GENESIS OF A SHADOW

An academic, John Dickenson OAM, BA Psycho, FAI, DIP, reinvented the hang glider in 1963. It was a triangular flex wing type with a sail that was very different from the original rigid types designed in the late nineteenth century. This design led to the worldwide sport of hang gliding, even reviving the rigid wing types too. This sport allowed the ordinary citizen to be part of the flying scene, previously costing far too much for the dream of flying.

Pretty soon small engines were added to the hang gliders and, being foot launched, led this sport into powered hang gliding. As the weight of these machines gradually increased, foot launching became difficult – wheels and a seat were added and many now resembled small aircraft.

This sport was totally unregulated with some designs being questionable as to their structural integrity. There were serious injuries occurring and soon regulation by the CAA (Civil Aviation Authority UK) devised a set of standards in the 1980's. This fresh category of aircraft was termed Microlights, whether they were flex wing or rigid types.

Within certain limits the rules for this category were minimum wing area, empty weight, and maximum two places for crew.

This allowed myself to initiate a design series called Shadow. My interest was to try to eliminate many poor and sometimes dangerous aspects of normal aircraft. Poor design has always been apparent to me in many military and private types. I was going to try to design out initial poor conception. My elderly friend, Volmer Jensen in Glendale, California, who designed and built 24 different aircraft, said to me, "Get it wrong at the beginning and it's wrong at the end".

To conceive an aircraft design, design it, build it and then fly it, is something quite rare from an individual. Probably very few people have ever achieved this – the Wright Brothers being the first to do so.

Stalls and spins occur on most aircraft. They are the primary number one killer of aircrew. To eliminate these would make aircraft less dangerous, which they are! So here are a few examples that pointed out seem wrongly conceived.

Most aircraft designers don't even fly, so how can they assume what a pilot needs most, a clear view, certainly forwards. We can see many obstructions stopping a pilot's view. These designers invariably do not have 'hands on' during constructions of the airframe, which I find extraordinary.

Initial design concept shows how wrong the engines were on the Gloster Meteor, being positioned slap bang through the middle of its wings. Whereas the ME262 jet of WWII had its engines in separate nacelles with its engines positioned beneath the wings, which ensured easy access for maintenance. It cannot have been easy for the draughtsman to pass the fore and aft wing spars in front and behind the engines to attach the outer wings structure.

British designers had obsessions with engines buried in the wing roots. All the V bombers, Victor, Vulcan and Valiant, Comet airliner, etc. This was to keep the aircraft ‘clean’ but it takes hours to change an engine whilst buried deep in the airframe. The success of these types is not denied but is a design error. Boeing, on the other hand, put the engines in separate pods beneath the wings of the Stratojet B47 bomber. Maintenance was easily accessible for the ground crew. Not only were the engines positioned ahead of the wing leading edge but this counter balanced for wing twist at high speed so wing structure could be made lighter. This design principle is so successful that every airliner in the world today has this feature.

From a powerful design concept who would deny the English Electric Lightning? Anyone who has witnessed an RAF Lightning at an airshow could not fail to be impressed. Yet I listened to a Lightning pilot say he could empty the fuel tanks in 15 minutes. Compare the 850 mile range of the Lightning to the Saab Draken, which could fly 2,000 miles and have a similar top speed of Mach 2 with just about the same climb rate, and this poses the question ‘is the Lightning a good design?’ The Draken used only one Rolls Royce Avon in comparison to two of these on the Lightning.

The Bristol 188 stainless steel Mach 2 test aircraft, which was meant to fly at over Mach 2 to investigate thermal heating, actually ran out of sufficient fuel as it reached that speed and had to return to base.

Let’s not forget the Spitfire and Hurricane that saved us all in WWII and had a 90 gallon petrol fuel tank positioned above the pilot’s knees, burning many when it was hit by enemy fire. Another example is the Tiger Moth with its fuel tank in the upper wing above the pilot P1 and this hot engine.

One could go on depicting poor design even in current aircraft. Consequently there was much to do regarding my Shadow design to prevent falling into similar ill-conceived concepts.

My conclusions for a design are based upon much study. All my life I have had an intense interest in aircraft. Being able to fly, plus being a design engineer, gave me a head start on structures, materials and everything mechanical. All these factors combined gave me the perfect opportunity to initiate a new design concept that hopefully eliminated all previous poor design.

The few British aircraft design faux pas pointed out are not limited only to the UK. Russian, French and United States designs and prototypes of aircraft all had their own failings, some of which even getting as far as production, which left the poor aircrew to sort out their limitations. The UK had some wonderful aircraft companies and designs - Miles, Fairey, Hawker, Supermarine, Blackburn, Folland and Vickers, with superb aircraft like the Hunter – aesthetically beautiful; Buccaneer – unstoppable; VC10 – lovely; Harrier – beautiful engineering; Hawk trainer.

Thus my design, the Shadow, was to be a conventional layout with wings, tailplane etc, as per normal. The aviation industry is very conservative. I am reminded that even though a pure flying wing design is very efficient, there are no flying wing airliners. Only with the latest military types of aircraft are aerodynamics used to obtain agility. Canards, thrust vectoring, even swept forward wings are seen. Views still differ as Ben Rich, Head of Lockheed Skunk Works said, “The only place for a canard is on someone else’s airplane”. I’d like to see comment by my associate who is the top Typhoon pilot, currently on an exchange with the USAF and flying F22 Raptors, as to whether the Typhoon’s canard is as responsive as the thrust vectoring on the F22.

The ‘all dancing’ fifth generation fighter Lockheed F22 has no HMD – Helmet Mounted Display – and no IRST – Infrared Search and Track – whereas the Russian MIG 29 as early as the 1980’s possessed all these assets when shown at Farnborough, as do current Eurofighter Typhoon and Dassault Rafale. Another point is that the USAF haven’t caught up with their inflight refueling system. Internationally the aviation community possesses probe and basket types that allow two or more inflight refueling. The USAF system with a probe from a tanker aircraft can only refuel one at a time. US Navy aircraft carriers and the French are the only ones not employing a ski lift deck and are still using steam catapults.

Russian latest technologies appear to be well ahead in aircraft, missiles and electronics. It is often the case that we in the West are not made publicly aware of Russian advances. Even in WWII I discover that the most formidable propeller driven aircraft in combat was the Russian YAK 3, whereas I thought it was the Hawker Tempest.

Most aircraft designers seem to rely on a specific material for their construction, e.g. wood, metal or composite, and use the same throughout. I recall a previous Shadow owner, now with a hot French design Bambi, saying to me "It's all carbon fibre, David". I retorted, "What, even the tyres?" My point being that what is required should be the best material for the job it has to perform. This will result in a lighter construction.

In about 1980 the Eurofighter Typhoon was being envisaged as a state of the art multi role combat aircraft. It was realized that the use of one material for the airframe was an outdated design format. It is constructed using 70% carbon fibre reinforced plastic, 15% metals, aluminium and titanium, and other materials. Of course differing materials had on occasion been used previously, e.g. Victor V bomber used honeycomb panels and araldite as far back as 1949 at its design initiation. Godfrey Lee, the designer of the Victor, visited me at CFM in Leiston, Suffolk to talk about a further problem with one of my designs. He was amused that my time with 57 Squadron of Victors had obviously influenced me in the Shadow because of the drooped leading edge of the wing, use of honeycomb and araldite. But differing materials have never been used so extensively as on the latest aircraft. I was ‘right on it’ with my Shadow in 1982.

Amusing: at the licensed Shadow factory in Clovis, New Mexico, USA, building the Shadow with all differing materials, a customer asked the Manager what a certain material was. The Manager wasn’t sure and replied “unobtanium” – the customer believed him!

During the lecture I gave at Rolls Royce in Paulesbury, I remarked that the Hawker Harrier would be lighter if this principle of ‘materials for the job’ had been followed.

Mr Fozzard, the Harrier’s designer, stood up and shot back at me. “How would you do that, Mr Cook?” Well, I had been called! Without details of the intimate use of the build materials of the airframe, I could not answer Mr Fozzard, but with a quick thought I proffered that if the undercarriage doors were made from hard set papier mache they would weigh much less than metal ones. After all, these doors only cover a hole where the wheels had folded up. That would be a start to lighten the Harrier.

When designing the Shadow I was determined to always keep in mind this principle of the best material for the job. If a major aircraft company were to have produced the Shadow, they could have made it even lighter than ourselves. Magnesium could have replaced many aluminium parts. Titanium could be used instead of steel. Carbon fibre could replace fiberglass. However, the cost would have probably exceeded a factor of three.

I was aware of a honeycomb composite material called fibrelam, which a company called CIBA GEIGY at Duxford produced for the flooring of wide bodied airliners. This material had a thin fibreglass backing either side of a paper impregnated honeycomb structure and was made in sheets of 8’ x 4’ wide in various thicknesses. It was very light and strong in compression. Neil Moran and I visited CIBA GEIGY and were introduced to David Southwell, Technical Sales Director, a pilot of general aviation aircraft and voluntary Air Traffic Controller at nearby Duxford airfield. He was greatly enthusiastic about the material being involved with an airframe. Several years earlier he had envisaged fibrelam being used for a fuselage, one that could be folded up rather like a cardboard box is formed and being bonded. One was made at CIBA GEIGY and sent to Cranfield where the concept went no further. When Neil and I turned up with the fibrelam idea he was so delighted and helpful in every way. We were gifted two sheets of fibrelam to go away and produce our fuselage. David Southwell and myself continue a friendship to this day and he and I won the ‘Dawn to Dusk’ competition in 1986, flying to 67 airfields in a day in my Shadow 02.

They showed me a ‘set up’ of steps, all of different materials but each of identical weight. These different steps were made alternatively from steel, aluminium, plywood and fibrelam, the fibrelam proving far the best with the least deflection of my weight as I ascended the steps.

Neil Moran roughed out a cockpit design which I then built using a special CIBA GEIGY epoxy that caused sensitization to my skin. From then on araldite 2005 was used, rated at 1,500lbs per square inch bond. This airframe went together quickly and in 1982 the first Shadow aircraft – 01 – was built. This was not entirely successful although it did fly at Flixton disused airfield. The cantilever wing without lift struts was not liked by anyone so a big re-think was necessary.

A very intense three weeks of design resulted in the Shadow aircraft that everyone knows today. The fibrelam monocoque had tandem cockpits shaped so that no separate seats were required. The whole airframe had to end up weighing not more than 331 lbs (150kg), thus the differing materials used for their properties of strength versus weight would result in an aircraft that would not only have to be minimum weight but also stronger …. and it was!

At first sight the CAA comment was that the rules didn’t expect to see a microlight that is fully enclosed with three axis controls, flaps and brakes. It took them two years to gain approval for this design, which it achieved without a single fault being found.

A friend, Paul Owen, kindly calculated all the structural properties and aerodynamic compliances without charge because he fell in love with the factors of safety. 1.5 above the maximum load is required by aircraft and this airframe topped way above that in all aspects. As a matter of interest, a factor of 8 to 9 is required for bridges.

Shadow 02's monocoque weighed 16 lbs and could be trial fitted prior to bonding because all the sides and back rests had mortise and tenon joints that automatically made it square without a jig. Bonding could then take place. This all proved very helpful for later kit homebuilders. An aerospace two sided insert could be bonded into the fibrelam with an interference fit. Rated at 1,500 lbs strain by Boeing test these could take a 3/16" diameter bolt or be drilled out for ¼" diameter. Perfect hard points for structural fittings etc. Very different from tubular airframes that have to have frames located where necessary. With these inserts we could have a hard point anywhere where required and use any number for structural integrity.

The cockpits were very comfortable, being slightly reclined but really for one plus one crew. The design of the second cockpit was similar to the thinking of a sports car, the main emphasis being on the pilot. The cockpit has been criticized for being too narrow but measurements were based upon myself, as when I was in the RAF my body dimensions complied exactly to 'SAM' (standard airman) in every measurement. Monocoque folded easily for side armrests and for side control stick and throttle. Without the control stick stuck in the centre, the entry/exit was free from interference, also allowing for maps on the pilot's lap, etc. This followed practice from previous Volmer designs and even General Dynamics F16. The whole cockpit gave a fighter type aircraft feel with a very prominent throttle falling easily to hand. The second cockpit was positioned exactly on the flying CG – centre of gravity – so that there would be no change of trim whether it had an occupant or not.

Vision for a pilot is paramount so the one piece canopy gave a clear view ahead and to the sides, which was similar to a sailplane type of aircraft. The canopy was constructed from polycarbonate. Polycarbonate is lighter than Perspex, possessing less specific density. Added to which this material is shatter proof should a bird strike occur in flight. The starboard side opening was amusingly criticized and controversial and provoked comments such as 'David doesn't know which side one mounts a horse'. As a matter of interest, the F104 Starfighter's canopy opened this same way. Because the Shadow's engine recoil starter system was biased starboard, the pull cord had to be routed as said and the canopy opened out of the way to port.

Normal foot pedals with brake levers attached without fore/aft adjustments. The flap handle is positioned in the area over the left shoulder and to operate was pulled down for 15°or 30° and pushed up for off position.

The control stick, which is mounted on the starboard side, could not be centred in an upright position as would be normal due to the lack of airframe clearance so prior to take off a check was needed to ensure that the ailerons were in neutral, which would therefore set the control stick's position.

A four point harness was fitted for both cockpits.

The instrument panel had to have mandatory gauges – airspeed, altimeter, compass, engine speed and temperature, fuel quantity. Rear cockpit had only an airspeed instrument.

Much thought was given to the fuel system. Fuel tanks were positioned below the fuselage and aft as the safest options in the event of sudden leaks or fire as opposed to the more hazardous option of placing in the wings or above crew. Initially only a rear 5 gallon fuel tank supplied the engine but later, when a 7 gallon slipper tank was added, the 5 gallon tank fed into it and the slipper tank fed the engine. This was also positioned on the CG so there was no trim change as the fuel was used. Too many fuel cock changes have resulted in engine starvation due to incorrect fuel management on aircraft. The Shadow fuel system was all automatic as the rear tank emptied into the slipper tank. Even when an extra long range fuel tank was added to the rear cockpit it fed to the slipper tank – again without any trim change. The fuel tanks were constructed of a thin lightweight fibrelam type, which in later years disintegrated from the addition of ethanol to petrol and they had to be replaced with aluminium construction.

The requirement for fuel cut off was mandatory in case of fire. This was a ridiculous waste of time as even after switching off fuel to the engine Rotax carburetors had sufficient fuel in their bowls for at least four minutes of maximum running before emptying, the theory being to select full throttle to swallow any flames. As any 'flyer' knows, it would have been better to switch off the engine, dive to the ground, land/crash anywhere, get out and run – if there was an inflight fire. Anyone obeying 'the book' should be called Mr Cinder.

Entry into the rear cockpit for P2 was difficult and one had to be slightly acrobatic. Female passengers managed better than male as they seemed to be more flexible. It was tight, unlike the front cockpit P1, which was easy entry/exit but still described by larger pilots as 'cosy'. However, when used as a trainer, instructors managed from the rear cockpit, which had a complete set of controls including brakes, and many potential customers and trainee pilots have been flown from the P2 position. Providing greater accommodation was difficult due to the empty weight rules.

The main undercarriage was made up of molychrome steel tubes with fibreglass pultrusion rods accommodating shock loads. Initially with only one tube, it soon proved necessary to double this construction. The CAA grounded all the

Shadows, after 20 years of operation, saying initial tests did not account for the pultrusion rods being tested with a factor of x2.0 for composites. An expensive replacement undercarriage was required for all UK aircraft – no other country's airworthiness authorities required or mandated this change.

The initial nose leg needed to be modified for shock absorption as was found during taxi tests prior to flight. This was redesigned to a marvelous piece of value engineering. It swiveled by use of differential brakes on the main wheels. A bungee cord provided the shock absorption with a catch wire. The whole assembly was secured by a stranded wire and a bolt at the top of the outer nose leg tube. The stranded wire could be wound up by rotation of the wheel assembly to allow resistance to swivel. This could be set to just the resistance that would eliminate shimmy. The design was so neat that even Ken Wallis copied it for his Autogiro machines.

Compliance for the nose leg was such that it required such an enormous load that this could not be sustained. The rules came from the need for other microlight designs where the pilot's legs and ankles were exposed to either side of the nose leg wheel. A collapse here would have serious injury. The extent of the rigidness of the Safety Regulations Group at the CAA – Civil Aviation Authority – was such that even though this requirement didn't apply to the Shadow, they still required it to comply! Questions were always going to be raised for any failure of Shadow's nose leg, even after a failure running into a rabbit hole. Our factory did pose the question of airworthiness when the aircraft is actually on the ground.

Brakes for the main wheels are operated by levers attached to the rudder pedals. Initially aluminium disc type was used but these proved too easily scored and any small leaks ruined paintwork. A drum type, as used on mopeds, was much more practical and, as mopeds use their brakes often and aircraft only when on the ground, this was a fine solution.

POWER:

The original 01 Shadow used a 45hp two stroke Cuyuna engine with my own reduction drive of 2:1. Giving up on this first aircraft, a redesigned Shadow 02 used a Fuji Robin of 50hp with its own toothed belt reduction drive. This failed spectacularly after a few hours in the air, sending the propeller into the wing. Luckily 02 landed safely, mortally damaged but repairable. The Rotax engine from Austria solved all the reduction drive problems with their own gearbox. We used 2.58:1 on a R447 40hp two stroke engine. Two stroke engines are used because they are lighter and less complicated than four stroke type of equivalent power.

Mounting the engine to the back of the fuselage as a pusher design rather than the normal front tractor propeller was a real safety method. Many people have been injured, even killed by aircraft with rotating propellers at the front of the aircraft. It is an obvious thing on a pusher type that the slipstream thrust is blowing when approaching the running engine. Also all the thrust slipstream air from a tractor type propeller causes drag all over the fuselage. None of this happens using a pusher type and therefore it is much more efficient.

WING

The Shadow wing was a revolution of my own thinking, as they say ‘a whole new ball game’. My wing was going to be classically pure in that it was tapered in thickness and plan form, mounted on a pylon in clean air, cantilevered with struts for double safety. Many designers just attach the wings straight on to the fuselage sides. This causes interference drag and all sorts of other inefficient influences. It seemingly seems forgotten that the wing is all that flies an aircraft – without it there is no flight.

A front ‘D’ box formed the main strength with trailing ribs accommodating ailerons and plain flaps. This structure of the wing was similar to the way a Spitfire wing was formed.

Wing profile was concluded after much study of wing sections by the hundred but found none that performed in the speed range 20-100mph. So I created my own profile airfoil section. For this type of aircraft with its speed range in mind, a 15% thickness to chord ratio was settled upon.

Wing area had to comply with the microlight class rules of not more than 10kg per metre square. As 150kg was the empty weight, so the wing area had to be $15m^2$ minimum.

The key to this profile was the drooped leading edge forming the 'D' box along the whole span. The root profile was almost symmetrical but as it progressed to the tip it drooped to minus 2.3° negative to the oncoming airflow – in effect washout. This shape took into account the pressure wave in front of the wing and kicked the air to a downward pressure aft of the 30% chord. This is opposite from the Bernoulli theory interpreted by theorists as to why flight is achieved. An aircraft flies due to the downward pressure by its wing having an angle of attack, as can be witnessed by pilots when landing with what is termed 'ground effect'.

Irv Culver was the top aerodynamist in the West. He worked at the Lockheed Skunk Works in California. In fact it was he who named it Skunk Works. Culver was prominent with Lockheed designs such as the P38 Lightning, Starfighter F104, Dragon Lady U2 and the Blackbird SR71. Being a friend of my associate Volmer Jensen, Irv Culver designed the special wing airfoil of the VJ-23. I built both VJ-23 and VJ-24 from plans and visited Volmer regularly in Glendale, California. The designations were 23rd and 24th designs by him. The Shadow's forward part of the wing emulated the profile of the VJ-23 but aft of the chord of 30% the trailing ribs were just a straight line.

Meeting Culver on several occasions with Volmer, we discussed, even argued about aerodynamics. One thing we had in common was surprising in that neither of us had a single academic qualification – we both thought things up for ourselves and tried to ‘see’ air. It was a privilege to talk to this exceptional man. I knew from flying the VJ-23, both as a rigid hang glider and when powered by a small engine, that it exhibited no defined stall. The Shadow has the same characteristic all due to the wing profile design. The pressure wave in front of this wing can be seen, for example, by dolphins swimming at the bow of a boat or ship and it is the unseen force on this aircraft wing.

Angle of incidence was set at +3°, which is probably about 1 degree too small as the Shadow flies slightly nose high. It has never been altered in production as the paperwork required by the CAA would have been too much and classed as a major modification.

Wing twist normally seen on aircraft as washout is not necessary on the Shadow due to the drooped leading edge. This makes wing construction simpler as ailerons and ribs do not have to be twisted to suit. The wing tip design keeps the high pressure downward force by the wing delayed from easily spilling off the tip. Designs which have upturned tips at the end of their wings are an unknown because delaying air spilling off the wing makes it think it has a higher aspect ratio, and therefore is more efficient. Flying during testing with and without these shaped end tips to the wing showed about a 7mph increase in speed when fitted.

Trailing ribs along the wings were widely spaced and made from Styrofoam. There was no profile, being straight top and bottom edges. There is little point having an airfoil profile when using fabric covering. Fabric between ribs does not follow the outline between them. Fibreglass bidirectional mat covered trailing ribs with uni-directional type attaching to 'D' section and rear spar.

A relatively new technique called 'hot wiring' consists of a resistance wire operating DC current, which carved through blocks of Styrofoam lined up on a jig for the leading edge. This was done in one pass to create the exact profile from steel insulated ribs at each end – some 13 feet apart. It was interesting to receive a telephone call from maybe Patrick Head of Williams Formula One racing team asking about our hot wiring techniques. They didn't know that urethane foam was not to be hot wired as it emits cyanide gas!

I was helped with this technology by Brian Harrison, who had previously developed much of it, building Goldwing canard microlights in East Kilbride. Brian was one of the original four founders of CFM – Cook Flying Machines – the two others were Steve Emmerson and Colin Buck.

Also new was the technique of bonding aluminium to other materials. Aluminium has a natural protective oxidized surface, thus this has to be abraded off to allow a special chemical called Accomet 'C' to be applied then dried off with a hot air gun. Araldite 2005 with a sheer strength of 1,500 lbs/inch^2 is then applied, usually with back up or rivets or bolts. This mechanical fixing was designed to be sufficient without the bonding. But the araldite bonding meant that these surfaces had no stress points. A wing structure that has been described as ‘without a fatigue life’. The sheer web between upper and lower spar caps was 1.2mm birch three ply kept exactly vertical by numerous ‘D’ box Styrofoam ribs. This Styrofoam is quite light but very resilient to compression.

Then the leading edge ‘D’ box was clad in 1.2mm birch plywood. Special attention had to be made to get the exact humidity for UK and Europe in the plywood, 13%, otherwise oil canning between nose ribs would occur. Talking by telephone to a glider manufacturer in Poland, who used a lot of thin plywood, was very useful. Three ply birch is produced in Finland and, calling at our factory, their representative salesman gave me his calling card, which was only 0.5mm three ply! The whole wing ‘D’ was a torque box exhibiting great resistance to twist and bending. Each complete outer wing which was 14 ft weighed only 45 lbs. The overall wing being in three pieces – central section 4 ft wide and two outer wings giving a span of 32 ft for Shadow’s and 28 ft for Streak and Starstreak. The centre section of the wing remained with the fuselage while outer wings were attached with two each massive vertical pins, leaving no gap cover required.

Rigging the aircraft took ten minutes and two persons but certain clever individuals managed to rig up alone. A special trailer housed the disassembled aircraft, keeping it safe and insulated against the weather. It could be towed by a car and taken home or left secure at the flying base.

Ailerons were constructed from aluminium, pine and plywood gussets using the araldite method for differing materials and pop rivet fixings. They were made to have a differential range of 20° up and 15° down to counteract adverse yaw.

Flaps were similarly made and operated from a common torque tube so that it was impossible to have only one flap operate.

Testing the wing under a static load showed proof without distortion at a 7.0G and a -4.5G, and even though it was a cantilever structure it still had wing struts making it doubly strong. A load of over two and a half tons was withstood in the positive test. That's about a strength to weight ratio of 27:1. It is not known what the real ultimate strength of this wing is as it was not taken to destruction. After load testing any distortion was unnoticeable.

Covering of the wing, tailplane, fin, rudder, ailerons and flaps are all covered in polyester fabric. The weft and weave samples sent to us from Coulthards showed ladies' dress lining type was best suited. Fabric was adhered to the surfaces using two coats of household type Bostik clear adhesive, placing the fabric on dried adhesive and activating it through the fabric with acetone. A hot air gun or domestic iron tautened all surfaces, after which two coats of clear dope sealed the porous weave. Helpfully the 30mm wide Styrofoam ribs provided a good area for bonding fabric, unlike most aircraft of this category, which use tubes for ribs where only a point area is available requiring extra securing.

A boom tube some 15 ft long runs from the front of the wing to the tail empennage. It is 5 ins diameter 18 gauge aluminium and is intended for irrigation on agricultural fields. Engineers would describe it as made from inappropriate material for use in the aerospace industry but it has two good qualities, being corrosion resistant and good in fatigue. Made from sheet material, the boom tube is rolled and machine welded, showing a uniform thickness throughout. Tested in the factory when set up as on the aircraft, failure under load was 600 lbs when the tailplane area was loaded, a factor of safety 4.8:1 from maximum tail loading. A reinforcing insert tube at the forward end was inserted for additional strength.

The Shadow tailplane and elevator were minimally constructed using aluminium tubes with wood compression struts, plywood gussets, similar to the ailerons and flaps. Tailplane weighed 9 lbs and was sized up by eye to ‘about right’. Over 400 have been made and it has never been altered for any of the Shadow series.

A small electric trim motor is built inside the elevator to a trim tab on the trailing edge. Operated from the cockpit via a rocker switch, a light panel shows neutral, full up and full down trimmer position. The flight could be adequately handled with trim tab either full up or full down at any speed to satisfy any runaway electrical failure.

For longitudinal stability a negative angle set the tailplane at -1.5°, later reduced to -1° for the faster series.

Vertical finlets are added to the ends of the tailplane to give some directional help and with these it looked aesthetically improved. Flown without these finlets a weird directional occurrence happens which is not easily describable. One Shadow in South Africa had the entire rudder with fin smashed off by a heavy bird strike but even without these directional surfaces it was flown by only the ailerons and elevator successful back to base because the tailplane finlets provided a minimal directional control (see Jas van Wyk's report on my website).

The remaining parts of the empennage are rigged or unassembled quickly with only two pins and safety clips. Rudder with fin stays with the airframe but is also detachable.

Controls, elevator, flaps and rudder are operated via teleflex cables whereas the ailerons have push/pull aluminium tubes.

The first Shadow B series at completion had an empty weight of 150 kg (331 lbs). At the World Championships in France 09 passed the weight test, much to the astonishment of the scrutinizers. Later the empty weight rules were updated to AUW (all up weight), allowing a maximum of each crew member to be 90 kg. Larger more powerful engine for the 'C' series and general upgrading these Shadows usually weighed 400 lbs empty.

Flight testing began using a Rotax 447 engine of 40hp. 02 machine was flown with development changing an all moving rudder separated to static fin plus rudder. Undercarriage drag struts were raised and tail skid shortened. A maximum speed of 100 mph and minimum speed 20 mph indicated. There was no defined stall break – the aircraft descending in a nose high attitude at approximately 300 feet per minute. This was wings level with no buffet or wing drop and the control stick held fully aft, full flaps. It just might appear too biased being the designer for the authorities to accept so I had requested a colleague, Peter Davies, to complete an independent flight submission. Peter confirmed my findings and took tests far beyond my own flying abilities. We found that the ailerons were subject to flutter at speed beyond VNE (velocity never exceed), i.e. at Design Speed. New ailerons design was proposed by Tim Hardwick Smith and were properly balanced and this cured the flutter problem.

The authorities found it difficult to accept that this design had no defined stall and could not be made to spin. Pitching a Shadow to the vertical, allowing it to stop then crossing the controls only resulted in half a spiral turn. These characteristics were confirmed by two CAA test pilots and confirmed Peter Davies' flight report.

The Shadow was allowed to have the term ‘spin resistant’. These tests by the CAA also confirmed that trim was maintained with a loaded or unloaded second cockpit P2.

Getting an aircraft CG (centre of gravity) correct is vital. All the clockwise moments and anticlockwise moments must add up to the projected CG. When checked on the first airframe the empty CG was within one tenth of an inch, unlike the Gloster Meteor that had to have 1095 lbs of lead added to the nose area to correct its CG.

Flying initially showed no trim change from full power to idle, meaning the thrust line was exactly at the dragline. This was not correct to the stipulations and had to be altered to nose up on full power.

The first B series Shadows were a gentle delight to fly. With their 40 hp engines they were responsive, giving 1,000 feet per minute climb rate. Exhibiting an almost gentle feminine characteristic, many female pilots enjoyed them. Progressing to the C series with a 50 bhp Rotax 503 engine allowed sufficient power for the Shadow to be used for training students at flying schools. Credit must go to Fiona Luckhurst at the Old Sarum Shadow flight centre, where her training Shadow amounted 4,000 hours flight time.

A step into the general aviation world was the Streak Shadow, not complying as a microlight through having less wing area. A new shorter wing with 12% thickness chord ratio and a liquid cooled Rotax 582 of 60 hp gave a step up from previous Shadows. Retaining the non-stall, non-spin characteristics, the power weight ratio allowed exciting performance. 1600-1700 rpm climb rate and a 0-60 mph time of 3.6 seconds made the pilot feel almost guilty at the sheer willingness given to them.

Progressing to the Starstreak with many of the Streak components, a wing with less chord made this version faster in response, especially with regard to roll rate. Some were fitted with 70 bhp engines.

As the Shadows and Streaks were lighter and more aerodynamic than all other aircraft in their category and stronger, using similar engines and power, they set new standards of achievement.

Thirty years on the Shadow is still the 'Gold Standard' for this type of aircraft, with hundreds flying world-wide.

CHRONOLOGY AND ACHIEVEMENTS

1. 1983 First flight of the prototype. Pilot David Cook
2. 1983 FAI 3km World Speed Record CAT C-1-a/o Group
3. Pilot David Cook. Doubled previous record
4. FAI Outright distance record. Pilot Peter Troy Davies
5. Doubled the previous record
6. 1984 CAA Certification achieved Primary A1 Manufacturer
7. CFM Factory achieved CAA Approval
8. 1987 British Design Award presented by HRH Prince Philip
9. 1992 British National Altitude Records
10. 23,600 feet U.K Microlight Category
11. 27,150 feet FAI Category. Pilot David Cook
12. 1983-1994 Manufacture of complete aircraft, aircraft kits, and arranging the licence manufacture in South Africa and USA
13. 1983-1994 The following Shadow variants were developed and certificated:
14. Series A, B, B-D, C-D, D, G, Streak, Star Streak and a version for paraplegic pilots
15. A total of 415 Aircraft were built.
16. 1994 Time to Climb: 0-10,000 Feet
11 min 04 secs UK Microlight : Pilot Jacob Cook
8 min 40 secs FAI Microlight: Pilot David Cook

LONG DISTANCE FLIGHTS, ETC.

In addition to the Shadow's main use as a recreational aircraft many long distance flights were made:

England-Australia: Pilot Eve Jackson – Segrave Trophy awarded

England-India: Pilot V P Singalia

England-Australia: Pilot Brian Milton

England-Beijing: Pilot James Edmunds

USA Coast-to-Coast: Pilot Andy Nightingale

England-Tanzania: Pilot Eve Jackson

Bournemouth-Kirkwall: 2 Shadows Non-Stop:
Pilots Peter Troy Davies and Brian Milton

Dawn To Dusk International Flying Competition: Outright Winner Duke of Edinburgh Trophy; Precision Navigator's Award; Microlight Award:
Pilots David Cook and David Southwell

The Shadow has been demonstrated at many air shows, has been used for training and surveillance, and 28 are in service with the Indian Air Force.

Shadows have also played active roles in two major feature films: *Slipstream* where it played a key role and *Dragon Heart* where it was camera aircraft.

None of the foregoing would have been achieved without the design genius, entrepreneurial spirit and the dogged determination of the one man over the past thirty years.

There has never been a serious injury or fatality caused by this aircraft's airframe failure from 1983 to the present, 2017.

'Son of a Gun!'

D G Cook

Web: davidcookaviator.com

Book: Flying from My Mind, published by Pen and Sword

ACCOLADES

Sitting in the Streak Shadow and giving it full throttle reminded me of my first jet ride; the acceleration is exhilarating.

Derek Piggot, Pilot Magazine UK

The engineering on this aircraft is like poetry.

Mick Broom, Engineer and builder of Hesketh Motorcycles, UK

Watching a semi aerobatic display by David in the Streak reminded me of the purity of flight – just like a Spitfire.

John Farley, Engineering test pilot, UK

The Shadow – David Cook’s genius of structures and aerodynamics.

Adrian Jones, BMAA Design Engineer, UK

The Shadow has perfect aerodynamics.

Francis Donaldson, LAA Chief Engineer, UK

I conclude that it is the case sometimes that some people, and David is one of them, have an instinctive genius when they know something is right.

John Dickinson, OAM, BA Psych, FAI, DIP, Australia

Cook said, “I’m not much of a pilot. I just want to fly.” Those words should be written in stone.

Armen, Pilot B-737, Ukraine

Front cockpit – ‘cosy’.

Peter Troy Davies, Aviator, UK

This incredible man with an incredible history – Shadow a benchmark that broke the mould.

Anthony Preston, Flying Instructor, UK

What a boring aircraft!

Bob Cole, CAA Test Pilot, UK

I am very impressed with the Shadow series of aircraft, the design, systems and construction, and flight handling. This unusual approach to engineering has resulted in an exceptional aircraft.

David Martin, Editor, Kitplanes Magazine, USA

I found the Shadow to be an OUTSTANDING aircraft. When seated in the front cockpit the pilot has a feeling of quality and control. In an age of look alike aeroplanes, it is nice to find a design that is truly on the cutting edge of both engineering and technology.

John W Conran, Sport Pilot Magazine, USA

The Streak chased and zoomed through the sky faster than my Canon's autofocus could follow. I am sorry I could not bring you the 'shot' of the Streak pushing up from level to a vertical climb, but it was just too fast for us.

David Hewson, Editor, Flyer Magazine, UK

The Shadow is one of the safest airframes that has ever been built. The wing on this aircraft will not let go under any flight condition. You can't stall it or make it spin.

David Cook, Shadow Designer UK

MATERIALS USED ON SHADOW AIRFRAME

FIBRELAM:	Fuselage monocoque, including instrument panel, tailplane finlets, fuel tanks
PLYWOOD:	Leading edge 'D' box 1.2mm thick Fuselage sides 1.2mm Gussets 1.2mm Pylon sides 3.0mm
BRITISH COLUMBIAN PINE:	Front wing spar, ribs – rudder, fin, tailplane, elevator, flaps, ailerons
ALUMINIUM:	Boom tube, throttle lever, rudder pedals, flap lever, gussets, rudder, fin, tailplane, elevator, ailerons, flaps, engine bearers, fuel tank straps, wheels, drag struts, undercarriage, aileron push/pull tubes, jackshaft ailerons, canopy hoops, canopy levers, flap torque tube, bellcranks, nose leg
STEEL:	Undercarriage, control stick, controls torque tube, horn levers, engine stay tube, axles, tailskid
STYROFOAM:	Wing 'D' box nose ribs, wing trailing ribs, rear spar, centre section top
URETHANE FOAM:	Wing tips, nose cone front
GLASS FIBRE: (B1 DIRECTIONAL)	Nose cone, wing tips, trailing ribs, rear spar, pylon front 90° angles
GLASS FIBRE: (UNIDIRECTIONAL)	Trailing ribs
PULTRUSION:	Undercarriage legs
POLYCARBONATE:	Canopies front and rear cockpits
POLYESTER FABRIC:	Wing covering, tailplane, rudder, elevator, fin, ailerons, flaps

NYLATRON:	Bush bearings
NYLON:	Tail skid, nose leg bearing, bushes – aileron push/pull rods
TUFNOL:	Bushes for bearings

CHEMICALS: Araldite, Accomet C, Loctite, acetone, cellulose dope, Bostik No. 1, paint, Epoxy Safe'T'

HARDWARE: Unified bolt system, nyloc nuts and plain, pop rivets, bungee cord, steel multi-strand wire, electrical wire, fuel tube, lord mounts, seat cushions, hand grips, cable wire runs, plastic mouldings and saddles, rod ends, tyres and tubes, ball bearings, drum brakes, thimbles, washers, safety clips, seat belts, propeller, wheels, placards, instruments, grommets, teleflex cable, trim motor, zips, fuel sender, filter, primer bulb, cord, pulleys, transfers, wing struts, shock rubber, tail ends, tie wraps, fuel clips, split pins, cap ends

Bristol 188
No fuel left once at Mach 2

English Electric Lightning
Low endurance

Boeing Stratojet B47
Engines in nacelles


Gloster Meteor
Engines through the wing


Typical Airliner
Engines in nacelles

Messerschmitt Me 262
Engines in nacelles

Blackburn Buccaneer
Unstoppable at low level

Hawker Hunter
Aesthetically beautiful

Saab Draken
Treble the range of Lightning

Handley Page Victor
Engines in wing roots

Shadow
Bernoulli Theory Busted!

Shadow

Streak Shadow

Starstreak
Pilot Jacob Cook

Volmer Hang Glider 1974
Silent Flight