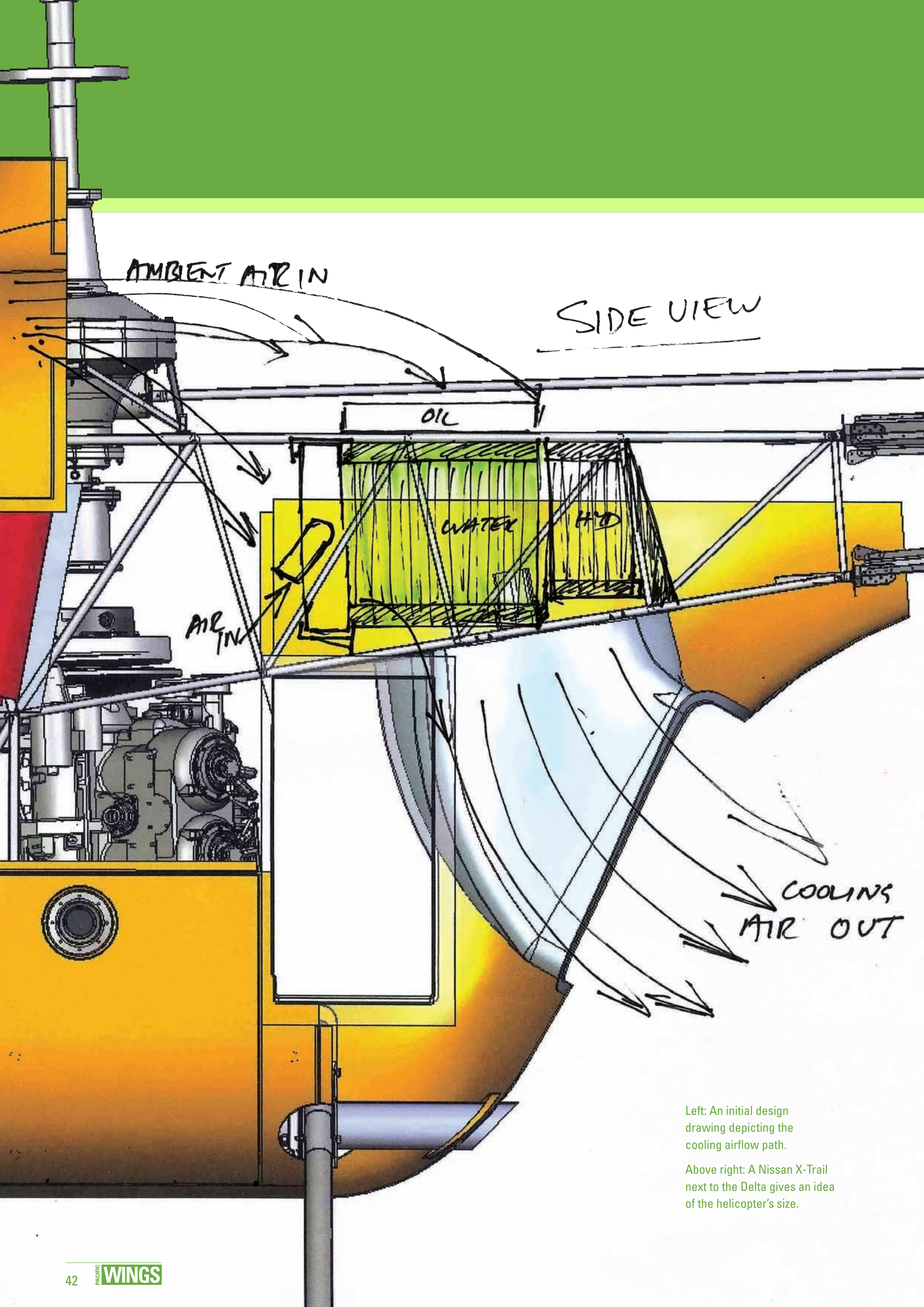


Left: An initial design drawing depicting the cooling airflow path.

Above right: A Nissan X-Trail next to the Delta gives an idea of the helicopter's size.

Amazing Aussie(s)

—The Delta D2

Article by **Pam Johnson**

Are you in the market for a new helicopter? How would you like to just fly your new machine up to your diesel tank and fill it up—and for your routine spares requirements, how would you like to be able to just stop in at your local Ford dealer to buy things like oil filters? Unreal? Unlikely? Possibly not any more.

For the past six years, three very determined Australian men—Graeme Smith, Andrew Reid and Bill Whitney—have been working hard to bring the Delta D2 helicopter to life.

Andrew Reid grew up on a 610,000-acre farm in the Gulf of Carpentaria that operated three Robinson R22 helicopters for mustering cattle, checking fences and general farm duties. While the Robbies did the job, Andrew always wondered if there might not be a "better" alternative for this kind of work. As a result, he investigated the RotorWay Executive—which was how he came to meet Graeme Smith, who had been the local RotorWay helicopter agent for around 10 years, and had sold around 40 aircraft in Australia, New Zealand and South East Asia.

After meeting Graeme, Andrew decided to try a RotorWay. After it was built in Brisbane, it had to be flown up to the Gulf and when Andrew had trouble finding a pilot, he flew the helicopter back himself.

While there was nothing inherently wrong with the RotorWay, it soon became obvious that it could not match the R22 in a number of areas—the most important one being its lack of power. While suitable for checking fences and several other jobs the helicopters were routinely used for, it also wasn't as manoeuvrable as the R22 and it soon became a "back-up" machine.

Andrew and Graeme began wondering whether the RotorWay might be improved by offering a different engine for the kits Graeme sold. At that time, with GST being introduced and the dollar being floated, the cost of "standard" RotorWays skyrocketed in Australia and people could no longer afford to buy them, so Graeme had to attract a new market. The two men thought that with a new engine, the RotorWay might become a good mustering helicopter and they began searching for a suitable engine.

Graeme soon came across the DeltaHawk (two-stroke diesel) engine on the internet and began doing some homework on it. The manufacturers were quite happy for it to be used in a helicopter (in fact, one of DeltaHawk's owners was an ex-helicopter person and told Graeme he had always wanted to fit the engine in a helicopter) and before long, a DeltaHawk engine was mounted vertically in a RotorWay. This was when the third member of the team—Bill Whitney—came on board.

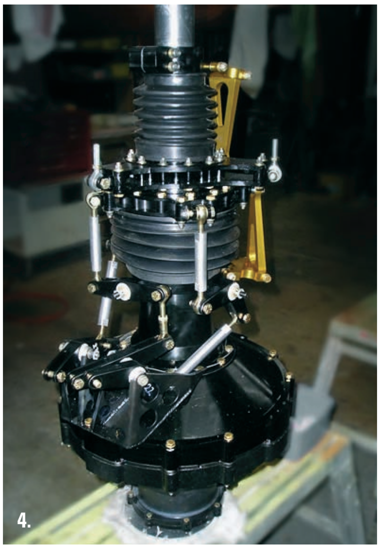
Bill's name is very well known in aviation circles in Australia. He has designed and built more than 16 aircraft including the Whitney Boomerang, the Seabird Seeker, a Vickers Vimy replica, a replica *Southern Cross*, the "Wedgetail" gyro plane, two Bristol F2.b replica aircraft, the Hughes "Lightwing" and a replica Wright Flyer. In addition to his own designs, Bill has been involved in the modification, flight testing, certification, analysis and repair work of many others during his illustrious (42 years and still going strong) career as an aeronautical engineer.

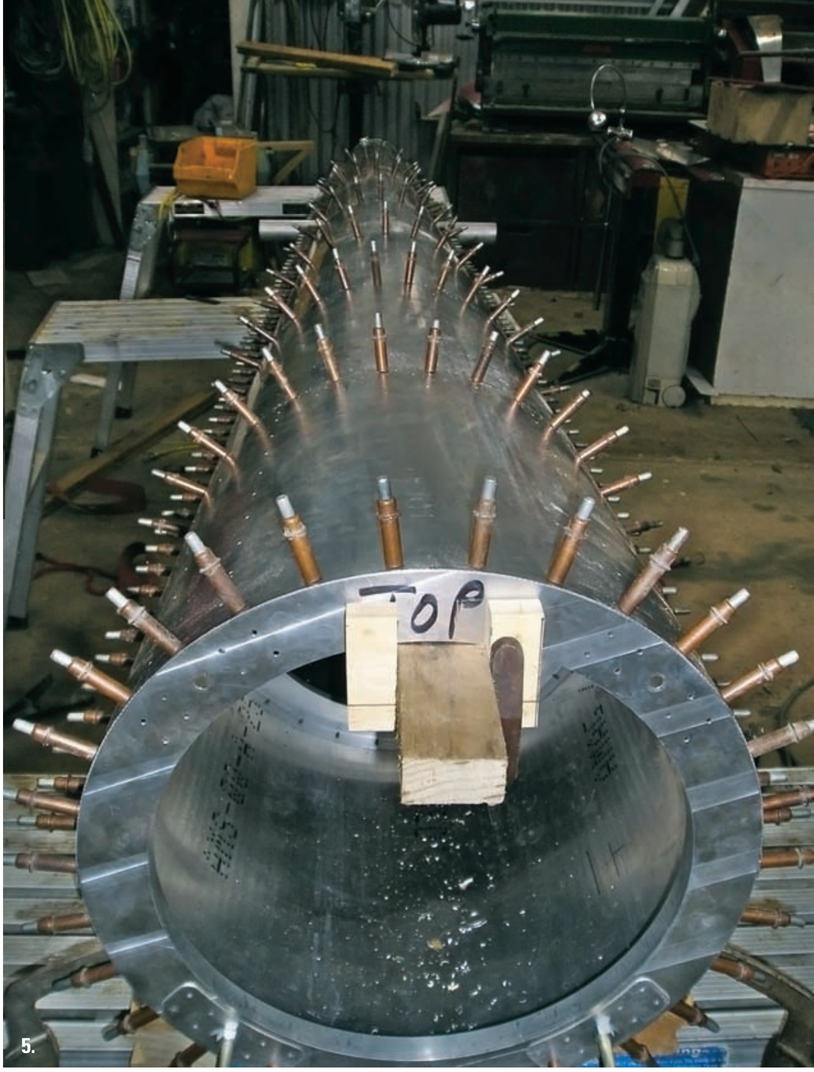
Bill and Graeme eventually managed to squeeze the DeltaHawk engine into a RotorWay airframe, but it was a significant challenge and took all of Bill and Graeme's ingenuity to get it to fit. Although they succeeded, it was obvious to Graeme that the skill level required to do so was too much to expect of a typical RotorWay "homebuilder" customer; RotorWay kits are supplied fully welded, with customers needing to do little more than bend a few brackets, run a few hoses and cables, and assemble things.

With the modified helicopter complete, it was time to begin testing it. It was tied securely to a very big trailer "so it couldn't get out and take off". With the helicopter securely tied down and the engine running smoothly, they began to pull pitch. According to Graeme and Andrew, a "stock" RotorWay typically runs out of power at anything much above five of the maximum 10 degrees of positive pitch physically available. With the DeltaHawk engine, they found they were able to pull the collective to the (10-degree) stop and still have power in reserve!

The next test involved placing scales under the trailer's four wheels and repeating the exercise. In doing so, they almost lifted the trailer off the scales. Two of the four scales registered "zero" and when they did the calculations, they were staggered to realise that the helicopter had lifted almost 1,000 kilos! During the exercise, even though the collective was at the stop—unheard of in a RotorWay—they were able to play with the throttle to increase and decrease the rotor rpm. According to Graeme, the DeltaHawk engine didn't appear to be working hard at all. "There was no groaning or moaning or anything coming out of the engine area; it was just doing it," he said.

While petrol-powered piston engines are particularly fussy about





1. Positioning the boom bulkheads in preparation for boom assembly. (Pam Johnson) 2. The DeltaHawk V4 200 hp engine. (DeltaHawk) 3. Main gearbox parts. (Pam Johnson) 4. The main gearbox and swash plate assembled and ready to be installed in the airframe. (Delta Helicopters) 5. Held together with Clecos, the assembled tail boom awaits final riveting. (Pam Johnson)

the fuel they require, the two-stroke diesel DeltaHawk engine runs happily on a wide range of different fuels. Graeme and Bill tested three different fuels: diesel straight from the pump, Jet-A from the airport and biodiesel from a friend who ran his car on it. The results surprised them. While standard diesel and Jet-A were so similar they couldn't pick the difference, the biodiesel gave slightly better performance—and it smelt better.

With the abundance of power available, the team now became concerned at the suitability of the standard RotorWay rotor blades and the possibility of over-stressing the helicopter. With too many "unknowns" involved, they were not prepared to jeopardise safety and had to re-think their plans.

So impressed were they with the amount of power and lack of vibration produced by the DeltaHawk engine that the team decided it would be better to build an entirely new helicopter around the engine rather than try to adapt the RotorWay machine to accept it.

The power and lack of vibration were only two of the DeltaHawk engine's many advantages, according to Graeme. Importantly, in remote locations—particularly in Australia—diesel is available everywhere, while Avgas can be scarce and expensive. Graeme says that another benefit of the DeltaHawk is that it was designed from the outset as a dedicated aviation engine rather than a converted auto-diesel. Because it is a two-stroke diesel, it has fewer moving parts and a greatly simplified crankcase/engine block. With fewer moving parts than four-stroke diesels or petrol engines, and no electrical ignition system, it is likely to be extremely reliable. Diesels are inherently cooler running than petrol engines. Combined with the fact that it is water cooled, this means that with a correctly designed radiator system, the DeltaHawk will be particularly well suited to the extreme conditions in places like Australia. The water-cooling has the additional advantage of eliminating the risk of shock cooling when operated in cooler climates.

Another big advantage for diesels—particularly in a helicopter application—is the amount of torque they produce and the characteristics of their torque curves. Petrol engines in helicopters operate at or near their maximum torque with a steep drop in torque "behind the curve" giving less flexibility or leeway in maintaining rotor rpm compared to diesels. From a pilot's point of view, the additional torque of a diesel is valuable in its ability to restore decaying rotor rpm.

Many people have died because of an inability to restore decaying rotor rpm in time. Helicopter rotor blades are designed to run within a very specific rpm range in flight. If the recommended rotor speed is exceeded, the centrifugal loading goes up exponentially, along with the associated load on all the bearings, bringing with it the risk of bearing and component failure. Conversely, if the rotor rpm decreases beyond a certain point, the drag on the aerofoil section requires a significant amount of power (and torque) to restore it. Therefore, an engine with a lot of torque is a good thing.

Operational tests of the DeltaHawk engine confirmed the valuable torque characteristic of the diesel in this regard. Graeme said that with the rotor RPM allowed to reduce, even without altering the pitch of the blades, the engine had enough power and torque to restore the rotor rpm simply by opening the throttle.

Above, left: The DeltaHawk engine being installed in the airframe. (Pam Johnson) Above, middle: A mock-up of the cooling system layout. (Pam Johnson) Above, right: Assembling body panels. Note the see-through sight gauge in the installed fuel tank. (Pam Johnson)

The DeltaHawk engine has a number of other advantages over existing petrol piston helicopters. It develops its rated power at a modest 2,700 rpm (compared to just over 4,000 rpm for RotorWay's own petrol engine) and thus doesn't need as much gearing down. Belying the myth that diesels are big and heavy, the DeltaHawk is also extremely light. Although water-cooled, it only weighs about the same as existing (air-cooled) petrol piston engines of similar output.

As far as its power output is concerned, the DeltaHawk has the advantage of being turbocharged so that its power remains constant at altitude, compared to normally-aspirated petrol pistons. Although it will not be operating that high in the helicopter, the DeltaHawk engine is capable of maintaining sea-level power to 17,000 feet.

Experienced practical designer that he is, Bill Whitney wanted to position the main rotor as high as practically possible for safety reasons; he didn't want anyone forgetting to "duck" and learning the hard way about how much kinetic energy is contained in a spinning rotor disc. As a result, the Delta D2, which has the engine mounted vertically in the airframe, looks a lot like the stylish (and equally practical and safe) MD900/902 series of (NOTAR) helicopters, with a high rotor sitting atop a stylish cabin.

The machine is very slightly taller and longer than a Schweizer (Hughes) 300. Its tail rotor is slightly higher than that of the Schweizer, and has a diameter somewhere between that of an R22 and an R44.

An awful lot of complicated mathematics was required to balance the height of the helicopter, the blade length and how much weight the machine was intended to carry.

Bill decided that the rotor blades had to be composite. Bill's son Eric is an aeronautical engineer with Boeing and has numerous PhDs to his name—one of which just happens to centre on rotor blade

Above, left: Graeme spraying the chrome-moly steel frame. (Pam Johnson) Above, right: Graeme pondering the location of the air filter. (Pam Johnson)

design and construction! Thankfully, he was available to assist Bill during the "lots of mathematics" stage when determining the overall parameters of the aircraft. Eric designed a computer program to help establish the ideal blade profile.

Having adopted the parameters and profile proposed by Eric, the team came across a French man who had worked for Eurocopter for 40 years—engineering Eurocopter's composite rotor blades! He tweaked Eric's design slightly as a result of his own experience. The resulting blade varies in chord profile along its length (a little more like an aeroplane's propeller than the historically typical constant-chord section of older metal blade designs) and features three different aerofoil sections between root and tip.

The team would have had to pay royalties on the original aerofoil they had chosen but the eventual profile they settled upon was not only very similar; it was also free. Their specialist composite blade engineer then designed the moulds and the manufacturing specifications to produce the three main blades and two tail rotor blades.

Bill chose a three-bladed fully articulated rotor system for the Delta D2 instead of a two-bladed teetering system like the Robinsons. This system gives a pilot another second or so in which to react in the event of an engine failure. An extra second is a long time in helicopter terms and gives a particularly valuable "breathing space" for a luckless helicopter pilot. It provides a greater safety margin by giving a pilot more time to set up an auto-rotation.

Another advantage of the three-bladed rotor system is that it is not subject to "mast bumping" under negative-G manoeuvres like a teetering two-bladed system is. Graeme says the Delta D2 will handle up to negative 1g with no problem.

He also says that the fully-articulated three-bladed system is smoother than a two-bladed teetering rotor. While such fully-articulated systems have their own eccentricities, Graeme says that having been used in so many helicopters for so long now, they have been largely overcome. Ground resonance is one such potential problem that requires careful damping in the rotor head and undercarriage.

Bill chose a three-bladed fully-articulated rotor system…

In addition to its greater negative-G tolerance, the three-bladed rotor system in the Delta D2 gives it a greater centre-of-gravity range than the two-bladed R22.

Bill designed the epicyclic main gearbox himself. One of the advantages of this type of gearbox is its great efficiency. With the tail rotor gearbox, the team's experience of mustering on hot dusty days in the hot Australian outback made them decide to incorporate some cooling fins into the tail rotor gearbox to dissipate heat better. The resulting cooler oil will last longer and will also increase the life of the gears.

When it came to cooling the engine, Graeme initially planned to have the airflow funnelling through radiators situated low inside the airframe and exiting out the back. However, he eventually decided to locate the radiators higher up, enabling him to use the space originally planned for the radiators for a cargo box. Scoops for the cooling air are located as high in the airframe as possible, lessening the likelihood of ingesting debris.

All of the filters used for the initial aircraft are car-racing filters, available from performance car engine suppliers. The main engine air filter is a large K& N washable filter. There is one filter for the engine oil, one for the fuel, and another for the gearbox and the hydraulic system.

The Delta D2 features a hydraulic pump mounted on the bottom of the engine, which supplies pressure to drive a small and very efficient cooling fan. Because of the location of the radiators, there was not enough space for the kind of belt-driven cooling fan typically found in small-helicopter installations without engineering an offset pulley system. This prompted Graeme to research hydraulic fans—commonly found in agricultural, contracting and industrial applications—and design a similar system for their helicopter.

From his own experience in R22s and RotorWays, Graeme knew that with the helicopter's doors on and no airflow through the cabin, it could get pretty hot while sitting hovering for any length of time. Accordingly, he wanted to have lots of airflow through their helicopter. The resulting design features four vents—one on each side and two in the middle, each of which is adjustable by the pilot or passenger. The cabin incorporates two exit vents leading to the

Above, from left: The prototype D2's analogue instrument panel; Wide view of the cabin—note the substantial vent/s at the cockpit sides; The central console, complete with drink holders; The tail rotor and its carbon composite blades; The three-blade fully-articulated rotor head. (all images courtesy of Delta Helicopters)

radiator ducting, with the idea that with the engine running, its cooling fan will also extract the cabin air and create an effective airflow through the cabin, even if the helicopter is stationary.

Also as a result of his experience with small two-seat helicopters, Graeme decided it would be a good idea if the occupants of the Delta D2 weren't squashed so closely together. The resulting design is even wide enough to incorporate two drink holders between the occupants. In addition to the drink holders, there is also a storage compartment suitable for things like cell phone, wallet, sunglasses and pens.

The seats are fixed, so the pedals are removable and adjustable, and have about six inches of adjustment.

...innovations...are all aimed at increasing the helicopter's usability and safety.

As far as instrumentation is concerned, the prototype uses analogue instruments, although customers will have a choice of either analogue or "glass". The glass cockpit Graeme has been working on, which features two screens side-by-side, will be more expensive but it will be lighter. Graeme says that all of the glass systems he has seen were adapted from systems that were primarily designed for fixed wing aircraft, and he thought that many of their features were neither needed nor wanted in a helicopter. For example, he suggests that an artificial horizon isn't necessary in a purely "eyes-outside" VFR market. Accordingly, he is designing what he feels is a more practical system.

The Delta D2 will feature a unique indigenous electronic tachometer for the engine and rotor. The gauge's needles are adjustable to compensate for parallax error and the tacho is also connected to a warning horn for the pilot. Unlike the case with some electronic systems, the Delta's tachometer will not be affected by either radio transmissions or temperature.

The numerous practical innovations in the Delta D2 are all aimed at increasing the helicopter's "usability" and safety. Graeme acknowledges the importance of thorough pre-flight checks for pilots—too many of whom have come to grief by assuming an aircraft is in the same condition it was before the last flight, or by failing to check seemingly "obvious" items—like fuel quantity. Thus, one of the Delta helicopter's practical safety features is an external sight gauge for each fuel tank. These allow a simple inspection to confirm the quantity readout provided by the internal gauge, and eliminate the need for dipping.

On the tail boom, a clear plastic cover over the tail-rotor drive-shaft at the pillar bearing support allows a pilot to see the flex-coupling fasteners as well as the teletemp indicator for the bearing without having to undo a panel. A screen section in the lower engine doors allows a visual inspection of the engine bay for water, oil or diesel leaks. The upper doors offer access to the main gearbox and control linkages. The open engine doors provide a step for a pilot to get all the way to the top and complete his or her checks. The team has done everything it can think of to facilitate and encourage comprehensive pre-flight checks.

The helicopter is designed so that the gearbox, controls and cooling system can all remain in place during engine removal, which can be accomplished within four hours. Graeme believes that individual features or components—however clever they might be in isolation—are not much good if the aircraft is difficult to work on as a whole. He says he takes an overview of the whole project.

Graeme says he has five main criteria to consider at every stage. The first is the cost. Next, the practicalities of manufacturing technique have to be considered. The third main consideration is safety. The fourth thing to consider is a pilot's perspective—what does a pilot need to do and how is he or she going to accomplish it most efficiently? The final consideration is determining the most practical and effective way to provide maintenance in service.

Graeme says he tries to balance all of these criteria whenever any new idea is presented, and says he is willing to listen to anyone with constructive ideas and incorporate them if he thinks they'll work.

He realises that if Delta is going to challenge Frank Robinson's market in any way, then Delta will have to do things even better than Robinson did. He adds that it was because pilots put the R22 through hell that it kept developing. "I want to do the same thing; I want to develop a great machine, which is why we are putting it into the experimental market for three years." Importantly, he insists that safety is the over-riding consideration before it becomes available at all.

During the first three years—when the machine will only available as a kit-built "experimental" machine—customers will be encouraged to provide feedback on potential changes or improvements. "If people

tell us we can improve something, I will look at it and then run it past the engineer. At the end of the three years, we should have a product that doesn't need any more major modification and we will progress to certification."

It is worth noting that although the first machines will not be certified, Bill Whitney designed the aircraft from the start to the standards and criteria necessary to meet full civil certification.

"We feel we already have a machine that will do what it's meant to and that looks the part, and the rest is just refinement," says Graeme.

Only two more things are necessary in order for the machine to meet all the FAR 27 requirements for certification. One is a fuel tank "drop test", in which a half-full fuel tank must survive a 50-ft fall without rupturing, and the other is to ensure occupant survivability in case of an 18-g "landing". The team is currently designing the landing gear, seat and cabin to "fold" progressively and "absorb" such an impact in order to meet this latter requirement.

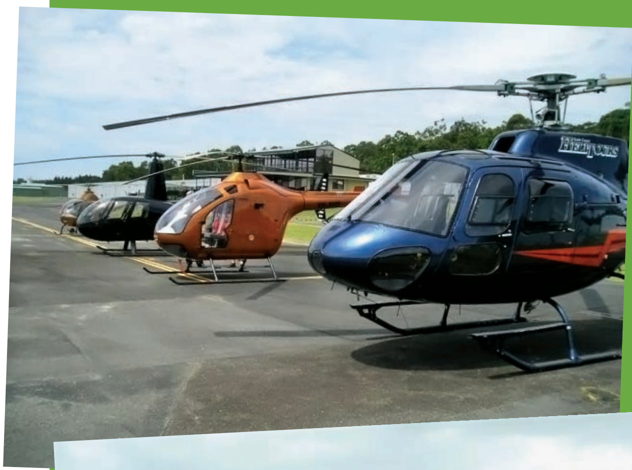
It has already been a massive project for three individuals to design and build a completely new helicopter in a shed in a Brisbane suburb: "We were lucky we had a property with a very large shed!" says Graeme. He points out that while none of them have been paid anything yet, they have had to pay for work done by modellers, engineers and other contributors to the project.

In addition to their forward-looking use of composites in many areas, they are investigating the use of titanium in some other areas, for example, some gearbox and rotor head components.

A cargo hook is already under development as a result of feedback from (potential) customers. Before the first machine even goes to a customer, the team is also considering a three-seat development. They believe they already have the power and performance to morph the helicopter into a three-seater by simply enlarging the body a little—about four inches each side—while retaining the same running-gear.

Moving beyond the D2 (and D3), the team is also considering a five-seat helicopter based on a V8 diesel engine being considered by DeltaHawk (basically, two of its V4s joined together), which might be 7–8 years away.

Frank Robinson designed the R22 helicopter at home and built the first prototype in a tin hangar at the Torrance airport. After three and a half years of testing, it was FAA type-certified in 1979. Despite its humble beginnings, this helicopter quickly became the world's top selling civil helicopter. Now, Graeme Smith, Andrew Reid and Bill Whitney are hoping they have designed a helicopter to rival the R22; their already amazing journey doesn't look like ending any time soon. PW



Top: On the flight line, where the Delta D2 belongs—this gives a good size comparison sitting between an R44 and a Squirrel. (Delta Helicopters)

Above: Twin ground handling wheels allow for single-person operation. (Delta Helicopters)