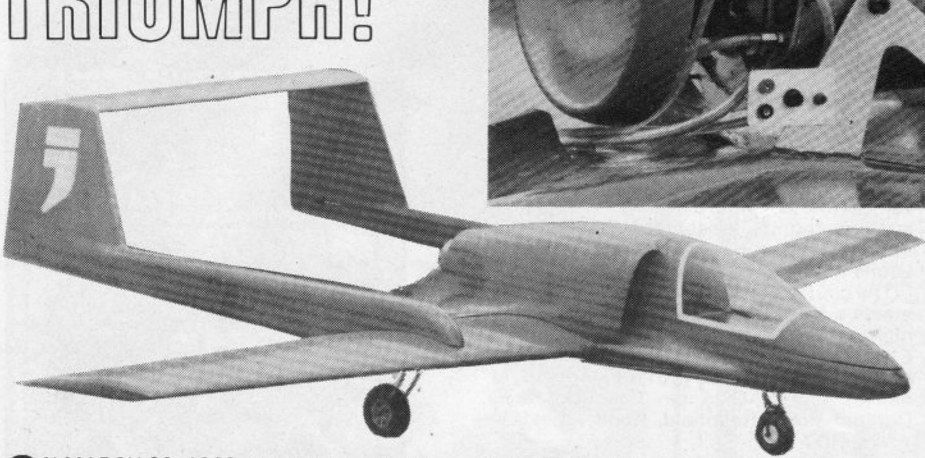
RADIO MODELLER

WORLD'S FIRST MODEL JET TURBINE

TURBINE

JET FLIGHT TRIUMPH!





The gas turbine engine is above in place on the *Barjay*. On the left is the completed aircraft ready to roll.

ON MARCH 20, 1983, a small red aircraft rolled down one of the runways at RAF Greenham Common and lifted into the wintery sky with the unmistakable whistle of a jet engine. A common enough occurrence at many airfields, but what made this particular event so important was that it marked the first ever flight of a radio controlled *model* aircraft powered by a gas turbine. Few of the people who wanted to see this momentous occasion were actually present, for in fact the purpose of that day's excursion was to be ground testing and taxi trials to check on the aircraft's fuel system, but the machine (which has been christened *Barjay*) showed such potential even with the throttle mechanically restricted to limit the engine to 60000rpm that the aircraft was allowed to accelerate to take off speed and gently lifted off into a smooth and historic three minute long first flight.

It has been Jerry Jackman's personal determination that has kept this project going through eight years of development. Jerry himself stresses, however, that the final achievement was very much the result of a team effort, the team comprising of Barry Belcher, Ray Carter, David Sitch and Chris White, each having a specialised talent essential to the project.

All team members are active aircraft modellers. Jerry, who started the project alone, recruited the individual members of his team from the flying field, each member feeling able to contribute some of his specialist knowledge to Jerry's particular problems which appeared to increase as the project developed and the technology evolved.

At one stage, eight years ago, Jerry had evolved a prototype which would self sustain but not accelerate. Chris White (machinery engineer for a petrochemical contractor) 'climbed aboard' and redesigned the compressor and power turbine blades. The improvements resulted in the requirement for a man to redesign the rotor mechanics. Consequently, David Sitch was recruited and further improvements resulted. Ray Carter joined five years ago and made dramatic improvements to the mechanical design. The last member, Barry Belcher, who's finest contribution was to conceive and design a superb test bed with eye appeal, also refined the turbine blade shape to achieve even better performance. Many setbacks and disappointments had been overcome to arrive at the main runway at Greenham on the 20th March and some problems have still to be solved to improve the reliability of the powerplant.

Basic principles

Mechanially, the jet engine is one of the simplest engines for there are so few moving parts. It is necessary, however, to understand a few of the basics of the jet before going into details of the construction and performance.

Air, like all gases, expands when it is heated. In an internal combustion engine, the air is mixed with fuel before it is injected into the cylinder and ignited. The expanding gases push the piston down the cylinder and the con-rod and crankshaft translate the linear motion into a rotary one, which has to be used to create thrust through some other medium; propeller, ducted fan, wheels, etc.

A jet engine is simpler in concept for the expanding gases are directed out of the open ended tube within which the fuel is burnt to create pure thrust on Newton's principle of action and reaction. For thrust to be continually generated it is essential that the expanding gases only come out of the rear end, while fresh air has to be fed into the front to maintain combustion. The ram jet gets around this problem by the simplest means possible, for it relies upon the ram effect of the air entering the intake preventing the exhaust going the wrong way. Unfortunately, this engine has to be moving through the air at considerable speed before it can be started, which is why it is infrequently seen.

A spring loaded shutter or valve fitted into the air intake turns a ram jet into a pulse jet. Air and fuel passes through the valve until the charge in the combustion chamber ignites. Back pressure then closes the valve as thrust is generated, this remains closed until the charge is exhausted when spring pressure opens the valve to allow more fuel and air to enter the engine, restarting the cycle. The drawback to this jet is lack of effective control both of the thrust pulses or the ensuing noise. Thrust increases as the pulse jet accelerates to create a ram effect at the intake. (See Fig. 1).

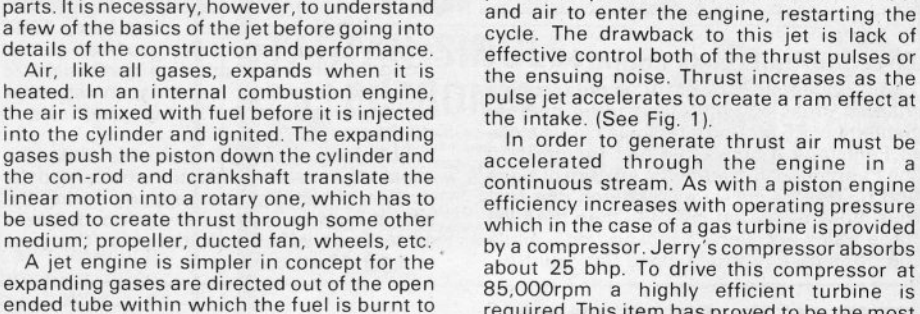
In order to generate thrust air must be accelerated through the engine in a continuous stream. As with a piston engine efficiency increases with operating pressure which in the case of a gas turbine is provided by a compressor. Jerry's compressor absorbs about 25 bhp. To drive this compressor at 85,000rpm a highly efficient turbine is required. This item has proved to be the most difficult single component to develop and manufacture. Energy that is left in the hot exhaust is converted to thrust by accelerating the gas down the tailpipe.

Jackman's Jet

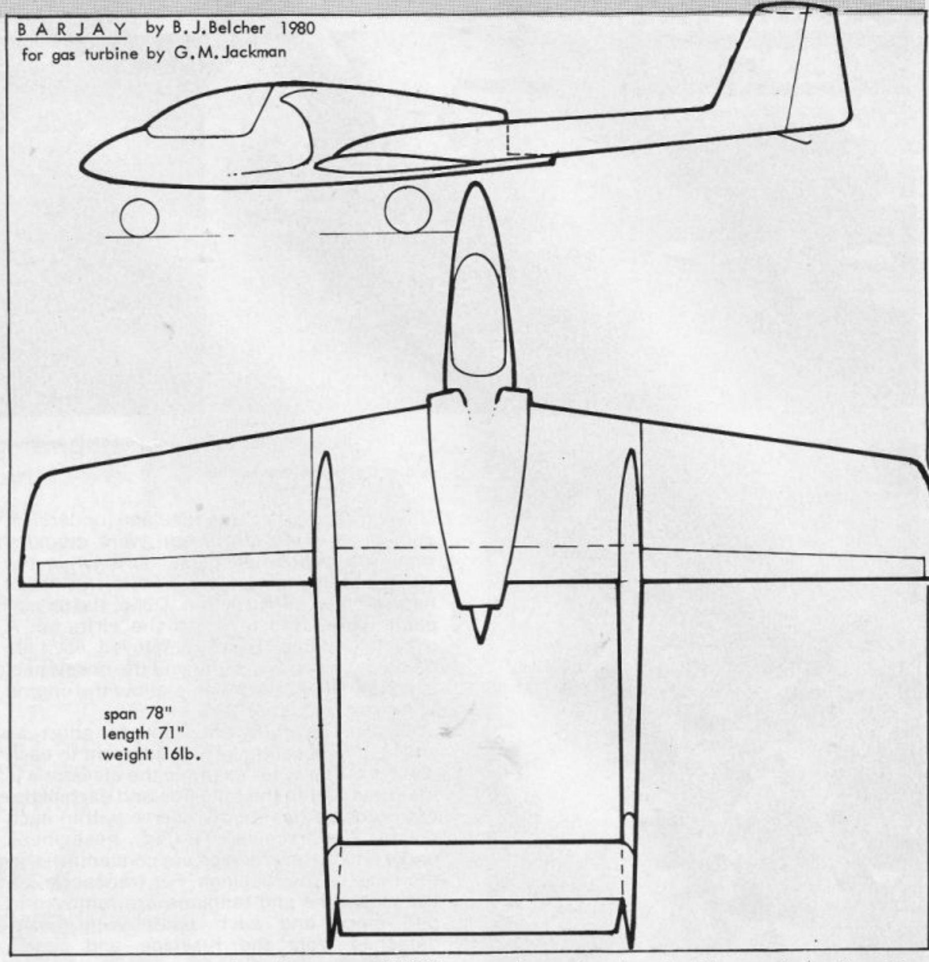
It would seem from the theory that a gas turbine would be an incredibly easy device to build, but the theory ignores the practical considerations of metallurgy, thermodynamics and aerodynamics.

One of the first facts that had to be realised was that the rotational speeds and

Fig. 1



Diameter: 4.75in.
Length: 13.5in.
Weight: 3¾lb.
Fuel: Propane.
Centrifugal compressor: 3in. dia., tip speed 1,100ft./sec. Pressure ratio 2 to 1.
Combustion chamber: Annular.
Turbine: Axial flow.
Exhaust temperature: 650°C.
Starter: 24 volts, 1.5hp at over 30,000rpm.
Thrust: in excess of 9lb. at 85,000rpm.
Top rpm limit: 97,000rpm.



temperatures were going to be far in excess of normal aeromodelling experience. For example, many modellers are reluctant to rev their two-stroke glow motors faster than 24,000rpm, but the model gas turbine cannot even be started until the shaft has been spun up above this figure. At about 37,000rpm the engine is self-sustaining but has to be run up to 45,000rpm to create thrust and obtain a rapid throttle response.

Externally, the jet is just a featureless cylinder with a large rear exhaust nozzle and a strangely tiny intake in the blunt forward face. The large diameter of the front is due to the use of a centrifugal compressor, a type that has contoured blades that spin a cylinder of air, centrifugal force throwing the air outward in a ring to create a low pressure at the centre which draws more air into the compressor. When the engine is turning over at 85,000rpm the compressor draws in five cubic feet of air per second into the engine through the approximately 2in. diameter intake.

After leaving the compressor the air has to be turned sharply back towards the annular combustion chamber and drastically slowed to increase the pressure. The air then passes back along the outside of a perforated shroud, between the combustion chamber and the outer casing. Considerable effort went into the design of the shroud, for holes have to be correctly positioned and absolutely the right size to allow the right amount of air through at the proper speed. For example, the front of the combustion chamber primary (or combustion) air has to be fed in at a very slow rate to feed the gas jets without extinguishing the flame. At the rear of the shroud the secondary air has to be fed in at the correct position for it to be heated by the gas flames.

The size of the flames are critical to the running of the engine. Too small and the engine will lack power, too large and they will hit the turbine and tailpipe causing a frightening rise in temperature. Obviously the flames cannot be seen when the engine is running so considerable theory and calculation had to be gone into to design the fuel jets and combustion chamber to produce the necessary flame. In the early days engines were built that glowed white hot and the team were highly delighted when the tailpipe temperatures were reduced to a mere 600°C.

It is the turbine wheel that takes the full force of these frightening temperatures and also has to resist the stresses imposed by the terrifically high rpm.

Nickel alloy is used for this particular part of the engine, which has to be cut from a solid disc as trials have proven that separate blades cannot be fixed securely into a solid hub. Alloys of such tensile strength cannot be worked on the kitchen table with a vice and file, and the team had to employ a spark erosion machine to form the turbine blades.

Spark erosion is a controlled use of the phenomenon that causes a car's contact breaker points to erode. The workpiece takes the place of the cathode and the anode is formed in the shape of the hole that has to be cut. An electric current caused sparks to jump from cathode to anode and each spark carries with it a particle of the workpiece.

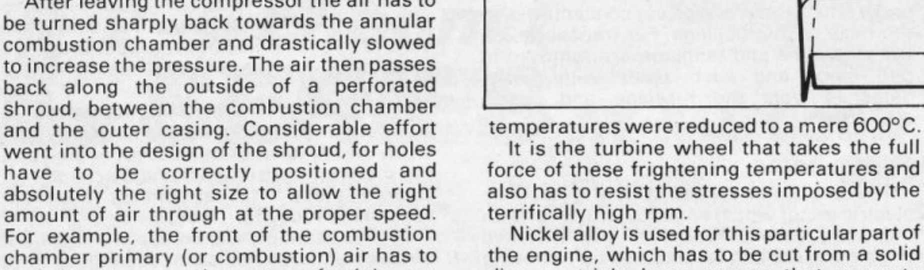
Commercial spark erosion machines are tremendously expensive to buy or to use through a sub-contractor, for cutting a wheel takes a few hundred hours. Jerry therefore developed his own miniature spark erosion machine, which was no mean technical achievement in its own right.

The turbine and compressor are linked by a 1in. diameter shaft, the size of which is an indication of the amount of power that is taken from the potentially available thrust in order to compress more air. Special high speed bearings support the shaft and these are both cooled and lubricated by a pressurised oil supply.

Oil is carried in a small pressure tight cylinder similar to a gas lighter refill, which is pressurised by an air bleed from the compressor. In the course of a ten minute run the engine will consume some 35ml of Castrol Turbine oil, the used oil being thrown out of the bearings into the gas flow through the engine.

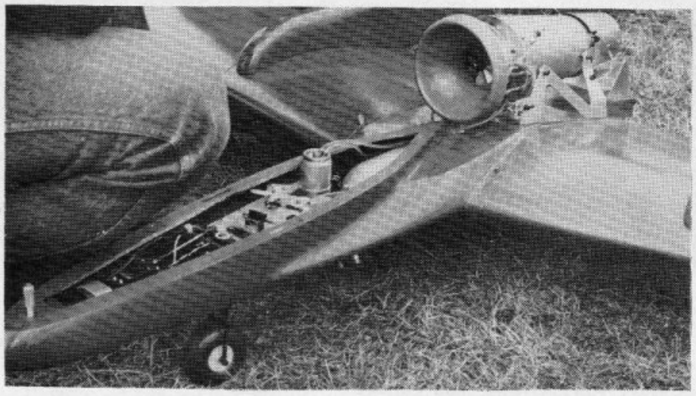
Fuel consumption is also quite staggering, for in the course of a seven minute run at 85,000rpm (about 90 per cent available thrust) the jet will guzzle 1¼lb of liquid Propane. In the aircraft, the fluid is carried in a lightweight pressure bottle in the fuselage below the engine. During the initial taxi trials problems with the fuel supply were encountered, which the team believes have now been solved. From the tank, liquid propane is taken via silicone fuel tubing up to the throttle valve, which is a servo driven needle valve, a barrel or butterfly valve being far too insensitive. From the throttle valve the fuel is taken, via copper tubing around the tailpipe of the engine to vapourise the fuel and then to the ring of fuel injectors at the front of the combustion chamber. There are a number of jets in the fuel manifold, their size, position and number being precisely calculated so that the quantity of fuel would be correct for the amount of air and the size of the flame required.

Fig. 2



GAS TURBINE JET ENGINE

TURBINE



Above: the packed fuselage. The fuel-tank can be seen between the wing root leading edges behind the oil tank.

Left: Ray Carter tops up the bearing oil before another flight.
Above: the *Barjay* is assembled.

Airframe details

The engine is supported by an alloy sheet frame on the back of the fuselage in the manner of the Heinkel He 162, although the twin boom layout of the whole aircraft reminds most people of the *Venom* or *Vampire*. Even though the aircraft has been designed expressly as a flying test bed for the engine, the finish is absolutely superb, the canopy in particular being crisp and flawlessly moulded.

The three parts of the fuselage (underside, engine cover and front top) were moulded from red pigmented glass fibre while the wing panels, tail booms and tail surfaces have a balsa construction. Dope, tissue and paint were used to finish the airframe. A tricycle undercarriage is employed, each leg being individually sprung and the nosewheel is equipped with a brake to allow the engine to be run up before take off.

Control linkages are kept as short as possible by locating servos adjacent to each control surface, for example the elevator's is mounted within the tailplane and each of the twin rudders has its own servo within each boom. The receiver Ni-Cad, nosewheel, brake and throttle servos are concentrated in the nose of the fuselage. For transportation the tailbooms and tailplane are removed in one piece and each outer wing panel detached from the fuselage and centre section.

Pilot's notes

The engine is started with a geared up electric motor which engages with a cone on the compressor. Access to the installed engine for starting is obtained by removing the front top of the fuselage, which also allows the necessary metering devices to be temporarily attached. These include a tachometer which works from a light source and photo cell within the air intake cone, pressure sensors to check on the effectiveness of the compressor and a tailpipe temperature sensor.

Jerry starts up the turbine for a test run. Fire precautions are in evidence, very important considering the volatile and explosive qualities of the Propane gas fuel.

To start the engine, the starter is engaged and the rotor spun up to about 24,000rpm, at which point the fuel mixture is ignited by a miniature spark plug set in the combustion chamber wall. After this first ignition the burners work continually like a gas cooker ring. The engine is then carefully monitored as it is accelerated to its normal running speed and the starter removed.

From the spectator's point of view this is the most exciting period of the flight demonstration. The engine, running at well below peak efficiency, bursts into life with a hoarse roar and then growls unevenly as the throttle is slowly opened. As the engine accelerates to its designed running speed it actually cools off and at peak efficiency it is possible to lay your hand on the outside casing of the engine.

When the designed running speed is achieved the engine note changes to the clean steady howl of the true jet engine and the metering instruments and starter are all cleared away. The aircraft is then reassembled ready for take off.

Several attempts were made at a first flight but problems can still occur even though the engine is perfected. Some of these will be familiar to all modellers, like those concerning fuel feed and contamination, and others associated with full size jets, such as FOD, (Foreign Object Damage), i.e., damage caused by stones, etc. being drawn through the engine.

The first flight was made almost upon an impulse on one of the days originally set aside for taxying trials. A mechanical stop was set up on the throttle to restrict the engine to 60000rpm, less than half the theoretical maximum available, and the aircraft taxied around to check upon the performance of the engine with the aircraft's fuel system. Even with such a restricted amount of thrust (which gave a power to weight ratio somewhat better than *Concorde* at full bore), the jet showed such willingness to go that Jerry allowed the machine to accelerate to flying speed and lifted off into a three minute flight of steady circuits. At the time of writing a flight with the engine producing 100 per cent thrust has yet to be attempted.

What of the future?

What indeed. It is unlikely that versions of this motor are going to be seen powering models at many clubs flying fields over the coming months, for although the idea of producing the engine commercially has been considered it would be extremely expensive, the price possibly exceeding even the fabulous Techno radials.