The SEQUOIA Finches ~ Development History

The existence of the Finch series owes everything to the development of an extremely accurate CNC Router/Miller machine system jointly developed between several companies including Sequoia Systems. So, a few words about that follows as it lends context to everything we do:

In 1988 Sequoia Systems had a major interest in design engineering, particularly control systems, acoustics and fluid flow. We used a British computer aided design (CAD) program for our work, (known then as RoboCAD, now as CAD4U), and in those days drawings were transferred from the computer to paper using pen plotters, where the paper is fed from a roll or laid as a sheet on a 'flat bed'. Eventually we took a dealership for RoboCAD supplying complete systems and so we handled a lot of pen plotters. It seemed to us that a beefed up version of a flat bed plotter could be used to carry a router spindle, (or other cutting device such as a laser or high pressure water jet), and be used to cut out material with at least the same accuracy as the pen plotted drawing, and eventually much better than that.

This was not a revolutionary idea of course, but the goal was a 'transparent' interface such as we are used to with CAD i.e. whatever was on the screen could be transferred to paper with a single key press without getting involved with another program to handle the transfer of the data. This was not then the situation with CNC, (computer numerically controlled), machine tools which required fairly complex 'programming' to get them to do anything, and training programs could run into months. We wanted to side step all of that and produce a very accurate machine with an easy to use interface between the CAD drawing and the machine. In this way there was a possibility of producing a machine which could be relatively low cost (for an industrial machine), and yet easy to use, making it attractive to small companies. Since this had not been accomplished before, there were many challenges ahead.

We had some ideas on how to do this in the early 90's, but coincidentally so also had another group of people – from Robocom (the company producing RoboCAD) and Pacer Systems, a machine manufacturer in Nottingham who also had connections with RoboCAD. An evaluation prototype was in early testing in Robocom's offices and this was moved to our workshops in 1993. The transparent link was courtesy of the RDF file format for RoboCAD, which is very well suited to work together with machine controller software.

Subsequently a lot of work was done on the software interface, and various electronic and mechanical systems, and a second machine was then made which incorporated the improvements. This showed we had achieved our basic objectives, and we termed the machine a router/miller because it had the size flexibility of a router and potentially the precision of a very good milling machine.

This machine was tested on a range of engineering work to prove the effectiveness of the system, some of which was specific to model aircraft, including prototype work for Peter Shepherd, the designer and a director of West Wings in Cornwall. This was for his new Piper Cub kit, and subsequently West Wings purchased this same machine.

This was reported in a number of RC model magazines at the time, as well as articles we wrote about the system, how it worked, and why we chose rotating milling/router cutters instead of lasers. (A decision we are unlikely to change – see end of this section). This machine was replaced with our second generation machine which had substantial changes made to the construction and a number of new automatic features, and made it's public debut at the Sandown show in 1995, where it was demonstrated cutting a wide range of materials.

We now use the fourth generation machine with many developments in performance and the user interface particularly for 3D machining, and we continue to use this and our earlier prototype machines for all kinds of precision engineering work, including aerospace and film set components, and of course our Finch kits.

However as far as the Finch kits are concerned, the beginning stemmed from the work we did on two model aircraft - a half scale Boeing Stearman made with Terry Bridle for the film 'The English Patient', and Paper Aviation's kit of the 'Regal Eagle', a 30's style racer of 84" wing span.

The Regal Eagle featured a soft foam board structure covered with thin card, which acted as a stressed skin. The foam board formers, fuselage sides and wing ribs were originally band-sawn by Paper Aviation. We re-engineered the fuselage construction to use a more rigid and machinable foam board, involving slot jointed and half jointed components giving a self-jigging structure. Although this added significantly to the cost of the kit, nevertheless it continued to sell well since there were considerable building advantages. The slot together construction was not new – other companies were using die cut components to the same ends with some of their kits. What was new was the exceptional accuracy of the components, much appreciated by those who bought the kit. In part this was because we could control the precise offset of any particular cutter from the design line no matter what the material, it's thickness or density.

For the Stearman, we needed to extend the slot together construction not only for the airframe (16 feet wingspan) but also for the exact scale appearance radial engine, requiring many hundreds of cylinder fins which interlocked with a jigging system to get the exact cooling fin outline. The tight integration of the CAD software and the machine control system enabled us to provide the parts very quickly, and allowed Terry to build the airframe in a ridiculously short time – essential, *as is usually the case with film work, to meet shooting dates. Details and photos of this will be made available in the Film section of our web site.*

The first Finch – the 22" wingspan low wing free flight Goldfinch for CO_2 and small electric motors – was loosely based on the Regal Eagle, but made with balsa and conventionally covered, and including the CNC slot together techniques developed for the big Stearman and the Regal Eagle. It was designed to fly in controlled circles in small fields and land when the motor stops, rather than fly away in thermals. It did this rather well.

The Goldfinch had a number of original features which laid the basis of our approach to model aircraft kits – that is, we would try to find interesting new ways of doing things, providing of course that there was a good reason for doing it. And one of those reasons is durability, having suffered with a lack of that over both our free flight and r/c flying experience. Another was realistic appearance. And another was to make the construction process more enjoyable and less of a hassle, but still providing plenty of interesting things to do. The Goldfinch had no strip wood – everything was cut from sheet. The wings were held on not by rubber bands or plastic bolts – but instead by a spring clip which was part of the undercarriage torsion bar springing. The wings had diagonal ribs,(not new, we know …) between the one piece spar web and the trailing edge, and this together with the spar caps gave the wing exceptional stiffness. The self-jigging slot-together leading edge, ribs and spar web ensured a straight and true structure, and the stiffness prevented warps no matter what covering material was used.

The Goldfinch was launched at the 1994 Sandown Show, where we sold out our stock of kits throughout the weekend, had some excellent magazine reviews which helped keep the sales going for a while, until everybody that was interested had probably bought one. At this point we needed to give the Goldfinch a new lease of life, and this was done by adding a top wing which could be retro fitted to the monoplane to produce the biplane Goldfinch II. This gave improved free flight performance with a lower wing loading, but also provided the wing area to support the weight of radio gear. Miniature radio was not so readily available then, nor so light, nor so inexpensive as now, nevertheless excellent kit reviews were made by Stephen Mettam, then editor of Electric Flight International, with an electric powered R/C version and David Boddington with a diesel powered R/C version.

The next stage was to produce something a bit bigger. Adding 50% to the Goldfinch resulted in the Greenfinch, which was originally produced as a free flight model, but soon after with options to make it suitable for R/C. This was reviewed in August 1998 Aviation Modeller International which was encouraging enough to progress with a biplane version, the Greenfinch2. This was offered as an option and could also be retro-fitted as with the Goldfinch. There were other options too, including r/c linkage components, ventilated battery hatch, beefed up undercarriage for heavier motors and batteries, custom motor mounts, even a gearbox for 400/480 sized motors. After a few years it was decided to rationalise the whole thing, and offer the biplane as a complete kit for r/c with most of the optional extras included, and a few detail improvements.

This kit featured on the front cover of the July 2005 Electric Flight International, with a 6 page review by Stephen Mettam. It had a relatively complicated undercarriage featuring independent torsion bar springing and friction damping for each leg. Although this raised the odd eyebrow - why not just use a bent aluminium or a simple wire u/c as is usually used - after trying it out in landing situations Stephen wrote some very positive things about it in his column Charged Flying in RCMW June 2005. As with all the other Finch kits, the lower wing halves were sprung together by the undercarriage torsion bar spring which also held the wings into the underside of the body. This gave a very positive wing location, but allowed sufficient flexibility to minimise damage in the event of an accident. It worked very well, but, yes, it WAS a bit fiddly … and was not easy to adjust the spring rate for variable motor weights.

Our own flying prototype, (initially as a F/F monoplane with a CO_2 motor, then speed 400 with R/C, then speed 480 with our own gearbox when converted to a biplane), had been around for a good few years before then. We had received a lot of feedback from our customers, and magazine reviewers, most of it very positive, though some had a problem with the limited space for r/c gear and batteries. If other problems occurred it was usually because the builder was not familiar with the Sequoia construction method of pre-assembling modular assemblies - and only then adding penetrating adhesive to the joints. Some thought the kit was 'over-engineered', though in fact no part was bigger than necessary and every single part served a distinct and useful purpose. Of course, it is possible to produce simpler construction, but that is to miss the point. Our design uses the construction method to improve accuracy, robustness and durability without a significant weight penalty. It also offers an interesting alternative to traditional building methods.

Next we produced a bigger version at 68" span essentially a twice size Greenfinch2, but with a relatively wider and deeper body, a plug-in tail and was designed around a 2mm light ply body structure. However, problems with getting consistent supplies of really good quality light ply made us think about using high quality birch ply instead. So the wings, tailplane and rudder were mostly made from this material, the main wing spar being a box section of 1½ mm ply webs and epoxy glass strips top and bottom. This was extraordinarily strong, and on our stand at an Old Warden show, we showed a wing panel, clamped at the root, carrying 18lb of bricks suspended from it's ribs. The prototype itself was uncovered, but received very *positive comment, and many requests for a production kit version.*

However, the body needed to be redesigned to use birch ply instead of liteply, and we also had other ideas to incorporate as well, including a much more elegant u/c design, and a sprung plug-in system for the wings. The new undercarriage would still have independent springing, and the strength of the spring could be adjusted for different drive system weights.

Since it was at this stage that we were thinking of developing the Greenfinch2 somewhat further, it seemed logical to take a fresh look at the Greenfinch construction, and use this as the blue-print for the next bigger prototype. Full circle! So a completely new Greenfinch was designed, then to be called the Greenfinch207, (early development started in 2007), but still mostly balsa in its construction, a proportionately wider deeper body even than the Bullfinch, plug-in wings and tail, and the new and rather interesting (we think!) undercarriage suspension design. Also a completely engineered r/c linkage system, an attractive new cowl, and a much revised stronger tail using 6mm balsa but machined into spars only 2mm wide, which dovetailed – and locked - into the leading and trailing edges.

While this was happening, a picture of our Goldfinch2, Greenfinch2 and the larger prototype, (then christened the Bullfinch, but that will change), appeared in the Radio Control Model Flyer magazine September 2007, illustrating an article about CNC manufacture written by Tony Draper. Some very complimentary remarks about our kits were made but he noted that they were 'sadly no longer available' … well, yes, we had stopped taking full page inside back cover adverts in Electric Flight Int'l, and others, some time before, and had decided to take a back seat while we developed a new range.

We advised editor Ken Shepherd that we had a new model waiting in the wings and we would be back in production once it was thoroughly sorted. A satisfyingly large picture of the first prototype 207 appeared in the second part of the CNC article the following month.

At this stage the basic design was well advanced, but we had issues with consistent sheet balsa thickness, which is most important with our halving joint construction. Also we were spending a great deal of time sorting the balsa for weight, grain, straightness and suitability for purpose. A major decision was then taken to swap most of the balsa for 1.5mm and 0.8mm birch ply. At the same time the design was made as scaleable as possible - in as much as the basic structure would be suitable for larger versions of the same design. Consideration was given to a 150% increase, 200%, and 300%, using the same basic design and much the same instructions and drawings, which would greatly reduce the time to bring them to market.

We use carbide cutters only 0.8mm in diameter for most of the Greenfinch parts, and following a change in the availability of cutters long enough for 6mm balsa, we had to change all the tail details to 5mm instead of 6mm. A number of other changes followed including details to improve the strength of vulnerable components, and changes to the u/c to make it easier to take off from grass strips. It has been renamed as the Greenfinch234 - (TwoThirtyFour) - ('2' for biplane, and 34" span), and listed below are the main differences to the previous Greenfinch2.

> *In building this model we would ask the builder to consider what it might have been if it had been full size. It represents an aircraft that could have been designed in the mid thirties and intended for advanced aerobatic training, perhaps made in some numbers, but production would have been halted over the war period. Some remained after the war, and limited production was restarted when it's aerobatic potential was realised. Notice the 'G' meter fitted at the bottom of the dashboard – a 50's modification perhaps, and a full set of instruments for navigation and to cover the up-rated engines that would have been fitted to take advantage of it's great structural strength. This model represents a single seat competition version, although two seats would have been normal for the training aircraft.*

So builders will be able to please themselves as to finish and colour scheme, as we have pleased ourselves producing it, albeit with countless design and development hours. (Well, they have been counted - doesn't bear thinking about ...)

What's New …
compared to the 2005 Greenfinch2

- *Mostly birch ply construction, engineered for very high strength to weight ratio.*
- *Over 970 machined parts.*
- *Fuselage twice as deep and twice as wide – accommodates new wing joining system, plenty of space for radio equipment, large batteries, good size fuel tank for i.c. power.*
- *Plug in, resiliently mounted upper and lower wing panels.*
- *Upper wing in 3 parts – with a fixed central upper wing panel permanently bolted to cabanes, and incorporates sprung mounting system for upper panels and is reinforced for under-arm launching and general handling.*
- *Individual built up u/c legs separately hinged to fuselage with spring system mounted inside the fuselage. Spring firmness easily adjustable for varying drive train weights. Spring force is absorbed by same formers that legs are hinged on, so heavy landings will not stress the fuselage.*
- *Firmly mounted but easily removable main wheel Spats.*

- *Plug in stabiliser with operational 'V' braces. Gives the stabiliser great strength, and simplifies repair if required.*
- *Tail from 5mm balsa stock, framework locked together with dovetail joints*
- *All control surfaces removable for covering or repair – useful for those practising prop hanging at ground level …*
- *All servo mountings pre-engineered for ideal control runs. Control links custom designed for adjustability, with due regard for visual impact.*
- *Detailed cockpit … believable instrument sheet printed on gloss photo paper & fitted behind dash, pilots seat, (removable for access to servos under), space for full length pilot, windscreen frames with machined plastic glass inserts.*
- *Large forward access hatch to take high capacity LiPo batteries, and to adjust balance.*
- *Planned attachment points for battery and ESC*
- *Custom balancing jigs putting balance suspension points near the vertical CG for very accurate CG positioning, provided with notches for recommended balance point.*
- *Large engine bay, with shaped cowl mainly from 0.4mm ply & laminations of 5mm balsa.*
- *Camouflaged mounting screws for cowl and cabanes.*
- *Custom mount for brushless out-runner motors up to 37mm dia. (Mounts for i.c. may be considered on request for specific engines).*
- *Two riblets per main rib bay instead of one for better covering support and appearance.*
- *Revised aileron construction, using heavily fretted 0.8mm ply and paper l/e wrapped around machined 5mm balsa nosings – gives incredibly stiff but light aileron.*
- *New plug-in Interplane Struts.*
- *Realistic tail wheel assembly.*
- *Clip-in inspection hatches not requiring metal catches or magnets – just using the natural springiness of thin birch ply.*
- *Comprehensive list of other parts incl. assorted tube, rod and wire, screws nuts & bolts, and wheels – as before- but also now penetrating aliphatic glue, (+ brush to help apply it & syringe for cleaning nozzle).*

So why do we not use lasers?

*In the mid 1990s we did consider fitting laser cutters to Sequoia machines, and though there are specific applications where lasers are absolutely ideal (some of them quite different, e.g. cutting steel and polyester yacht sails) there are severe limitations with aluminium and epoxy laminates (incl. carbon fibre of course). Furthermore, samples of other manufacturers' laser cutting in ply – at the time - showed a very variable cutting, (i.e.vaporisation), width, which of course seriously affects dimensional consistency. Adjusting power and focus for a wide range of thickness and density is also problematic when trying to achieve vertical edges with minimum carbonisation **and** consistent cutting width. Absorption of laser energy passing through thicker materials can result in edges not being vertical. Increasing the power to get a more vertical edge results in more reflective – and unsightly - burning to the underside of the material. There are techniques for minimising this, but not best suited for constantly varying cutting profiles. It is possible to reduce the burning/oxidation by surrounding the laser beam with inert gas, but that increases the running costs.*

In 2008 we invited a leading laser machine manufacturer to demonstrate to us if - and how much - things had improved with the latest available laser technology. We used our Greenfinch files for 1.5mm balsa and ply and also 5mm balsa. The results, despite time spent on optimisation, were not sufficiently acceptable compared to our normal production. Varying cut widths and non vertical edges on the 5mm balsa were the main issues, besides the burnt edges.

The vaporisation width of a laser varies with the properties of the material, which in natural materials can vary significantly over short distances. This affects the dimensional accuracy of components by significant fractions of a millimetre: Bear in mind that the difference in the cutter's effective cutting width between a tight fit, a good sliding smooth fit, and a loose fit is very small - around 0.001" (0.025mm) in each case. A cutting system needs to get close to this order of repeatability to get a chance of getting parts that consistently fit well together and that is the design intent of the Sequoia machines.

We require our machines to cut most common engineering materials – and some that are not so common – in any thickness from almost nothing up to 100mm, including 3D shaping work. This cannot be achieved with a single type of laser, and in some cases, not with any type. Typically we might have in the same kit various thicknesses of balsa, epoxy glass, carbon fibre, aluminium and ply up to 9mm thick or more, and we need a system that will reproduce the same accuracy with all these materials. By careful selection of cutters and proper adjustment for effective offset, we can achieve this.

As an example of the practical benefits of Sequoia router/milling, have a look at the website www.jotika.co.uk. They have two of our machines to manufacture the ply and other wood parts for their R/C and static boat kits. Note the cleanliness of all the cutting and the accurate joint work. For some years now they have taken on contracts for other manufacturers who used to use laser cutting. Jotika's kits are very well known for the excellent fit of their machined parts.

However this is not simply a case of laser v. router/milling – just as important is the attention to detail in the machine that's positioning the cutter whatever cutting system is used. The controller software and firmware should allow the machine to optimise all cutting situations, and the mechanical system be developed sufficiently to maintain exceptional accuracy and repeatability over a range of operating speeds and acceleration.

We have seen, in 2005, at the La Ferté Alais show in France, some excellent laser cutting for Peanut scale models, but the manufacturer admitted he could only do it with the very thin wood material, (not ply), that he used and careful setting up for each batch of material.

We rest our case … for the moment …