NEWSLETTER   September 2018

FORTHCOMING EVENTS

- **Workshop Morning:** Tuesday 18th September 10-12 noon.
- **Visit to Parkol Marine Shipyard (Whitby)** plus lunch option: Thursday 27th September – 10.00am
- **Club Meeting:** Wednesday 3rd October ~ “Bring and Brag”
- **Workshop Morning :** Tuesday 16th October 10 - 12 noon
- **Club Meeting:** Wednesday 7th November ~ Annual General Meeting (AGM)

i) CLUB MEETING: Wednesday 5th September.

There was a very good turnout for this club meeting, and our Chairman David Proctor welcomed all visitors, and invited them to join us on a more regular basis.

Before the talk, by Ivan Shaw, there were some announcements by the Chairman:

- **GDPR:** All the forms from people that David knows about are now in, but if there is anyone who he doesn’t know about please could they let him know. There were some queries about the forms from some members which David wanted to clarify with them.

- **Visit to Parkol Marine Shipyard (Whitby)** plus lunch option: Thursday 27th September 10am-12noon.

  The names of people who were interested in the visit were taken.
  The meeting point will be Eskside Wharf, Church Street, Whitby Y022 4AE, which is just outside the yard.
  The meeting time will be at 9.45am in order to present ourselves at 10am sharp. Latecomers will almost certainly be left on the doorstep.
  Parkol is on the eastside of the river. Parking can be difficult and is not straight forward. There is parking in the streets up the hill. The main car parks are about half a mile away. David said that he could offer a lift to three people, and asked if others could offer lifts. Parkol recommend that our members wear flat non-slip shoes or boots, a close fitting jacket or fleece. Parkol will provide hard hats. Those wishing to bring cameras can do so, but this has to be at their own risk. Hopefully, (weather and tide dependent) the tour should be able to done conducted as one group, but it be may needed to split into two groups. One ask is that visitors take note of the instructions from the Parkol guides and do not wander off or become separated from the main party.
  After the visit we can go to a local fish and chip restaurant - probably *Hadleys* - as they have the capacity and the potential to reserve places. If you would like to join us for that then please let me know **by return** so I can advise them of numbers.

- **Advanced Notice Of A Potential Visit To The British Horological Society, Upton Hall, Newark.**
  Richard Gretton has been organising this trip. The museum has undergone a considerable reorganisation in the last year. The museum contains 8,000 to 10,000 clocks, watches and time pieces, and there is a library.
  The museum now offers a guided tour of about two hours. It is open Monday to Friday 9.00am to 5.00pm.
  Group sizes can be around fifteen to twenty four people, and entry is £10/person. There is a minimum charge of £100 for groups of less than ten people. Weekend visits are £20/person.
  There is a possibility of visits into the training workshops, if there are no courses in progress.

There is a café on site which will provide lunches if required. The museum has full access and free parking. A hand count was taken to see what the interest was. David asked what dates were suitable for a visit, mid December this year or late February next year. The concensus on the evening was that mid December was the best time. There was then a discussion about travel arrangements, cars or a hired coach.

ii) Mini Bring and Brag

Mike Sayers brought along his model Bentley engine radiator. He had been teased over a couple of years about why he hadn't finished it. So, this evening he brought it along as proof that it was finished. It now has its core installed as well as drain valves, which makes it complete and ready to be fitted onto the engine. It has now been pressure tested, and doesn't leak.

iii) A Talk By Ivan Shaw On The Design And Build Of The 'Merlin' Personal Aircraft.

This was a special occasion, because this was the first time the *Merlin* aircraft had been unveiled to the public.

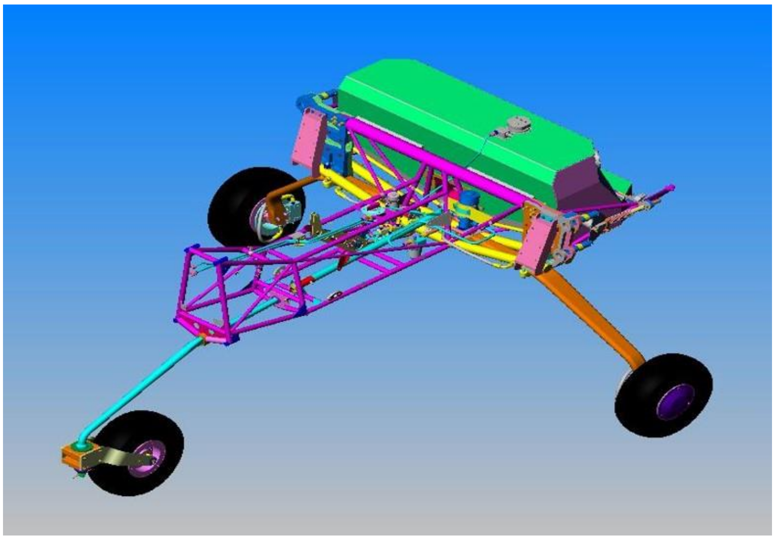
Ivan began by saying that the aircraft had been newly named as *'Merlin'*. Its previous designation was ISA180A (Ivan Shaw Aircraft 180 kt cruise speed). He decided to call it *'Merlin'* because the merlin is the smallest bird in the falcon family, and the North Yorkshire Moors is one of the main nesting sites for merlins sometimes reaching 40% of the total in Britain.
Ivan said that next year he will have been in the aviation business for 50 years. How he got involved in aviation is unusual. In 1968/9 he was working as a professional musician (drummer) with the BBC, (British Forces Broadcasting). He was booked for a show in the Middle East to entertain troops. It was the first aircraft he had ever been on. It was a support command VC10. He got on at Brize Norton. He was very impressed with the smoothness of the ride, balancing a threepenny bit on the arm rest. The pilot came out and Ivan asked if there was any chance of going onto the flight deck. The pilot said that if Ivan introduced him to the dancing girls on board he would introduce him to his co-pilot. Deal done, Ivan walked onto the flight deck, not even knowing the left hand seat was the captain's seat, which he sat in. At that time there was a co-pilot, flight engineer and navigator. Just coming over Rome at 33,000 ft the co-pilot told Ivan to push the stick forward and the houses will get bigger. He was hooked, and his life was changed. He then learnt to fly. The first 10 hours at Doncaster cost £50, including instruction, in a *Rollson Condor* tail dragger aircraft. With his "RAF time" he soloed after 8 hours. He learnt to fly for £40 and has been flying ever since.
Ivan has always had this parallel interest as a pilot and engineer, and so he went on to build aircraft and also fly aircraft both as a private and professional pilot. He retired from 'Jersey European' flying HS 748 twin turboprop feederliners in 1992 when he started designing and building the *Europa* aircraft.

The *Long EZ* is the second aircraft he built.
He modified it to include twin pusher propellers and a retracting landing gear. This is the aircraft that got him into development. This had the registration G-IVAN which he got from the CAA and which cost him £5. This was the first amateur built twin engined aircraft to fly in Europe. He did this in 1985/6.
The engines were originally Hewland NR62 and then Norton Wankel rotaries. This was a very fast aircraft, based on a design by Burt Rutan who also designed the *Virgin Atlantic Global Flyer* in which Steve Fossett flew for 77 hours nonstop around the world. Rutan also designed *AirShipOne*.
In the eighties Ivan knew about canards and composites and was recruited to put into production the *Mercury* light aircraft that Rutan had designed for Colin Chapman of Lotus fame.

The *Long EZ* and *Mercury* got Ivan into the business of test flying and aircraft development. This is when he designed his own aircraft the *Europa* from a blank piece of paper. This was very successful and Ivan then set up his own company *Europa Aircraft* in Kirkbymoorside. This is Britain's most successful light aircraft selling more 1,000 in 33 countries, more than de Havilland, Miles, Auster or Beagle.
Ivan only intended building one for his own use and people kept asking to buy one. He suddenly found himself in the aircraft business, and after 1,000 aircraft he still doesn't have one for himself.
The *Europa* is a kit plane which you can build yourself. There are various versions, monowheel with outriggers and tailwheel, and there is also a longer 42 ft wing span carbon wing for gliding (this has an extension on the rudder). The wings can be changed on the day for gliding. Ivan sold the company in 1999 (the company is still trading).
The *Europa* is still flying in 33 countries and used for game spotting in Africa, and cattle farming in New Zealand.

Here is a video link to the *Europa* aircraft : https://www.youtube.com/watch?v=0EYAQsVWCMs

After the *Europa* Ivan went on the design the *Liberty XL2* aircraft which is a certified design. If an aircraft is designed from scratch, there are always aerodynamic risks. Ivan knew that the *Europa* would have met certification standards and so he scaled it up to the Liberty. The *Liberty XL2* is made in America, and is certificated to F.A.R. 23 standards.
The whole idea behind *Liberty* was its modular build. Most aircraft are built by craftsmen for wealthy clients, but for *Liberty*, Ivan wanted to make it highly modular with precision parts. Ivan has his own *Liberty* which he flew back from Dubai. It was designed with folding wings so he can store it in a shipping container.



Highly Modular, Precision Parts and “Plug and Play” Electronics and Structure.

The *‘Merlin’* is a “New Paradigm”, a “New Concept”.

Aviation is a bit like Model Engineering which tends to be male dominated (unfortunately). Ivan and his friends usually found that they were flying around with empty passenger seats, and realised they were flying “the wrong aircraft”. What they really wanted was a single seat “personal” aircraft. Normally single seat aircraft are either aerobatic (eg. *Pitts Special*) or racing aircraft, or they are very basic entry level aircraft like the “*Volksplane Evans VP-1*” made from plywood with a Volkswagen engine at the front.

When you design a new aircraft, you sit down with a sheet of paper and write out the requirements.
For the Merlin the requirements were:

- Single place personal aircraft.
- High utility
- 180 Kts cruise speed from 100bhp Rotax 912 engine whilst returning 50mpg.
- At 120Kts economy/loiter cruise speed, return 70mpg.
- With the newly announced Rotax 915, 135bhp engine a max cruise of 300mph at 12,000 is calculated.
- Long range, greater than 750nm.
- High useful load with enough space for a folding bicycle.
- Good grass field performance
- Folding wings for home/trailer/container storage.

Ivan wanted a personal aircraft for a 100 percentile person like himself. A lot of aircraft flying now were designed in the 1940s, when people were smaller. He also needed high utility and the ability to carry a folding bike. Ivan likes “aerial cycling”. An aircraft takes you from somewhere you don’t want to be (an airfield) to another place you don’t want to be (another airfield), so a bike is the transport out. Ivan has visited many islands from the Scilly Isles to the Western Isles in his aircraft, and he likes exploring by bike when he gets there. He also wants folding wings. Hangarage costs are usually high for aircraft. Someone he knows is paying £360/month to hangar a *Europa*, which is expensive when you are only flying 50 to 100 hrs a year. He wanted folding wings for home storage.
He didn’t necessarily just want speed but speed through efficiency. Fuel is getting expensive, Avgas costs around £1.80/litre.
The *Merlin* will fly on ordinary 4 star petrol. He wanted 180 kts cruise. A *Cessna 150* has a cruise speed around 90 kts and a *Piper* 95 kts. This is the sort of cruise speed you get from 100 hp. At 200 mph Ivan wanted 50mpg return from 4 star, and his numbers, if correct, show that at 140mph, 4 star will return 100mpg. This means that a return journey from Wombleton to Paris will use around 10 gallons. If this works out, it will mean the *Merlin* will be the most efficient form of personal high speed transport in the world. Ivan wanted to fly off grass fields, and didn’t want to be restricted to hard runways like many high speed American aircraft.
Starting off designing the aircraft, the most important issues are weight, balance and aerodynamics. Ivan looked at scaling down the *Europa* but this was impractical. He also wanted variable useful load carrying capability, so he could carry a folding bike and luggage. Weight and balance were therefore imperative. This aircraft is designed so it balances over a 3 inch longitudinal range with pilot and fuel installed. He decided to go for a “pusher” because all

the variable useful load would then be on the centre of gravity. The pilot sits in front of the CG, the engine behind, and the baggage and fuel are on the line of the centre of gravity. There is also a good field of view for the pilot.

The aerodynamics were catered for next. A 1000lb take-off weight light aircraft would typically have a wing area of around 100 square feet , giving a wing loading of 10lb/sq ft. A microlight will have a wing loading of around 5 lb/sq ft, an Airliner will have approx. 120 lb/sqft and a *Tornado* 80lb/sqft.
The faster you go the more wing loading is needed. Ivan has compromised and has gone for 16 -17 lb/sqft, which is on the low side for the speed he is going. The drawings have been done by Dave Lister and the structural calculations have been done by Nevile. Robert who was present at the meeting, and who has built a *Europa*, was the “apprentice”. Robert was the senior member of the team and Nevile the youngest. All OAPs!
Once the aerodynamics have been decided, the wing area, tail volume and fin area have to be derived.
The tricky bit is getting everything to work, as Ivan wanted a retractable landing gear in order to get the drag down to the absolute minimum. Designing and building an aircraft from a blank sheet of paper is a big job, especially one as sophisticated as the *Merlin*, all pre-preg carbon fibre and all moulded. Ivan has been working on this project for the last five years, virtually full time, and expects it to be fully complete in a years’ time.
The main requirement, once the design is settled, is a workshop. Ivan was going to get an industrial unit, but he has done that too many times, so he converted his double garage into a workshop.
The first thing was to take the drawing and loft out the fuselage. He mounted a 1300cc/100bhp engine and lofted out a full size fuselage to see what it looked like. He then checked the ergonomics with a dummy EFIS (Electronic Flight Instrument System).


Aerodynamic Concept


Checking Ergonomics


Checking Instrument Ergonomics

Ivan needed to fit his 27 gear/ 20 inch wheel folding bike into the aircraft, as well.

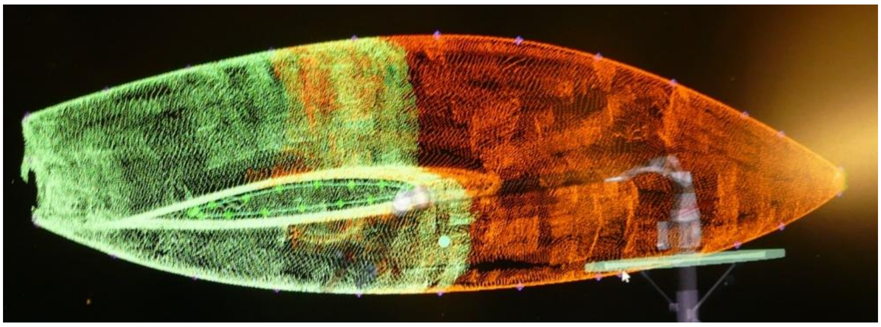
A fuselage plug was then made from wood. Upper and lower fuselage female moulds were taken from this plug.

The fuselage plug was painted white so that Ivan could then play with the canopy lines.

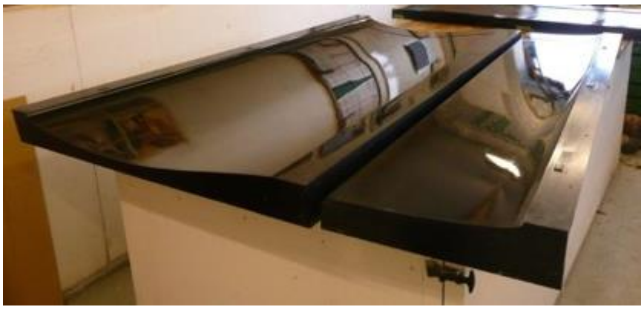
The fuselage plug could be rotated so that all areas could be worked on.

Top and Bottom Fuselage Moulds

The products taken out of these moulds are high temperature carbon fibre prepregs, vacuumed down at 1 bar and put in an oven at 85°C. The fuselage plug was manufactured by hand, and the rest were made by CAD/CAM (Computer Aided Design/Computer Aided Manufacture), where a computer file was sent off and the plug manufactured on a five axis router out of tooling block.
Tooling block is far more stable than wood or aluminium when machined.
The fuselage plug was then scanned with a FaroArm laser scanner, which measured all of the surface. This allowed all the surface coordinates to be put into the aircraft CAD model, so that all the interfaces, for example, wing, canopy, engine and boom would be correct when they were designed.



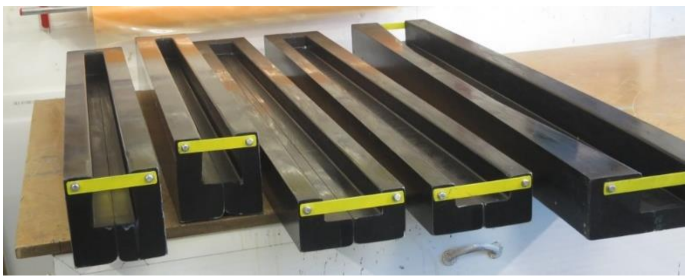
A male mandrel was then made, over which the perspex canopy could be drawn. A canopy frame was then required, and also a reveal on the fuselage into which the canopy latches. The fuselage is like a boat hull with a top moulding mounted on a lower moulding, and is 10 feet long and 6 feet wide including the inner wing. Once the tooling had been finished after a year, the fuselage plug was destroyed as it was no longer needed.
The wing skin plugs were manufactured with tooling block on a five axis mill. This was done to an accuracy of 4 thou, over an area of 6ft 1” x 3 ft. Moulds were then layed up from the plugs. The wing skin was then layed up with foam sandwiched between carbon cloths, and was then bagged down in the wing mould with a breather cloth and a vacuum bag. Vacuum was then pulled (1 bar) and the whole moulding put in an oven. The oven is home built in the workshop. The Hoover 2.5 kW fan assist which will comfortably reach 85°C. The skins were cured in the oven for 14 hours at 85°C.



Wing Moulds

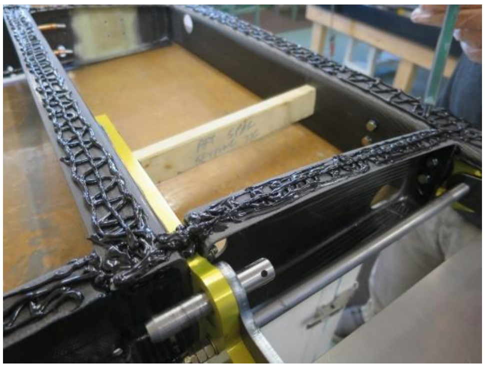
Wing Skins

For smaller and less dimensional critical parts, the plugs were made from MDF because tooling board is expensive. MDF is sufficiently stable for this application. Ivan showed the half of the tail boom with the main landing gear retracted (see next page) to illustrate the precision nature of the build. He eventually ended up with 140 moulds stored in two containers, ranging from 6 ft to 10 ft long, all just to manufacture one aircraft.
The design and build were quite organic with the design being updated as the build went along. As the design was updated, detail drawings were produced. It was considered far too slow to design everything first before committing to production. The CAA have to be convinced by the design, which is why structural analysis and testing must be carried out to demonstrate structural integrity. There are two spars in each wing (main and rear) and a main central spar in the fuselage. These spars are made in moulds taken from MDF plugs. The good thing about composites is that you don’t have to be restricted by stock sizes as you are with metals. The cloth can be tailored so the strength can be positioned where it is required, thus saving weight. Cloths were layed up between 1mm to 10mm thick.

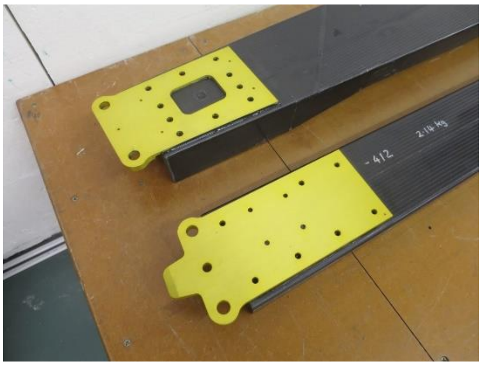


Spar Moulds and a Spar being layed Up.

Because of the folding wing, jigs had to be made so that the wing fittings could be fitted with precision. The wing fitting plates were then bolted and bonded to the spar. Once the spars and ribs had been assembled, the wing skins were bonded to them. The rib and spar flanges were “buttered” with a toughened aerospace adhesive before sliding the wing skins on. A complete wing weighs just 27 lb.



Buttering The Wing Ribs And Spars With Adhesive

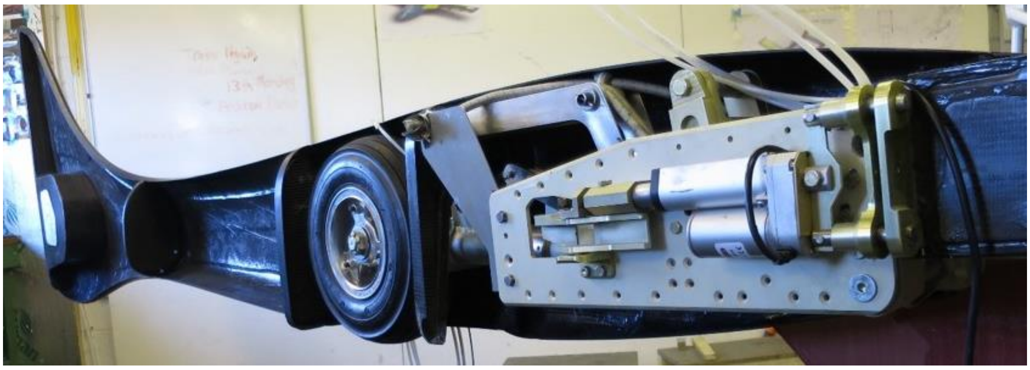


Wing Fittings Bonded To Spar.

The wings come with “flaperons”. Normally there are flaps and ailerons on each wing. The flaps normally go down together to produce lift, and the ailerons work differentially to give roll control. As wing is only 6 ft long, there isn’t the space for flaps and ailerons, so flaperons are used. The flaperons can go down or up together and a mixer unit allows them also to be moved differentially.

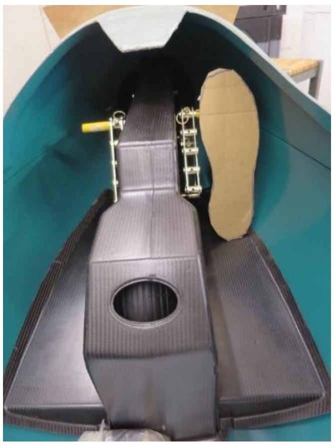
The retractable main landing gear is made from Aerospace AISI 4130 steel which is weldable and has good after weld properties. All the parts are laser cut (at Malton Laser) for accuracy. A jig was designed and built so that all the parts were held accurately while they were welded. They were then sent off for heat treatment to 125,000 psi strength and were also stressed relieved and honed. The metal components were then cadmium plated.

The tyre and main gear retract into the boom.



Main Gear Retracted Into Half Boom To Show Complexity Of Fit

Ivan then showed us the CAD (Cardboard Aided Design!) of the nosewheel retraction mechanism. Cardboard is the best way to model a mechanism. On a computer it would be a nightmare! Cardboard was the easy way. The nose gear leg is carbon fibre rather than metal. The nose gear retracts between the pilot’s legs, as space is at a premium. The nose gear energy is absorbed by an elastomer strut. The elastomer was tested and analysed by a student at Coventry university as part of their final year project. Ivan said that this was the first time this system had been used on an aircraft. The elastomer does the job of being both a spring and shock absorber. The carbon gear leg has a final weight of 27 ounces (0.77 Kg) . The nose gear retracts into a nose wheel box which has a sight window at the back to show that the gear is retracted. The adjustable rudder pedals, incorporating hydraulic brake pedals, and a master cylinder are also mounted on each side of the nosewheel box. The nose gear is retracted with an electrically operated linear actuator.



A view on the nosewheel, nosewheel box, rudder pedals and brake master cylinder sub-assembly.

Also a view from the inside of the cockpit showing ergonomics of the rudder pedal and the site window for the nose gear retraction.

The main bulkhead or firewall, onto which the engine mounting frame bolts, consists of foam sandwiched between layers of carbon fibre. Wood inserts replace foam where equipment is attached at the engine mounting frame, attachments, and aluminium plates are bonded in where the engine mounting frame attaches.
The fuselage was then layed up. As it was such a large component, the oven had to be extended so the fuselage could go inside.

The inner lower wing (which is integral with fuselage) contains the fuel tanks and centre spar and the fuel tank ribs are bonded to this. The fuel tanks have a sight gauge in the fuselage so that the pilot can see the fuel level rather rely on a fuel gauge. The fuel tanks carry 16 gallons in total. 100mpg will get you to North Africa from Wombleton. During the build, the drawings were constantly updated.

The engine mounting frame is also manufactured from AISI 4130 steel in the normalised condition (95,000 psi strength) and is of a welded construction. The after weld strength of the frame is 76,000 psi strength which is taken as the design strength. Again welding jigs had to be made for precision build.

After checking the fit of the folding bike and luggage behind the pilot, the cockpit module was ready to be installed. This consists of the moulded pilot's seat which forms part of the structure. The seat shape was checked for ergonomics and the tooling block plug was manufactured on a 5 axis mill. The seat mould was then created as a single moulding (not a split mould) off the plug. The seat incorporated the aperture for the stick. The instrument binnacle is part of the canopy and opens with the canopy (see below).

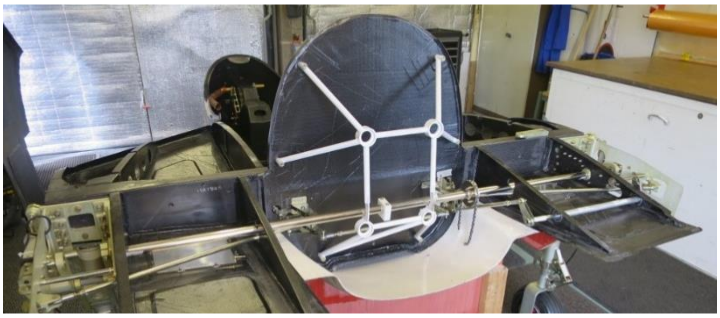
After plumbing out, the fuselage was ready for the upper skins to be fitted. Before that, the fuel tanks were coated with a fuel proof resin. Ivan had to take advice on the latest resins, as fuel contains extra chemicals such as ethanol, and there is also winter grade and summer grade fuel. This has been a problem for aircraft, where engines run on Mogas. The upper fuselage was then bonded on with a fuel proof aerospace adhesive.

A drop test was carried on the main landing gear. What was of interest was the deflection of the main oleo and tyre under load.

Integral Seat In Fuselage

Bike Fit

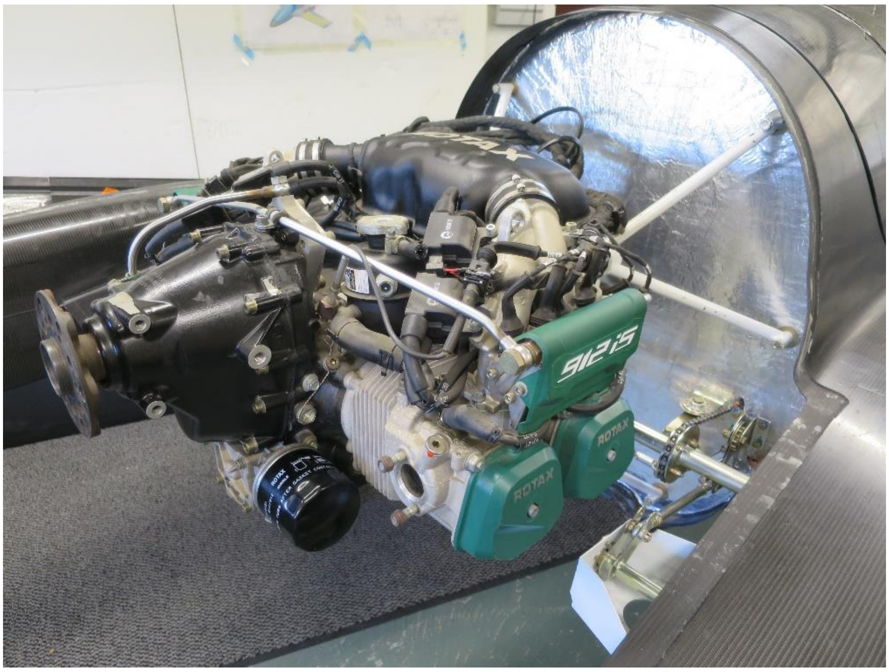
Luggage Fit

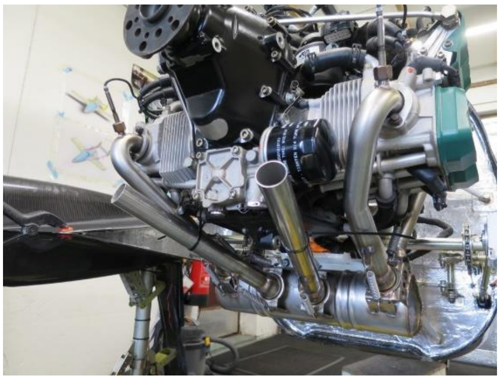


Engine Mounting Frame Installation and Main Landing Gear Drop Test

The engine is a Rotax 912iS. Ivan was going to fit the 912S, but decided on the fuel injected model with fuel specifics of 0.41lb/hr/hp which is very good. Two strokes come at 0.7lb/hr/hp, and an ordinary 4 stroke 0.5lb/hr/hp. This engine is as good as the latest car technology. There are two plugs per cylinder and two fuel injectors per cylinder so everything is redundant. There are also two alternators.

Ivan had to design his own exhaust. It weighs 8.7lb (10lb was budgeted for). A 10% saving on a weight that was estimated. The exhaust will have ejectors developed by NACA .





Rotax 912iS Engine Installed.

Weighing inhouse designed exhaust
and exhaust installed on engine

The wing tips have been designed to reduce drag due to tip vortices, and are therefore a complicated shape. The tip moulds were produced in ABS by 3D printing. The propeller spinner and back plate moulds are 3D printed high temperature nylon.

The cockpit has been trialled with 100 percentile people like Ivan and Robert, and also a 75 percentile person such as David.

Ivan couldn't get anything from B&Q or Jewsons for this project, all aerospace parts were sourced from America. The only thing he could get from Jewsons was sand. For the proof test he bought 2 tons of sand, and then took it back after the tests and got his money back.
Proof tests were then carried out on the aircraft. This is the maximum load that the aircraft should experience. In the case of the wings this is 3.9G and the engine frame 4.4G. For the tailplane the load was the maximum it would experience in flight. The loading was accomplished with 25Kg, 10Kg and 5Kg sacks of sand. This is a flying aircraft, that is why it was only taken to proof load. Eventually a test fuselage, wing and tailplane will be built, and these will be tested with an ultimate factor of 1.5, and a further composite factor to take into account hot/wet conditions. This means the structure will have to sustain a test load of 2.25 x proof load. This represents a total wing test load of 8752 lbs.

Wing Proof Loading = 3890 lbs (1764 Kg)   Wing Tip Deflection 60mm

Tailplane Proof Loading = 551 lb (250 kg)

Engine Frame Proof Loading = 827 lb (375 kg)

Acknowledgement And Thanks To Ivan Shaw For Allowing Use Of The Photographs And For Proof Reading This Article

Note:

Ivan has kindly invited PEEMS members for a visit to his workshop, once the engine is ‘burning and turning’. We will keep you updated when the time is right for the visit.

Question And Answer Session

Following a welcome cup of tea and biscuits there was a question and answer session. Judging from the length of this session, there was a lot of interest in this subject. Please note that some further clarity and explanations have been added to the answers given on the evening.

Q *Are you going into full production on this aircraft?*

A I'm doing this project for the creative joy it brings, and I am creating a "turn key" operation. There are currently 1800 computer models, 1200 drawings, stress calculations and a full suite of moulds. There will soon be a flying prototype that will have undergone a flight test programme. If the moulds are looked after, several hundred aircraft could be produced from them. I also have the masters, so two more sets of moulds could be produced.

Q *At what stage in the build does the aircraft have to be inspected by the CAA?*

A The aircraft and its systems will be inspected by the LAA [Light Aircraft Association] who are the responsible organization under the CAA [Civil Aviation Authority]

Q *I have spoken to other people who have done something like this and each mix of resin/hardener has had to have a test sample to prove compliance with the requirements.*

A The aircraft is being built with pre-preg, where the fibre/resin mix is already optimised within the material itself. The problem of resin mix compliance is therefore catered for. It is just in the processing where procedures must be correct. The design allowables for the various layups, have to take into account hot/wet material degradation and statistical confidence (composites have a wider spread of test results than metals), by using half the manufacturer's quoted strengths at maximum factored load.

Q *What does the aircraft weigh?*

A The complete aircraft ready to fly will have an empty weight of 560lb (254 Kg), with pilot and fuel weight to be added. The target empty weight was 535lb (243 Kg). Fuel weight is 100lb (16 gallons) and the pilot design weight is 190 lbs. Including baggage, the maximum total weight at take-off should be below 900lbs. The structural analysis has been carried out at 1000 lbs take-off weight.
The aircraft will probably be cleared for 950lbs. In the history of aviation, no-one has said *"this aircraft is lighter than expected".* There is a saying *"watch the ounces and the pounds take care of themselves".* You have to fight all the way for weight reduction. For an aircraft with a retracting undercarriage and folding wings, 560lbs really is light.

Q *Is the aircraft stressed for aerobatics?*

A No. I did think about it being aerobatic, but aerobatics is generally in the 6G to -3G region and you then have to factor those load levels up by 1.5 for design. For an aerobatic aircraft, the aerodynamics would also be different. You need an unstable aircraft for aerobatics ~ *"stability fights manoeuvrability".* This is a "*get in and fly to Paris for lunch and return*" type of aircraft. I want this to fly as if it is on rails. To get to Paris should take one hour and forty minutes. I am putting the 912iS engine in, and that is 100hp. Rotax has just brought out a new engine which is 140hp. I did think about putting that in, however it is a very complex engine. There is a saying *"never put a new engine in a new aircraft".* The new engine has a turbo and intercooler which also complicates the situation. With the 140hp engine, the aircraft will cruise at 300mph at 8,000 ft. The 912iS true airspeed will be 250mph "flat out". It is designed to fly comfortably at 200mph in a straight line.

Q *Could you talk about Nav-Aids, because you said you were going to use an i-Pad for information?*

A There are two things which have made this aircraft possible. One is the Rotax engine. If it had been a Lycomming or Continental engine, they are "a yard wide and 30 inches high". If you put that sort of engine into a "pusher" aircraft, this will make pressure recovery difficult, and you would need a propeller extension. Remember, a Jumbo Jet is blunt at the front and pointed at the back. It is how the air is pushed back that is important. A Jumbo cruises at around Mach 0.87. It is one of the fastest airliners operating.
A larger engine than the Rotax would make it difficult for a "pusher" aircraft to get the required pressure recovery. The engine has a dry sump and is only as wide as my shoulders. Not only is the power to weight good, its size to weight is good too. It is compact.
The other thing that has made this aircraft possible is the advance in information technology. I now fly everywhere with my mini i-Pad. When I retired professionally from flying, I didn't know exactly where I was when flying. I used to fly beacon to beacon, VOR (VHF Omnidirectional Range) to VOR and cross checked with an ADF (Automatic Direction Finder) which sometimes pointed to the nearest thunder-storm! I also used DME (Distance measuring Equipment). All of these gave a position relative to beacons. When I used to fly the question was *"where am I?"*. Now we have moving maps. I have flown around Europe with

no more than a compass, watch and my finger on the map, that is, dead reckoning. Now, when you think about it, *"not knowing where you are"* has been eradicated like smallpox. This is wonderful for pilots. I now have more information on my i-Pad than I did in an airliner. We now have more awareness of what is happening. When the aircraft is complete, I should be able to take off from Wombleton, programme in a hundred waypoints, put on autopilot, and it will fly me to Paris. Hopefully I won't have to talk to anyone. Soon all aircraft will have *"sense and avoid"* transponders, and aircraft movement will be controlled by computers. Some of the experimental work is advancing faster that what they have on Airbus and Boeing. We also have *"simulated vision"* where you can see through clouds. This system isn't on the i-pad but is on systems such as those provided by *Garmin*. These cost a few thousand pounds.

Q *There was a question about the quality of the materials used, and was welding and processing done by approved specialists?*

A Aerospace standard materials have been used for the *Merlin*, for example AISI 4130 steel and 7075 aluminium, which come with quality certificates. Bolts etc are also aircraft quality. All welding, heat treatments and plating have been done by specialist companies. Welding has been done by CAA approved welders.

Q *What is the maximum temperature that the composite can operate in?*

A Well, as you have heard, the pre-preg is cured at 85°C which should give a 'Glass Transition Temperature' (Tg) of around 120°C. The Tg is the temperature at which the resin starts to break down and structural integrity is lost. The aircraft will be painted white and will be able to operate anywhere in the world. Resin technology has really moved on from the past. With wetlayed up (bucket and brush) resins, the cure was 60°C in a hot box which resulted in a Tg of around 80°C. The prepreg is also being consolidated (debulked) under 1 bar vacuum which results in a much stronger laminate. With modern resins you can lay up more layers in one go. In the past you could only lay up a limited number of layers before the resin started to exotherm. These layers would need to be compacted (debulked) with rollers to remove air before the next layers were layed (and further debulked) and so on. Using the vacuum bags with prepregs, debulking is done in one go.

Q *Is the aerospace adhesive a single component?*

A No. It is a 'two pack'. The gun mixes the adhesive and hardener. The technology has really moved forward. In the past we used Redux 420 which had to be mixed with a thixotropic agent such as cotton flock to thicken it. With these latest adhesives, they are already workable and not runny. The adhesive can also be used as a gap filler.

Q *Is the adhesive just used for composites?*

A No. The one we use is a toughened adhesive and can be used for metals. Adhesives are very good in carrying shear loads, but not tension (peel). Now rubber balls are put in (nano-technology) to improve peel strength. The main wing attachments are bonded to the spars, however the CAA insist that for major load carrying joints, plates are bolted as well as bonded. For non-structural parts, metal to metal or metal to composite joints are common.

Q *Is the aircraft fireproof?*

A No. If you set fire to the aircraft it will burn. It will start to smoulder and may sustain a flame.

Q *The introduction showed you flight testing an aircraft. Do you think that you may have to change the aerodynamic shape after the first flight?*

A A good point. I am taking an aerodynamic risk. I could have done a one off aircraft using "mouldless" technology where foam blocks are hot wired to shape, and then covered with composite. That would have been a heavier aircraft. It is a risk. Hopefully we won't have to start modifying the moulds after the first flight. I have been conservative aerodynamically, in terms of stability, tailplane and fin coefficients, and don't feel I am taking great risk there. There is a flight test programme to do, and I hope nothing major will appear.

Q *With Europa, you did the same thing, didn't you, using "the wind tunnel in the sky"?*

A Yes. When first flying the *Europa*, we found it was divergent in pitch and we had to go back and think about it. We had all sorts of problems. We re-hinged the tailplane at 26% chord rather than 28% chord. *Europa* has a very powerful all flying tail as does the *Merlin*. The performance was OK for *Europa* apart from the pitch divergence. Directionally it was too stiff. If an aircraft doesn't have enough fin area, and it hits a gust it will 'fish-tail'. In a cross-wind it also 'weather-cocks' into wind. The rudder will overcome the fixed fin, so you have to have enough rudder to provide correction to cross-wind, and gust conditions.

There is a balance. The *Europa* had too much fin and not enough rudder. The ailerons were good. Luckily I had Don Dykins who retired as technical director of BAe . He was also chief aerodynamicist on the Airbus wing design. He retired just six months before I started the design of the *Europa*, and helped out. But even then there was still a lot of work to do before we got it right. *"The more I practiced the luckier I got".*
There will be a flight test programme for the *Merlin*. I expect everything to go smoothly and I don't expect to have to take a hacksaw to the moulds, although there may be some "tweaking"

Q *Are the instruments all digital?*

A Yes. There will be no "mechanical instruments". The digital instrumentation now is like having a flight engineer in the cockpit with you. For example, each of the engine cylinders has an exhaust gas temperature (EGT). It samples at 30 times a second. The screen gives you an engine page. With the old "mechanical instruments", if the oil temperature went up, you could miss it, now it will warn you. Not only do you have an EGT, but you have cylinder head temperatures x 4. EGT is the best indicator of engine problems. If a cylinder is going cold you can see, because all four temperatures should be the same. As soon as anything is going wrong the indicator comes straight up on the screen.

Q *How do you intend to start flight testing and who is going to be the test pilot?*

A I am an experienced test pilot, so that will be me. I am not going to just take-off, fly and land straight away. There is work to be done before-hand to determine handling characteristics. I hope to fly somewhere like Church Fenton, which is quiet and doesn't have other fliers in the vicinity. Before becoming airborne, a lot of information can be obtained from high speed taxy trials on the runway. This will pick up things like control surface effectivity and control efficiency.

Q *A question was asked about the fatigue of the aircraft composites.*

A Composites, if designed and manufactured correctly are far more fatigue resistant than metals, with the fibres acting as crack stoppers. It is the metal components that are fatigue critical. The most fatigue critical item on the aircraft is the Engine Mounting Frame (EMF), especially as it is welded. The welds introduce further stress concentrations into the frame. To mitigate this, normalised AISI 4130 steel was used (steel is more fatigue resistant than aluminium). This steel has very good after weld properties. The welds have been inspected prior to the frame being fitted on the aircraft. Analysis shows that the maximum stress in the frame is around the fatigue limit for normalised 4130 steel, which means a theoretically indefinite life. However, we must be conservative, and the frame welds will be checked at regular intervals. For full certification, it is normal to carry out a fatigue test on the EMF.

The Newcomen Society Lectures

Tony has requested that the upcoming Newcomen Society Lectures for 2018/18 are included in the newsletter for those who are interested:

NEWCOMEN
The International Society for the History of Engineering and Technology

Newcomen Society, South Yorkshire

Meetings Programme 2018 -2019

Meetings are held at Kelham Island Museum, Alma Street, Sheffield S3 8RY, between 6.30 – 8.15pm unless otherwise indicated. Visitors are always very welcome and no charge is made for attending the lectures.

Monday 24th September 2018, 6.30 pm

David Boursnell: *Armour for the Grand Fleet*

Monday 22nd October 2018, 6.30 pm

Professor Roderick A Smith: *A history of metal fatigue and the development of an understanding of what it is and why it still causes problems*

Monday 26th November 2018, 6.30 pm

Ivor Lewis: *The development of the engineering drawing office 1780-1980*

Monday 28th January 2019, 6.30 pm

Julia Elton: *Who Designed the Clifton Suspension Bridge - Fact and Fiction*

Monday 25th February 2019, 6:30pm

Dr Gillian Cookson: The Age of Machinery – Engineering in the Industrial Revolution

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Tuesday 12th March 2019 Ken Barraclough Memorial Lecture
Holiday Inn Royal Victoria, Sheffield (Speaker to be confirmed)

Monday 29th April 2019(AGM)

Chris Hodrien: *Steam below sea- the Royal Navy K Class steam turbine submarines of WW1*

Travel to Kelham Island
For directions to Kelham Island Museum please visit:- http://www.simt.co.uk/find-us
For further information please contact John Suter on:- meetings.syorks@newcomen.com

Brian Stephenson ~ Magazines Free To Collect: *'Engineering in Miniature'* magazines, Volume 1 April 1979 through to 2011. Free to collect, from Brian Stephenson. Tel. 01723 354415

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