EAGLE V

An Entry-Level Turbine Powered Model For The Sport Flier

By Giancarlo and Alessandro Genta

Part I: The Turbine Revolution in R/C

This article is dedicated to Luigi Giordano; jet modeler and fantastic pilot, expert aerobatic flier, airline pilot and, above all, good friend, who died in a full-scale aircraft accident at the age of 29.

Jet Engines

All types of aero engines work on the same principle: producing a forward thrust by accelerating a stream of air in a backward direction. It is an application of Newton's third law of dynamics. (Newton drew a sketch of a cart propelled by a jet of steam from a boiler: just a conceptual experiment to show a principle.)

In propeller airplanes such acceleration is performed by mechanical means, thanks to a propeller operated by an internal combustion engine. The idea of creating a high speed jet, exploiting the chemical energy of the fuel burnt in a combustion chamber in which the air is heated and then expelled, instead of converting the chemical energy into mechanical energy and then using it to operate the propeller is old, but it was only in the 1930s that the first experimental successful jet engines were built.

About the end of World War II, technology was advanced enough to allow the production of reliable and workable jet engines, and in the 1950s the dominance of propellers operated by piston engines was at its end. Jet engines proved to be much simpler, more reliable and less costly, both to produce and to operate. Their application now went well beyond the fighter planes for which they were initially meant. The application of jet engines to airliners brought about the revolution in transportation which made our world increasingly smaller and brought transoceanic travel within the possibilities of a large number of people.

For low speed flying the high speed jet produced by turbojets is less efficient than the slower stream of air produced by propellers, but even in this case engines based on the same layout of turbojets (turboprop) proved to be better than piston engines. At present, reciprocating engines survive in full scale aviation only in light aircraft where the difficulties linked with the miniaturization of turbojets and

EAGLE V

Designed by:
Giancarlo & Alessandro Genta

TYPE AIRCRAFT
Sport Jet

WINGSPAN
50.4 Inches (1280mm)

WING CHORD (root, incl. LEX)
37.3 Inches (948mm)

TOTAL WING AREA
971 Sq. In. (62.66 dm²)

WING LOCATION
Mid-Fuselage

AIRFOIL
NACA 64A-010 (Symmetrical)

WING PLANFORM
Delta w/L.E. Extensions (LEX)

DIHEDRAL, EACH TIP
0

OVERALL LENGTH
68.5 Inches (1740mm)

RADIO COMPARTMENT SIZE
6" (L) x 4-1/2" (W) x 3-1/2" (H)

STABILIZER SPAN
17.7 Inches (450mm)

STABILIZER CHORD (inc. elev.)
6.3 Inches (160mm)

STABILIZER AREA
111.6 Sq. In. (7.2 dm²)

STAB AIRFOIL SECTION
Flat

STABILIZER LOCATION
High (T-Tail)

VERTICAL FIN HEIGHT
9.25 Inches (235mm)

VERTICAL FIN WIDTH (average)
8 Inches (203mm)

REC. ENGINE SIZE
Wren MW 54 Turbojet or Equivalent

FUEL TANK SIZE
45 Oz.

LANDING GEAR
Retractable Tricycle

REC. NO. OF CHANNELS
5 (6 w/optional Air Brakes)

CONTROL FUNCTIONS
Elev., Ail., Throt.,
Nosewheel Steering,
Retracts, Optional Air Brakes

C.G. (from L.E.)
(at the wing-LEX connection)
7.35 Inches (187mm)

ELEVATOR THROWS
±3/4 Inch (±20mm)

AILERON THROWS
±3/8 Inch (±10mm)

RUDDER THROWS
–

SIDETHRUST
–

DOWNTHRUST/UPTHRUST
–

BASIC MATERIALS USED IN CONSTRUCTION

Fuselage	Balsa & Lite Ply
Wing	Balsa & Lite Ply
Empennage	Balsa
Wt. Ready To Fly	13 Lbs. 4 Oz. (6 kg)
Wing Loading	31.4 Oz./Sq. Ft. (96 g/dm²)

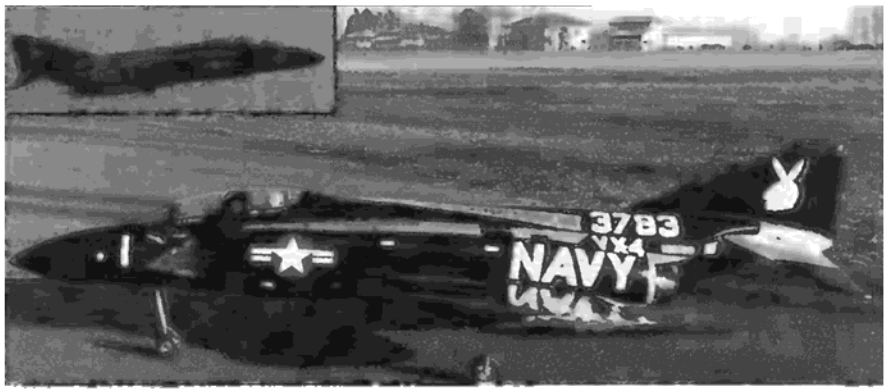


Photo #1: An F-4 Phantom "Black Bunny" scratch-built by the authors with Byrojet fan unit and Rossi 81 engine.

turboprops are still leaving them a niche.

Until a few years ago the situation at the modeling field appeared to be completely different. The 2-stroke piston engine was unquestionably the most popular choice for all types of model aircraft, owing to its intrinsically simple layout and ease of operation coupled with a very good power/weight ratio and reasonable cost. Its main drawback was, and still is, its noise, which became an increasing nuisance, in Europe even more than in the States. It became increasingly difficult to find and keep flying fields, particularly for the larger and noisier models.

An increasingly large number of modelers were interested in scale models of jet planes, and many didn't accept the idea of using a propeller on the grounds that "it is impossible to see it in flight." The simplest solution was to hide a small propeller driven by a 2-stroke piston engine in the fuselage, but the thrust obtainable in this way was barely enough for very lightweight free-flight planes whose behavior was far from simulating that of true jets. This idea eventually evolved into the modern ducted fan units, which are actually able to supply "jet-like" performance."

However, ducted fans do not solve, in a satisfactory way, all problems linked with modeling jet planes. In particular:

- They require high performance 2-stroke engines with a tuned pipe and high nitro fuel (in Europe less common than in the States), which are expensive and not easy to operate. To optimize the high-end operation, their idle characteristics are often marginal and their lifespan is not very long.
- The fan unit is large and it may be difficult to put it inside the fuselage.
- If the unit is designed to optimize velocity, take-off characteristics are often marginal (like a propeller with high pitch, small diameter). In the opposite case, take-off is better but the thrust decreases with increased speed.
- They are very noisy, and the type of noise is very different from that of full scale jet engines.

As a conclusion, ducted fans are restricted to modelers with much experience both in building and flying, ready to invest much time and money in the hobby.

True jet engines, that is engines in which the acceleration of the jet is performed by heating the air taken from the atmosphere, can be built in different

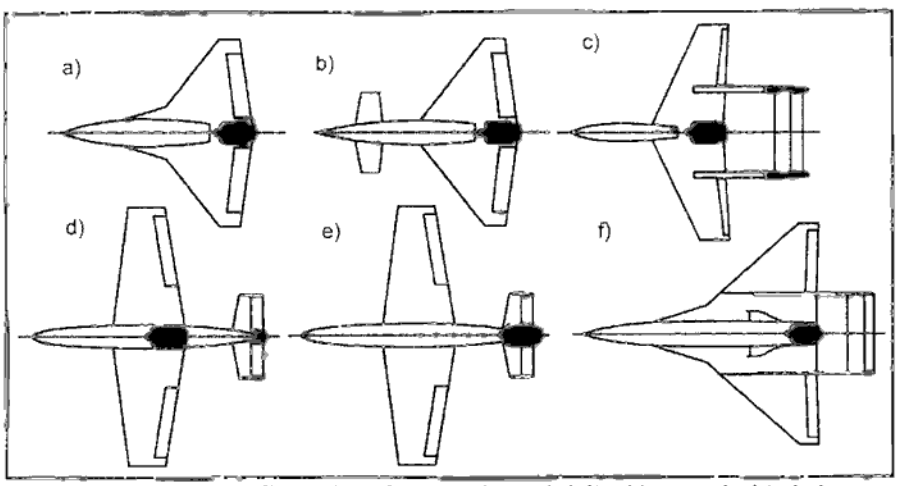
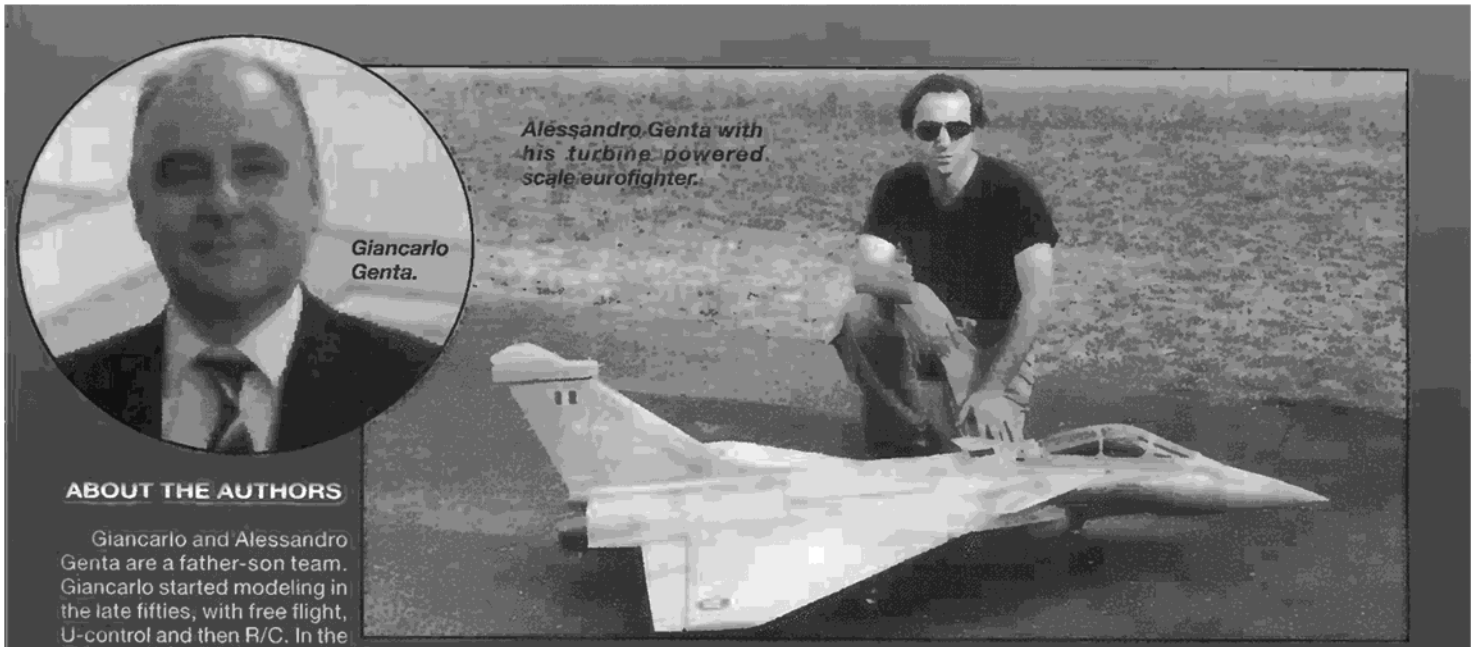


Photo #2: Alternate configurations for sport jets: a) delta, b) canard, c) twin booms, d) conventional, turbine on top, e) conventional, turbine in tail, f) the Eagle V.



Giancarlo Genta.

Alessandro Genta with his turbine powered scale eurofighter.

ABOUT THE AUTHORS

Giancarlo and Alessandro Genta are a father-son team. Giancarlo started modeling in the late fifties, with free flight, U-control and then R/C. In the early seventies he got a degree in Aeronautical Engineering and then one in Aerospace Engineering. Since then he has worked at the Technical University of Torino, Italy, where he teaches several courses in mechanical design, vibration and construction of aero engines. He is the author of more than 200 scientific papers and 9 books, some used as textbooks in Italian and American universities. He is active in Mechatronics, particularly in the areas of magnetic suspensions and robotics, and has designed mechanical hardware for the Italian Space Program. He is a corresponding member of the Academy of Sciences of Torino and of the International Academy of Astronautics. His latest book is *Space, the Final Frontier?* published by Cambridge University Press, a popular science book on the future perspectives of space exploration.

Giancarlo's son Alessandro started flying and building R/C models at the age of six; and developed a particular interest in jet planes. While Giancarlo likes working wood and traditional modeling technologies, Alessandro prefers to build fiberglass and foam planes. After secondary school he entered the Technical University of Torino, where he is about to graduate in Mechanical Engineering with a thesis on micro-turbojet engines.

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ways. The difference is mainly in the way in which air is forced into the combustion chamber and compressed, i.e.:

- Ramjets: no compressor is present; the air is forced into the air intake just by the motion of the aircraft. They cannot work at zero speed, and need to be accelerated by other means to high speed, which is too high for modeling use. While they are promising for some aerospace applications, they were seldom used in full scale aviation, and never used (to my knowledge) in models.
- Pulsejets: like a ramjet, but the air passes through a vibrating valve, which is set in resonance by the air expanding in the engine, in a way similar to what goes on in a tuned pipe. The pressure fluctuations in the engine are strong enough to suck air into the intake, so that the engine can also operate with the aircraft stationary. It was seldom applied in aviation, with the notable exception of the V-1 flying bombs, but was and still is used in model airplanes, in the beginning for U-control, then R/C.
- Turbojets: the air is forced into the engine by a compressor, which is operated by a turbine extracting some power from the jet. The large majority of full scale jet engines are of this type, but for decades no turbojets were available for modeling use. Now things have changed, and this change is the main topic of this article.
- Engines in which the air is compressed by a fan driven by a piston engine, a sort of a ducted fan with an afterburner. Although there is no common specific English name for it, it was used in the 1940s in an experimental Italian airplane, which was successfully flown (it could be a good modeling subject using a ducted fan and a custom-made combustion chamber). Its complexity and the fact that it mixes more of the drawbacks than the advantages of piston engines and turbojets, caused it to be abandoned.

PHOTO #3: A Kangaroo built from a kit by Abramo Nerva of the Biella Aero Club. Note the completely exposed turbojet.

Jet Engines In Modeling

Until recently, the only jet engine available to modelers was the pulsejet. It has, however, a number of disadvantages, which restricted its use to a small number of modelers. The first one is the impossibility of regulating the thrust: it either runs full throttle or quits. The only way to land a pulsejet plane is dead stick. Although there are pilots able to do that routinely, even gliding inverted and then rolling upright just before touchdown, to land a highly loaded aircraft dead stick is not the easiest way to land. Other drawbacks are the extreme noise (only a few flying fields accept pulsejets), and the fact that the outside of the engine is red-hot in operation. (In most applications the pulsejet is external, although many scale models with a ducted pulsejet have been built.) Additionally, there is the need of complex ground facilities for starting (although once a foot- or hand-pump was used for starting, today scuba diver air bottles are considered essential) and the high chances that in case of a crash the highly flammable fuel (gasoline) will come into contact with the red-hot tube, starting a fire.

ABOVE, Photo #5: A Crusader scratch-built by the authors from RCM plan #1030, enlarged and modified. She was tested with a pusher propeller on a Rossi 81 and then converted to carry a Wren MW 54 turbojet.

BELOW, Photo #6: An Albatross from the Spada kit built by the authors with a ducted fan and then converted to turbojet with minimal changes. It is powered by a Wren MW 54 located in the tail and exhausting directly outside, without ducting. It requires just 7 oz. of ballast in the nose.

ABOVE, Photo #4: A Delta 2000 built from a kit by Abramo Nerva. Same engine as the Kangaroo.

The difficulties of manufacturing turbojets were many. First, turbomachines are difficult to miniaturize. Since the peripheral speed of the blades must be high enough to ensure a good efficiency, the smaller the machine the higher must be the spin speed of the rotor. A model-sized turbojet engine must rotate at about 100,000 rpm, and higher.

This very high speed causes several problems with the bearings and the lubrication system, not to mention rotor balancing. The bearings are located in a hot section of the engine, so plastic caged, high speed, precision machine-tool bearings are marginally suited and often in the first attempts failed due to overheating. Only the high-speed bearings with uncaged ceramic balls developed for liquid rocket turbopumps were able to solve this problem.

Another point is that the compressor uses a large amount of power, supplied by the turbine and then subtracted from the power of the jet. If these two elements (turbine and compressor) have low efficiency or if the bearing drag is strong, the chemical energy of the fuel is not sufficient to operate the compressor alone and the engine is not able to remain in motion. This consideration has a positive side: if the equilibrium point is reached, any small increase in efficiency can set free large amounts of power for the jet. Once the designers finally reached the point where the engine was barely able to remain in motion, small improvements have allowed it to reach higher and higher thrust/weight ratios, and this trend is bound to continue.

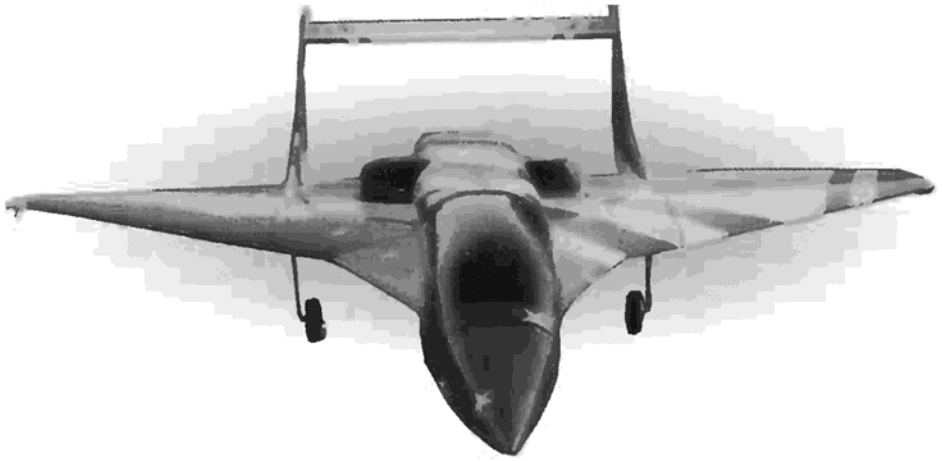
Photo #7: The ducted fan Eagle I (behind) and the Eagle II. A featured construction article ten years ago in RCM (plan #1159).

Further difficulties are linked with the regulation of the engine. The early turbojets had very complex mechanical-hydraulic control systems, mainly for regulating the quantity of fuel entering the combustion chamber. These control systems could not be miniaturized until simple and economical microprocessor-based systems became available.

This does not mean that it was a technical impossibility to build micro turbojet engines. Turbopumps used in small anti-aircraft liquid rockets for example were based on a similar technology, but with costs higher by orders of magnitude. However, it was certainly impossible to build them at costs compatible with modeling use and to make them suitable for non-professional operation.

The first model turbojet flight (or at least, the first the authors know about) was in 1983, when Jerry Jackman flew a BarJay powered by a turbojet he built. *(RCM, September 1983, p. 148.)*

In the 1990s things suddenly change due to a number of reasons. First, the automotive industry started large scale production of small turbochargers for car engines. A turbocharger is not much different in layout from a turbojet, except for the fact that it works the other way around. It uses the hot gases from the engine to turn a turbine to



operate a compressor. Since it recovers waste energy, the issue of efficiency is less important and the gases the turbine deals with are already spent gases, so are less hot. Usually plain lubricated bearings are used. However, they forced the development of a low cost technology on which micro-turbojets could be based. Attempts, often successful, to convert a turbocharger into a turbojet were made, by keeping the same rotor (turbine and compressor wheels), adding a combustion chamber and ball bearings.

A problem soon became apparent: turbochargers are based on radial-flow compressors and turbines. While the first is suitable also for turbojets (all early full-size machines had a compressor of this type), an axial flow turbine is almost compulsory for a jet engine. So the problem of the early designers of micro-turbojets was to build an axial flow turbine wheel, using difficult to find and very hard to machine high-temperature, aircraft grade materials.

Continuing advances in materials, components and control electronics took place almost at the same time and the first model jet engines appeared at the flying fields, and above all in magazines. The early model turbine engines were so costly and their operation was so difficult that most modelers only saw them in pictures, or in an air show where they were presented as exceptional achievements.

Turbojets For Modelers

The main drawbacks of the early micro turbojets were:

- Very high cost.
- Use of liquid propane as a fuel, with the related problems of safety and fueling ease.
- Need of the same ancillary equipment for starting as pulsejets and difficulties of regulation.
- Need of an on-board oil tank.
- Need of very frequent servicing, including rebalancing of the rotor and replacing of the bearings.

The first and last problem are typical of a new technology and, while they prevented wide usage of these engines in the modeling community, turbojets entered the modeling field and started to be a viable alternative to pulsejets and ducted fans. A technical revolution was underway and, as usually happens, small improvements started adding up.

A big improvement was the use of propane only to start the engine with a switch to kerosene for normal running. It was then possible to keep just a small, safe and inexpensive gas bottle in the field box, and the fueling operations involved kerosene, far less dangerous than the gasoline used in pulsejets and spark ignition engines. Another advantage was the possibility of mixing some oil for bearing lubrication with the kerosene, avoiding the need of an on-board oil tank. And, a thing which can matter to aviation buffs, at last you have a jet plane which not only performs and sounds like a jet plane, but smells like a jet plane too!

Small and powerful electric motors allowed starting without using compressed air by either using a hand-held starter or, better, with an on-board unit. This has made it possible to start the jet engine as easily as a piston engine. Reliability improved and the need of frequent maintenance disappeared. A turbojet is intrinsically simple, even simpler than a 2-stroke piston engine and, if properly built, can be as maintenance-free as the latter. A modern model turbojet can be as easy to operate and as reliable as a sport 2-stroke engine, and surely more hassle-free than a high performance one like those used in ducted fans. It idles much more reliably and is far less likely to quit in the air. While more units were sold and new manufacturers entered the market, costs started to decrease. Larger turbojets were designed with increasing performance, in terms of thrust/weight ratio and smaller units were produced as well.

Wren Turbines recently introduced a turbojet kit, making available a turbojet unit at a cost which is substantially lower than that of a complete unit. In our opinion the advantages of the kit are much larger than a simple reduction in cost: assembling the engine is a very enjoyable project for an experienced modeler (however, because of their high speed, a newcomer to the hobby should not try to fly jet planes). Above all, it gives the user hands-on information on how the engine works and how to maintain it. The excellent instruction manual and the overall quality of the parts make building possible without the need of workshop equipment or engineering knowledge (except for perhaps one point which will be mentioned later).

Although not strictly related to turbojets (but based on the same technology and in some cases built around the same engine), model turboprops and gas turbines for helicopters have proved feasible and are currently being marketed.

Future Perspectives

This is the situation today. What will be the impact of this new type of engine for model aircraft? Will a sort of jet revolution, similar to that which took place in aviation, change the modeling world?

Predicting the future, especially when technological matters are

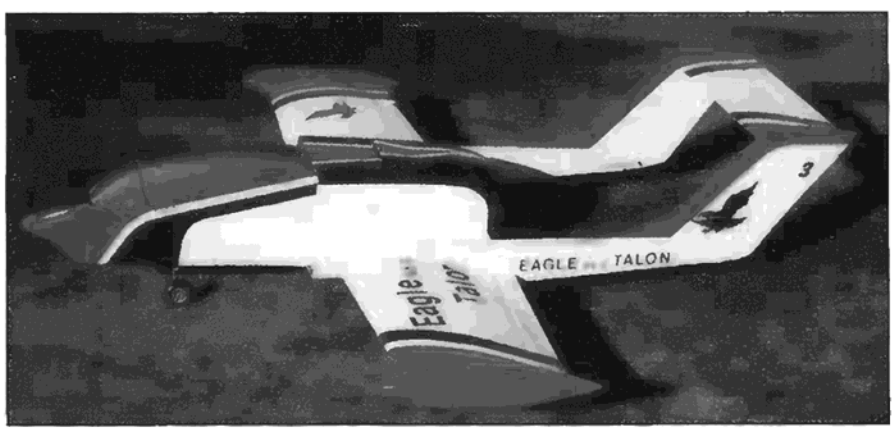


Photo #8: The Eagle III — a not-very-successful upgrade to the Eagle II.

concerned, is a dangerous exercise (it has almost never worked in the past), but perhaps some trends can be identified. Apart from jet engines, another change has been going on for a number of years in model aircraft: the so-called "quiet revolution." No doubt that the continuing progress in the battery field and the decrease in the cost of power electronics (and then in brushless motors) will make available more powerful and lighter electric propulsion systems. So it is possible to predict that, gradually, electric motors will replace piston engines in the smaller models, trainers and planes for the "Sunday flier" and that the market for low performance (and potentially low cost) 2-stroke engines will shrink. This is true for propeller as well as small jet planes, where electric ducted fans are becoming a standard propulsion system.

On the other end of the performance range, dedicated modelers who look for very fast and large models will increasingly shift to turbojets. It is likely that the market for ducted fans and the related engines and for pulsejets will further shrink, and some manufacturers are already reducing their involvement in this sector. Turbojets will become cheaper and easier to operate and will attract intermediate modelers. Perhaps we will see modelers who will start with electrics and then shift to turbojets. It is unlikely that we will see primary trainers of this kind, even though that is now common in full scale practice.

Piston engines, particularly 4-strokes, will continue to be used, especially where they cannot be substituted, i.e., in larger scale models of propeller planes, particularly in the cases for which electric motors are less suited, and in competitions where the rules make them more suitable. Still, there is a basic difference between models and full scale aviation: in the latter field economic reasoning and reliability dictate the choices, while in modeling the preferences of modelers, and their likes and dislikes, have a far larger importance when deciding which engine to use for a given application. There will always be modelers who use "old time" power units, whatever type they may be.

EAGLE V BILL OF MATERIALS

Lite ply	1/8" (3mm)	Equivalent of 2 sheets 60"x24" (1500x600mm); max length of part 24" (600mm) (52" or 1300mm if fuselage in one piece)
Plywood	1/16" (1.5mm)	1 sheet 20" x 4" (500x100mm)
	5/32" (4mm)	1 sheet 20" x 4" (500x100mm)
	1/4 " (6 mm)	1 scrap 7" x 2" (170x50mm)
Balsa	1/16" (1.5mm)	14 sheets 40" x 4" (1000x100mm)
	1/8" (3mm)	2 sheets 40" x 4" (1000x100mm)
	3/16" (5mm)	4 sheets 40" x 4" (1000x100mm)
	3/8" (10mm)	4 sheets 40" x 4" (1000x100mm)
	1/4" x 1/4"(6x6mm)	Square, 8 x 40" (1000mm)
	3/8 x 3/9"(10x10mm)	Square, 2 x 40" (1000mm)
	1/2" x 3/8"(12x10mm)	Square, 1 x 40" (1000mm)
	1-3/4" x 3/8"(45x10mm)	Tapered (t.e. stock) 1 x 40" (1000mm)
	2-1/2" x 9/16"(60x15mm)	Tapered (t.e. stock) 1 x 40" (1000mm)
Hardwood	5/16" (8mm) dowel	6" (150mm)
	1/4" (8mm) dowel	6" (150mm)
Aluminium	1" x 1" (25x25mm) square tube	16" (400mm)
	1/2" x 1/2" (12x12mm) L	10" (250mm)
	Lithographic plate	14" x 6" (350x150mm)
Other	Hose clamps 4" (100mm)	2
Materials	Spring latches	3
	5/32 bolts with nuts (various length)	11
	1-3/4" wheel	1
	2-1/4" wheel	2
	Nylon control horn	3
	Fuel tank	45 oz. (1500cc)
	Retracts, control cables, accessories as shown in the drawings	

R/C Sport Jets (The Best Place To Start)

It is not advisable to choose a scale model as a first turbojet plane. The reasons are many, from the higher wing loading to the more complex shape, but the main one is that in a scale model the turbojet is usually mounted inside the fuselage and hot gases must be channeled through a pipe. The construction of the duct and its cooling add complexities which can be avoided using a different configuration. Moreover, the efficiency of the engine is usually reduced, at least if the ducting is not designed, built and aligned in the proper way. The operation and the maintenance of a turbojet enclosed in the fuselage is also more complex, and a beginner in this area should probably keep things as simple as possible.

Many very good kits exist for "jet trainers," or as we prefer to say, for sport jets. Most are fiberglass and foam kits, and their cost is higher than that of a standard kit, although generally less than the cost of a scale jet.

With a few exceptions (the Bob Violett Bandit, for example) they have no exhaust duct and in many of them the turbojet is completely exposed, although sometimes it is enclosed in a cowling which can be easily opened.

The possible configurations are many, but all are usually dictated by the need of locating the heaviest component, the engine, close to the jet exhaust. It is possible to subdivide most Sport Jets in the following categories:

- Delta (Photo #2a), like the Reaper *(a few planes are mentioned as examples. Most of them are excellent performers, but they are included just as examples and the author does not endorse any specific design. Many excellent designs have also been left out)*, the Kangaroo (Photo #3), the Hotspot, the Firebird, and many others. Propeller deltas, like the Enforcer, have been successfully converted by simply adding a turbojet over the fuselage. They are usually sturdy, fast, and have very good low speed characteristics. The engine is not far from the center of mass.
- Canard (Photo #2b), like the Super Reaper, the Delta 2000 (Photo #4) and many others. Also conversions of propeller designs, like the Crusader, have been flown (Photo #5). If the

main wing is a delta wing, they have the same characteristics of deltas, while being less nervous and more maneuverable, but the engine is farther to the center of mass

- Twin booms (Photo #2c), like the Bob Cat, the King Cat, the Five Jet, and the first turbojet model ever flown, the BarJay. They behave more like a conventional design; the engine can be very close to the center of mass. The stabilizer must be high, well above the jet, and this can produce some problems at very high angles of attack. The low speed performance is usually not as good as deltas, but the overall handling is generally better.
- Conventional, turbine on the back (Photo #2d). Many sport models and also many trainers can be converted to turbojet application and it is possible to build fairly slow and easy-to-operate planes with this configuration. Perhaps it can be recommended to the less experienced modelers. The engine can be set on the center of mass, but seldom can be cowled. There have also been conventional planes with the turbine under the belly, although we do not like to have the most valuable object in a position so little protected.
- Conventional, turbine in the tail (Photo #2e), like the Heatwave. The engine is quite far from the center of mass, which implies a long nose and often requires ballasting. This configuration is possible now thanks to the introduction of lighter turbojets and can be used for scale models of many different types (Photo #6). When comparing this configuration with the more usual one with the turbine inside the fuselage at the center of mass, it must be remembered that avoiding the internal ducting means a savings of 7-10 ounces. With the same amount of ballast, no increase in weight is obtained, but even if a ballast of 21 ounces in the nose is required, the greater thrust available due to the lack of the ducting more than compensates weight increase.

The Eagle V

The configuration chosen for the Eagle V is twin boom, with a delta wing, in the attempt to join the good low speed performance of the delta wing with the higher maneuverability and the good stability due to the presence of a stabilizer. The choice was also dictated by the desire to put to work the experience gained with the author's previous twin boom Eagles.

The planform is very loosely inspired by Laddie Mikulasko's North Star, which is considered an excellent design, particularly when the leading edge extensions (LEX) are considered. The idea was to add LEXs to a basic delta wing to improve the performance at high angles of attack, but to keep them small since previous experience did show that turbulence on the upper wing surface due to large LEXs tends to sharply decrease engine-off maneuverability at large angles of attack.

The tail is essentially that of the previous Eagles, but lighter and simplified, since the turbojet must be located more rearward than the ducted fan. In particular, the stabilizer has a simplified airfoil and the fins have no rudder. This also allows saving the weight of two servos (or of a complicated linkage).

The wing airfoil is an NACA 64A-010. The 10% thickness with the huge root chord gives a substantial wing thickness at the root, allowing the central part of the wing to be very stiff in torsion and bending (an essential thing in twin boom designs), and very strong to carry the landing loads, while still very light.

A long nose and a large fuselage are musts in a plane like this in which you have to put a lot of equipment as far forward as possible and carry a large fuel tank. The resulting size is of about 50 inches wingspan and 70 inches length. It's a fairly large ship, dictating the need of dismantling particularly if it had to be transported in small cars. Ease of transportation is achieved by removing the outer wing panels and the forward fuselage section. To remove the outer wings you must remove just two screws and unplug the aileron servos, a very quick operation. To dismantle the front section you must remove three screws, but a lot of wiring needs to be disconnected. An alternative is to use longer wires and to fold the front fuselage section onto the main central part. With the gear retracted, the disassembled model fits into a box 40" x 20" x 20" and needs just five screws (and to plug in two cables) to be in the ready-to-fly condition.

If you choose to build the fuselage in one piece, you must enlarge the central hatch to install the fuel tank, since the tank is presently inserted from the front of the central fuselage section.

The Breed Of The Eagles

The Eagles are a number of jet R/C models based on the twin boom configuration designed around the power unit for maximum performance. The design goals, which were stated for the first ship and then maintained are:

- User-friendliness, and in particular stable and predictable behavior in the air. Owing to high speed, these planes are not trainers.

- Good take-off characteristics, without the need of very long paved runways. Ability to slow down for landings without loss of control.
- Ease of operation. No need of starter extension for the fan versions.
- Overall look of a jet fighter, although not a scale model of an actual plane.
- Good speed performance. The initial goal of 130 mph was fulfilled with ample margins by all designs.
- Very good maintainability, with easy access to the engine and all other parts needing servicing.
- Ease of construction, with conventional materials. Low cost as a secondary requirement.

The Eagle I and Eagle II were described in the January 1994 issue of *RCM* (Photo #7). They were based on the Byrojet unit with a Rossi 81 engine. The Eagle II was a good flier and attracted much attention whenever it was presented. In particular, it was one of the few ducted fan designs at that time that was able to take off from a short runway (less than 100 ft.).

The Eagle III (Photo #8) was built several years later. It was essentially similar to the Eagle II, but a little smaller and lighter in the attempt to further increase the speed. The larger differences were structural ones, since it had the central wing section in one piece with the tail unit, and detachable outer wing panels. It was slightly faster than the Eagle II, but also slightly less maneuverable.

To increase maneuverability, Eagle IV was built. It had a small flying canard on the fuselage pod, connected with the elevator. The results were not satisfactory since it was too nervous (much too nervous). I'm sure the position of the center of mass was to blame for this, but further tests could not be performed, since it entered a spin and crashed the first time the engine quit.

The Eagle V was built around the Wren MW 54 turbojet. As already stated, a delta wing configuration was chosen, to improve low speed performance, without decreasing the top speed. The wingtips are provided with downward winglets, of a particular design which was tested on various wing configurations and always proved quite successful in reducing induced drag and improving low speed performance. They were tested on a delta wing Byron Bullet, resulting in much improved glide characteristics.

Structural Design

Most of the structure is made from 1/8" lite ply, or, to be more precise, from leftovers of door skin which is one of the cheapest modeling materials available. Note that its density is less than half that of aircraft grade plywood, providing a very good strength/weight ratio. Balsa was used in the tail section, for the wing skin and for fuselage and wing parts which required some shaping.

A few parts, like the retracting gear supports and the tongues to join the fuselage are made of aircraft grade plywood.

Since this plane is not for beginners, only the details which are unique to this model will be covered. The model was built using metric sized material. In the drawings all measurements are in inches, using the following conversion table. The difference between the exact and the approximated equivalence shown in the table is less than the thickness of the line in the drawing and hence is immaterial. The table can be used by the reader living in places in which materials are available in metric sizes:

mm	Inches
1.5	1/16
3	1/8
4	5/32
5	3/16
6	1/4
8	5/16
10	3/8
12	1/2

Some sizes mentioned in the article may not be easily available, like the 9/16" x 2-1/2" triangular stock used for the ailerons. In this case, you can shape a thicker piece of balsa sheet to fit.

The screws used to mount the turbojet and to assemble the model are M4 metric screws of various lengths. On the drawings 5/32" screws are shown.

White glue was used for all the wood-to-wood connections, with epoxy used only to secure the nuts for the screws keeping the turbojet in place and to assemble the plane and to glue the hinges.

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Construction begins in the next issue. In the meantime, order the plans (Plan #1340) and assemble the materials ... and save up your pennies for the Wren MW 54 ... Welcome to the Turbojet Revolution!

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