Dr David Warren AO
- the Scientist, the Black Box Saga and Lessons learnt.

Lecture by Dr Bill Schofield, AM, FRAeS
to Royal Aeronautical Society, Melbourne Branch,
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Australians have, from the earliest pioneering times, always been inventive. Faced with a difficult problem but few resources they have time and again come up with a practical solution. They have shown determination in the face of opposition and usually great persistence in following their vision. David Warren was such a person and his invention of the Flight Recorder, known throughout the world as the black box, exemplified this tradition. I worked for David, and later, with him as a colleague in the same DSTO division and we became good friends. He was an inspiring scientist, great fun to work with and an irritant to all administrations he came into contact with. In the next forty minutes or so I will try to illustrate these points. It is important to remember that the black box saga started almost 60 years ago in a very different Australia than the one we live in today: with different allegiances, institutional structures and culture.

So let me start at the beginning.

Soon after I graduated, I went to the Melbourne University Appointments Board looking for a job in research. The man at the Appointments Board handed me a set of cards from his engineering research box - each card had the name of the employing organisation, a description of its work, a duty statement of the position, the salary band and contact details. When I had read them all he said to me ' I've got another job here, but I am afraid I know very little about it – he then handed over a card on which was typed the words 'If you want to do research ring Dave Warren' .....and that, apart from a telephone number, was the total information provided. This very slender piece of information was my introduction to a life in research and also to David Warren's way of getting around the regulations concerning the approved method of advertising and recruiting staff into the public service.

And so one day forty five years ago, a very young Bill Schofield turned up at the Aeronautical Research Laboratories to work as David's assistant. He greeted me with the news that he had thought up a way to eradicate rabbits by building a very inefficient, but stable burner that could be built into the exhaust pipe of a farm tractor, to produce sufficient carbon monoxide to asphyxiate rabbits, and.... the beauty of it all was that the back pressure of the tractor engine could also be used to pump down the burrow a mixture of foam filled with carbon monoxide from a foam unit attached to the end of the tractor's exhaust pipe. At this stage, I thought to myself -'they did say aeronautical research didn't they?'. Anyway Dave said that my first job was to go up to the front gate and pick up a large box from the Department of Vermin and Noxious Weeds that contained 10 wild rabbits. So I walked up to the front gate and took possession of a box with rabbits inside going Kaboom – Kaboom and I thought to myself David seems to be an unconventional chemist. And so he turned out to be.

When I returned with the box, Dave got right into it saying that the first thing to establish was how much Carbon monoxide was needed to kill an Australian Bush Rabbit: he went on to explain that, as they lived in confined burrows, they could probably survive in an atmosphere with a Carbon monoxide concentration that would kill human beings. In not much time at all Dave had cobbled up a crude

electrocardiogram to detect the rabbit's heart beat as we fed it increasing amounts of Carbon Monoxide. Having finished this, he addressed the problem of how to measure the rabbit's breathing rate – His solution to this problem was to use a long thin balloon wrapped around the rabbit's chest with a small microphone inside it so that, as the rabbit breathed, it would compress the balloon and the change in pressure would be detected by the microphone – he then announced my second job - which was to go out and buy three dozen long thin balloons. Now in those days these long thin balloons were only sold at chemists, in those days were not even allowed to advertise them and what's more, from my experience that day, three dozen of these balloons was an exceptionally large order for a young lad like myself – so large that I had to go to two chemists shops to buy three dozen of them:

---working in the public service was turning out to be more exciting than I had anticipated ----

- when I returned with them in a brown paper bag, David said 'Bill are now working for the public service which you will have to come to terms with, so take those receipts up to the front office and make a claim through the Commonwealth petty cash system'--- so up I went to the front office and found the clerk in charge of the petty cash – however, what David had neglected to tell me was that he had the week before, put in a petty cash claim for three boxes of Monopole magnum cigars [to produce smoke for airflow studies] and 10 dozen sparklers [to light his combustion chambers.

The public service clerk slowly considered my receipts for three dozen condoms, gave me a funny look and then said 'could you ask Dr Warren that if he is running parties down in Building 19, can we please be invited'.

In all, I would have to say it was a memorable first day in my new job.

David was a great example for a young graduate to work with – he was above everything else incredibly enthusiastic - he was also visionary, persistent, multi-skilled and if there was a box Dave was supposed to think inside, Dave had never heard of it. On top of this

he had an attitude to authority that was unconventional to say the least – if he considered that an administrative decision was in any way faulty – there was but one thing to do – you went direct into the Chief's or Director's office and put him straight immediately and kept up pressure until the unhelpful administrative decision was reversed – it is no exaggeration to say that in most cases this did little to endear him with management.

David's work habits were highly enthusiastic, but also rather unconventional. In my first month at ARL, we worked back quite late every second night. I would turn up the next morning at the appointed starting time of 9 o'clock and then usually wait for Dave to arrive sometime later, I think the record was 11AM. One Friday night we were working on developing the rabbit-killing highly inefficient burner when, at about 7 o'clock, much to my relief he said –'I have to go and take Ruth to the pictures' – however, my relief was short lived as David's next sentence was 'wait here, I'll be back in about 45 minutes' .

David's next idea was a new type of impingement cooling system for a jet-pipe. For the heat source, he built a tunnel burner which achieved the mixing of fuel and air by an oscillating shock wave that made a very loud, single tone noise. Such was the intensity of this ear piercing noise that we could only run it after hours when everyone else had left for the day- it was January and a very hot night when we started about 7 PM and the air temperature in the lab gradually rose hour after hour until near midnight it was 50 degrees in the lab and we were both sweating profusely, we had stripped down to our underwear, but retained our safety boots, safety glasses and earmuffs. Suddenly, bursting through the door with a fire hose at the ready came the Port Melbourne fire brigade – we had set off the fire alarm in the lab but, because of the noise of the tunnel burner and our earmuffs, we hadn't heard it. The astonished look on the firemen's faces wondering what on earth they had come across as they confronted two strangely dressed sweating scientists working on this flaming wailing test article, stays with me to this day.

Working with Dave was never dull !

I joined ARL in 1965 when the work on the black box was winding down – David had written his first memo on the idea some 11 years before, and it was about the time I joined him that Davalls in the UK released its Series 1100 Red Egg crash recorder based on David's work. David often talked to me at length about the history of the flight recorder and it always seemed to me that he was not so much angry that he had not been taken seriously by the powers that be but was upset that, in the end, Australia missed out, through gross ineptitude in exploiting an invention of which there are today hundreds of thousands in aircraft, ships, trains, trucks and are now being introduced into cars overseas.

A book simply entitled 'Black Box' was written by Janice Witham who collaborated closely with David Warren – it was published in 2005 by Lothian Books and I had the honour of launching it at the 2005 Avalon Air Show. It tells the story in more detail than I have time to cover here tonight.

The Black Box saga started in the wake of the famous Comet crashes in the 1950s. At that period, Australia and ARL, in particular, was closely wedded to the UK – not just because of the strong historical links between Australia and the UK that governed most things at that time but also because ARL was led by its founder Laurie Coombes who had come out from the UK's Royal Aeronautical Establishment in 1938 to set up ARL as a carbon copy of the Royal Aeronautical Establishment. ARL in those days had little research connection with the US aircraft industry – its international aeronautical collaboration was mainly through the now defunct Commonwealth Aeronautical Advisory Research Council- CAARC- and this was particularly so in the Engines Division of ARL where David worked. All the senior people at ARL had, at some time, been seconded to the RAE or to the UK's National Gas Turbine Establishment. So when the Comets were inexplicably crashing, all the member countries of Commonwealth Aeronautical Advisory Research Council convened their best and brightest to assist the UK in what was immediately seen as a threat to the UK's aircraft industry, if not to jet air travel in general. David was invited to the first of these meetings and as a combustion chemist he was tasked with calculating whether the Comet's fuel

tanks could have exploded and caused the crash – David duly presented his calculations showing that exploding fuel tanks was a highly unlikely explanation for the crash …… when he had finished his presentation, he was then stuck in the all-day meeting while others said things like ' we have to face the prospect that we may never know why these Comets are crashing'.

And that statement was the 'ah-ha' moment when Dave said to himself 'what we haven't got here is any data'. He then started thinking about '…how to get data after a crash when everything could be burnt and destroyed' – and then thought of the world's first wire recorder- the Minifon- that he had seen just two weeks before at Australia's first post war trade fair. He thought that probably the people on the doomed Comet would have known what was wrong and could have recorded it and……if the recording medium was wire, not tape, it would survive the crash.

This is a photo of David holding the Minifon recorder that he kept all his life.

Lesson 1. Breakthrough ideas often come to prepared minds that have all the facts, but are unfocussed and even bored with what they are doing at the time.

In fact we now know that the Comets crashed due to metal fatigue initiated at square window corners and no one would have had time

to record anything. But interestingly, the first thought was to record the pilot's speech, not the aircraft data.

David went back to the laboratory and wrote his famous memo proposing an aircraft flight recorder; the Memo is only a few pages long giving an outline of the idea to record cockpit data on wire- the tech memo concluded with a request for permission to work on the idea. His Divisional chief saw some merit in the idea but reminded David that his job was 'as a combustion chemist blowing up fuel tanks, not building electronic instruments'. And so David's idea was duly passed to the Instruments section in another division, the Aerodynamics Division, in order for David to get on with doing what he was paid to do. Quite unsurprisingly the Instruments' section in Aerodynamics Division had its own research program and, as it was not their idea in the first place, they did absolutely nothing with it. Which brings us to our second lesson…

Lesson 2: ' *Laboratory managers often believe that the agreed program of work in any well run laboratory should not be deflected by interesting but unproven ideas and that scientists should stick to what they are employed to do'*

And of course:

The 'not-invented – here' syndrome is always a strong performer in any technical innovation story'.

So nothing happened for some time ……until something very important in this story occurred - a new head of David's Engine Division was appointed – his name was Tom Keeble - and Tom, for all his faults, just loved good ideas and supported David through thick and thin, for over a decade, in the face of often fierce opposition and ridicule, and is one of the heroes of this story.

Lesson three: It helps to have top cover when you are fighting entrenched opposition.

While nothing had been done with David's idea by Instruments Section, Comets continued to crash and were eventually withdrawn from service; and, as we now know, recovery of wreckage from two

crashes led in time to the conclusion that fatigue cracking had been the cause of the crashes.

David, while still officially conducting research into combustion chemistry, had no resources to work on the Flight Recorder. However his new boss Tom Keeble said nobody could stop him writing an expanded version of his proposal. So David wrote a more substantial technical report which defined all the essential attributes of a flight recorder. Much of what he wrote in this second publication stands up very well today after four decades of flight recording. This report was sent to all aviation organisations in Australia and around the world. David and Tom waited anxiously for the responses from their colleagues and friends around the world. After several months, they had not received a single response from anyone. So they then submitted the same report to the Commonwealth Advisory Aeronautical Research Council which had to review any report submitted to it. After some months, they received the minutes of the meeting which solemnly recorded that 'after some discussion it was agreed that no action should be taken'.

So David and Tom continued to face the problem that there was no official laboratory program on flight recording……. Tom Keeble then suggested they buy a Minifon wire recorder, as 'office equipment', and test its ability to record cockpit conversation. This work was done completely unofficially and I don't know what David's time was booked to during this period, but he always recommended to me that general laboratory services was a good one to use as was the cleaning number.

David's tests with the Minfon showed that the background noise drowned out cockpit voices….. which led him to experiment with different types of microphones set into the instrument panel, or on the cockpit roof, or at the sides of the cockpit. Our combustion chemist then started to design filters to delete the background noise and he eventually decided that improvements could be made by removing the high and low frequencies and that he could use these frequencies to record at least two sets of aircraft data, as well as voice, on the wire. And so aircraft data entered the recordings. To record the data, he designed transducers to convert the analogue

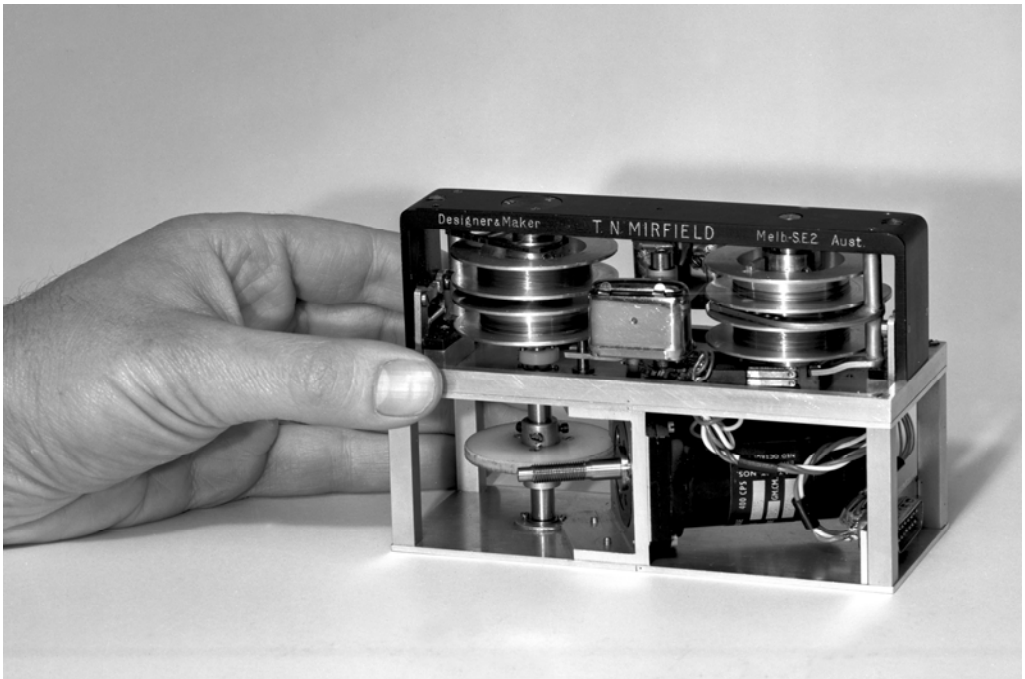
signals from the aircraft instruments into digital signals in the form of Morse code.

Lesson 4: Good scientists need to be multi-skilled'.

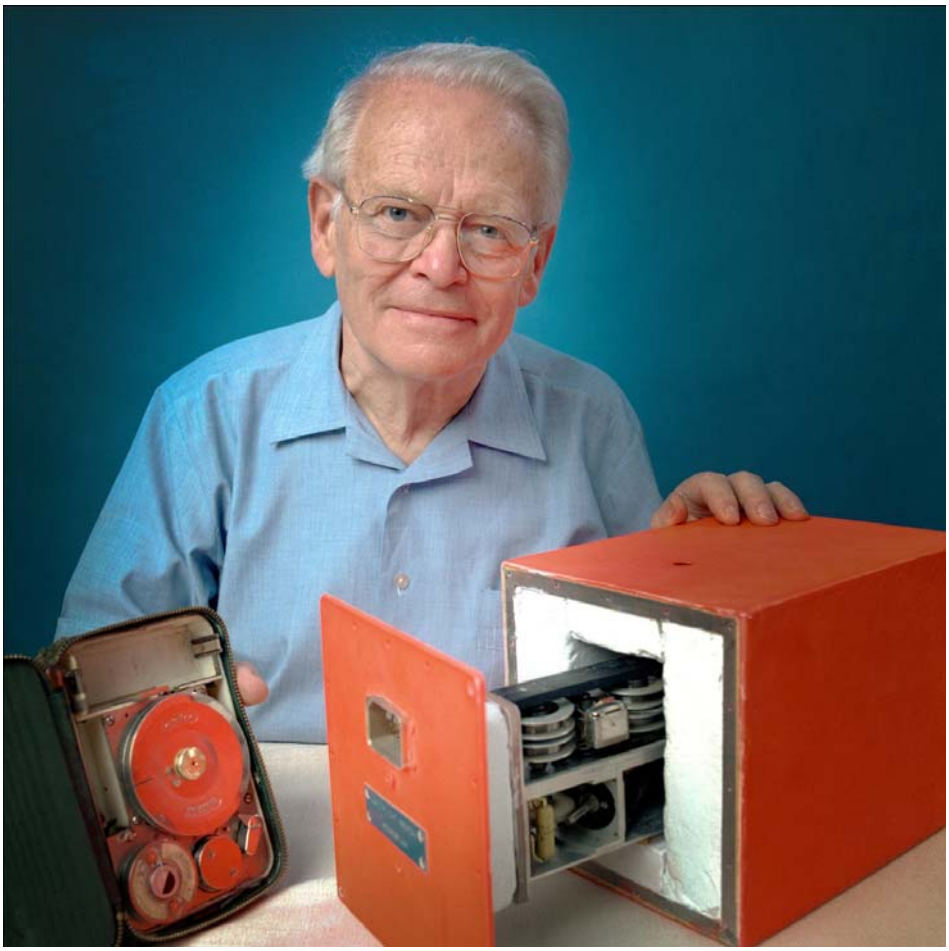
This instrument built around a Minfon recorder worked OK, but to get people really interested, David knew he had to make a practical prototype to demonstrate it working. Again, Tom Keeble backed him and expended $1200 of his division's cash budget on a piece of equipment very vaguely described in the division's accounts as a 'laboratory Instrument' - $1200 was quite a lot of money in those days – it was about the yearly starting salary for a professional engineer, say $50,000 in today's money. Although David's project had no official endorsement, the laboratory Director Laurie Coombes by this stage knew what was going on in Building 19 down the back of the site.

Lesson five: S*ometimes you can't tell the authorities what you are actually doing because the authorities need deniability.*

And so the first flight recorder of practical design was constructed and, nearly five years after Dave's first memo, he had a working prototype. It was to be a 'fit and forget' system that continuously recorded and stored four hours data and voice on a continuous wire spool. This photo shows the first experimental recorder made by Tich Murfield.



And this photo shows David with the first flight recorder in a box that would survive a crash. It is held today at the DSTO laboratory in Melbourne where it was invented.



The break came from an entirely unexpected quarter. Sir Robert Hardingham, the Secretary of the Air Registration Board of Britain, visited ARL in a general tour of Australia. He was shown the Recorder by the Laboratory Director Laurie Coombes during a lunch hour break – his immediate response was 'Now that's a damn good idea – Coombes, put that young lad and his gadget on the next Hastings courier to London'. In passing, it is hard to imagine a UK official directing an Australian Lab director in such a manner these days.

It is interesting to note that:

- in spite of David doing everything he could think of to publicise his concept in Australia and overseas, and
- the close connection of ARL to the UK and
- that it was the UK that had had the Comet crashes and

- that the UK-led CAARC where David had had his concept considered, the head of UK Air Registration Board had never heard of the idea.

Lesson 6: In transmitting new ideas, face to face contact is usually the only effective way.

However this very welcome invitation posed a difficult problem for the management of ARL because, as far as Head quarters of the department of Supply in Canberra was concerned, the project did not exist, if in fact they had ever heard of it. So Coombes recommended to Canberra that Dr Warren attend the Seventh International Symposium on Combustion in the UK, in spite of the fact that combustion had been a rather minor interest of David's for some years. They did slip in on the last page of the 10 page travel request the sentence that David would 'discuss a novel apparatus which he has developed for determining the cause of aircraft accidents'. The fact that this elicited no response from Canberra shows what I have always suspected that no one read those interminable overseas visits requests that we had to write. In preparation for his visit, David wrote a new paper entitled 'A Device for Retaining Data in Aircraft Accidents' and then really pushed the Australian authorities for some response to the memos that he had sent them over the years as he wanted to go to the UK with the backing of his own country because, as we all know, the first question when you take a new invention overseas is '…and what is the response from your home market'.

Just in time before he left, a letter arrived from the Department of Civil Aviation in which the opinions held by aviation experts around the world of the value, if any, of fitting flight recorders were reviewed. The letter concluded with a phrase that has become infamous, it stated that 'Dr Warren's device has little immediate direct use in civil aircraft.'

This was bad, but worse was to follow in the form of a letter from the RAAF that stated 'Such a device is not required. In our opinion the recorder would yield more expletives than explanations'.

Lesson 6: *officialdom seldom supports new innovation when writing on official letterhead.*

The lack of official support as expressed in these two letters is not, I think, unusual – what is unusual is the strong negativity expressed - the norm in such cases is to be non-committal, but also non helpful. The negativity I think revealed some hostility to the invention.

And so David went to the UK with not only no support from the home market, but two officially sanctioned negative assessments.

In the main, David's presentations and demonstrations in the UK were well received by Scientists, regulatory authorities and aircraft companies. However it is interesting that few of them saw the flight recorder as something that would be fitted to all aircraft – instead they saw it simply as something to be put on prototypes in case they crashed during development. The Bristol Aircraft company sent a telegram asking for a quotation for the delivery and price of two only flight recorders: a response would have been quite difficult for ARL as flight recorders were yet to be an official project and ARL was far from becoming a manufacturing company. The trip also revealed that there were a number of instrument companies starting to develop competing products and some manufacturers talked to him about marrying their ideas with his or taking over the development of the device themselves; however, only on the condition that the UK air registration board officially endorsed it.

You will possibly have noted that up to now I have not mentioned the word Patents, and this was now being raised by the UK manufacturers who assumed that David had patented the device. However David, as a public servant, had assigned his patent right to the Commonwealth and the flight recorder project, as far as the Commonwealth was concerned, still did not exist so not even a provisional patent had been lodged.

In contrast to Australia, the UK was so enthusiastic that David asked for permission to come back to Australia through Canada and the US to demonstrate the recorder and, surprisingly for the times, permission was granted although the overseas trip was officially to

study combustion processes. In the US and Canada, he saw a raft of competing systems under development, none of which in the end proved to be practical. The strong impression gained from the US was that they were not interested in anything that did not originate in the US.

Lesson 7: Not invented here is usually stronger internationally than domestically

On his return, the Laboratory Director Coombes wrote to the Head of the UK Air Registration Board stating that the US was not interested but they had some interest from UK companies to develop the device. He then essentially gave the project away for Australia by finishing the letter with the statement ' The crash recorder is not strictly in Warren's line of country as he is a physical chemist working on combustion and we would be glad to get rid of the commercial development'. Coombes then wrote another letter to Australia House in London stating that something could come out of full development by a UK company and "We hope this will eventuate as we should like to get rid of the device which is not strictly in our line of business'- what!!! this is the Aeronautical Research Laboratories saying that it is not its job to advance aeronautical sciences. However, it was agreed that David had to write up a patent application for the recorder.

However the urgency of patenting was quickly dispelled by some considered responses arriving from the UK companies – Ultra Electric concluded that there was no market for a crash recorder and EMI had assessed the market to be at most 2 to 5 hundred units a year and therefore not commercially viable.

Completely undeterred, David decided that he would have to build a pre-production model to demonstrate its utility – he would build a new recorder with a longer recording period and much enhanced data recording. The main unit would contain the speech amplifier, multiplexing switch, flight data electronics and reserve power supply and would be housed in the standard radio rack – the second unit would hold the wire continuous recording unit in a fire proof container housed in the aircraft's tail. Meanwhile, there were

increasing reports of rival systems to aid crash investigation being under consideration or under development.

On the 10th of June 1960, a Fokker Friendship crashed attempting to land at Mackay airport in foggy conditions. The subsequent Board of Inquiry was informed about David's recorder with the result that in the Board's report, it firmly recommended that flight recorders be developed for Australian passenger aircraft. Two weeks later, the federal government announced that, from January 1st 1963, Australian civil passenger aircraft had to be equipped with instruments to record both conversation and data. Hence Australia became the first country in the world to mandate the fitment of flight recorders, and this was completely a consequence of David's unrelenting advocacy. The Department of Civil Aviation now maintained that they had always wanted a large number of parameters recorded on civil aircraft; however, in 7 years they had not once asked to see the ARL recorder. The minutes of a meeting in the Department of Civil Aviation, which was convened to see how to comply with the government's directive, said 'our approach may close the doors to the ARL recorder unit because of its lack of development.'

Meanwhile, Canberra had not progressed submitting the patent application on the grounds that the ARL report which contained a full description of the recorder had had a world wide distribution.

Lesson 8. *Always put in a provisional patent before you publish anything.*

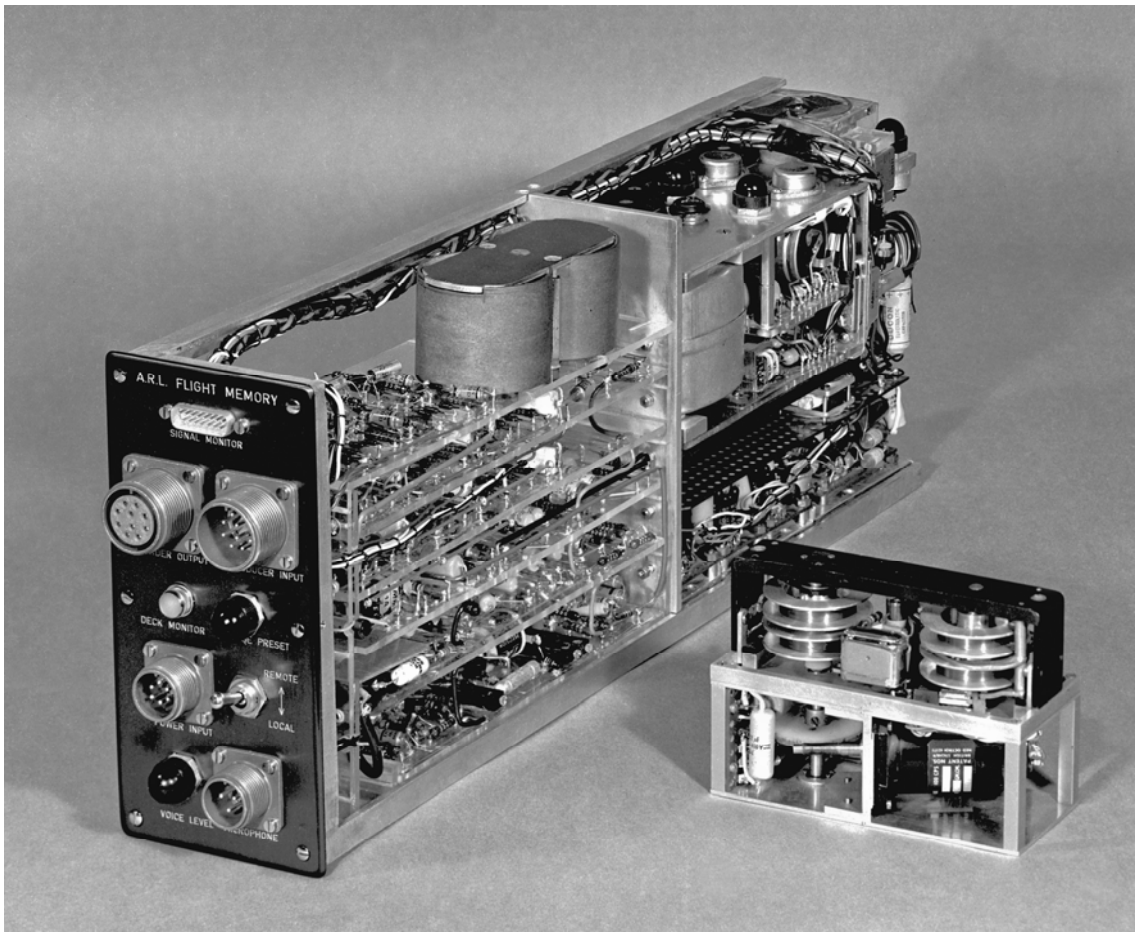
That said, in this case it would have been very difficult as ARL did not recognise the project until it had world wide interest initiated by David's publications, and for David to patent it in his own name would have broken public service regulations.

On 7th of September 1961, ARL learned by reading the Financial Review that, although the two Australian Domestic airlines had been in negotiations with ARL for some time, they had both placed an order for flight recorders from a US company - United Data Control. These united data control recorders were heavy, recorded only 30 minutes of voice and were later found to be unreliable and

in fact were unserviceable at the time of an air disaster at Winton involving an aircraft in which they had been fitted.

In spite of this, David and his team continued the development of their prototype and on 23rd of March 1962 the first and only flight test of the new recorder on a Fokker Friendship was undertaken and performed faultlessly – the data and speech recognition had an accuracy of 99% and a time discrimination of about a tenth of a second. The team had increased the speed of the recordings from four to 24 readings per second and the inaccuracy of data had been driven down from 5 to 10% in the initial unit, to half a percent – not bad for the early sixties. It was a remarkable technical achievement for the ARL team.

Above is a picture of David with Ken Fraser looking at the two recorders: the original, and the preproduction model on the right of the picture. Ken Fraser on the right was a key member of the ARL team and led the electronic development of the pre production model.



This photo compares the pre-production model with the original experimental one on the right……you can see the level of sophistication and complexity has increased by an order of magnitude.

The Secretary of the Department of Supply then wrote to the Department of Civil Aviation to consider the future market potential of the ARL recorder as it was now ready for production. However the process of drafting and approving the letter for his signature took six weeks and David felt the world was passing them by due to inaction and disinterest in Australia's official bodies. An urgent request from Davalls in the UK for a commercial proposal was never answered by the commercial arm of the Department of Supply.

However David did get permission to go to the UK and assist in the transfer of technology for the first Davall flight recorder which appeared in 1963. The sales material of the time acknowledged ARL, but this soon disappeared with subsequent models. Davalls sold their first recorders to the BAE fleet; however, they did not want

voice recording because in their words 'investigating authorities continue to say that statements by cockpit crew under stress were unreliable'.

ARL could not have a patent for the complete recorder due to its prior publications but it did have four other provisional patent applications on specific features of the pre-production recorder. However, the Chief Commercial Officer of the Department of Supply decided that the completion of the five patent applications into full world-wide patents could not be justified – the cost would have been over 2,000 pounds. This statement has been quoted as showing that the Department didn't realise the importance, nor the value of what it had. While this was probably true, I think it is likely that these part patents would have been challenged and it would have been very hard to enforce these patents in the marketplace and patent enforcement was an unlikely role for the Department of Supply. ARL did continue to push for some years for the patents to be pursued but in the end they were just dropped.

In 1965 Davall released its Series 1100 Red Egg magnetic wire crash recorder based on the ARL unit and, with it, won a large part of the British and overseas market of the time. As ARL did not have an all encompassing patent, they legally owed ARL nothing; however, they did make an ex gratia payment of 1,000 pounds which went into federal government consolidated revenue.

In 1968 work in the area ceased at ARL as work expanded rapidly in the flight instrument companies around the world.

So ended the black box saga.

In retrospect …..what should have happened? Ideally the idea would have been recognised as having sufficient merit to justify some preliminary investigation and at that time a provisional patent should have been lodged. To give the idea a fair trial, David should have been seconded to the Instruments group as its champion and the instrumentation program changed to provide resources to support David – and the combustion program should have been allowed to languish for a year or two. The objective should have been to get a practical prototype into the air as soon as possible,

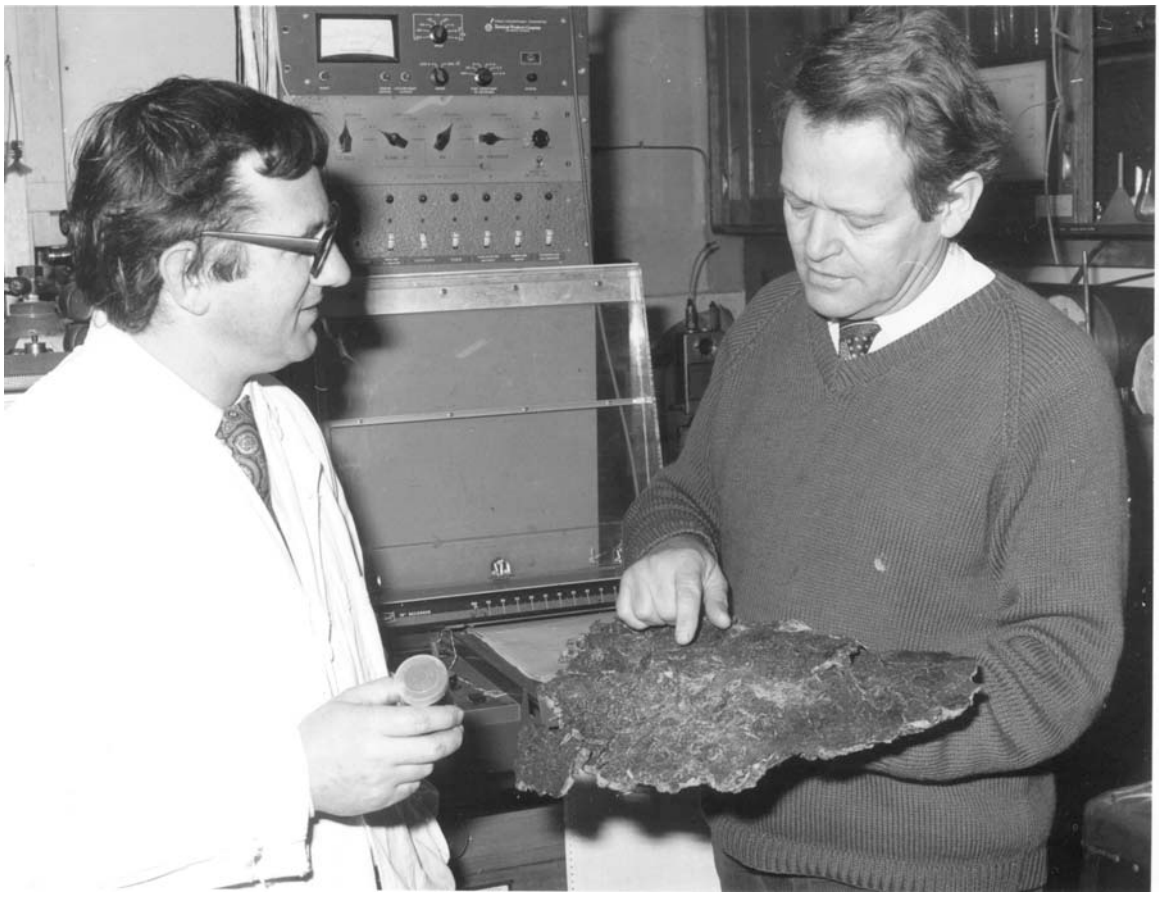
gain experience, develop the science and be far ahead of the world. Instead we dawdled for 11 years and did not patent before publishing.

David was always philosophical stating 'our idea simply came at a time when we didn't really need it in Australia and as soon as it was needed overseas it took off there instead'.

After such an experience, you could expect someone to be a little chastened if not crushed. This was not the David I met when I reported for work in April 1965. I found an enthusiastic innovative scientist at the top of his game looking for new fields. He had, again on his own volition, started work on high temperature fuel cells which David recognised as having the great advantage of converting fuel directly into electricity without a heat engine and thus avoiding the Carnot inefficiency. He was the fuel chemist and I was recruited to be the mechanical engineer assisting him. We made good progress and in about a year we were getting better results than had been previously published. However, after three years the powers that be again saw no application for the work and closed it down.

Germany today is putting fuel cells into its submarines and they are likely to be used in the submarines that replace the Collins in 2030 – 2030, that is, some 70 years after David started work on them. He was again about 30 years ahead of the pack.

After fuel cells, David in the early 70s started work on alternative energy sources, their relative merits and the relative cost of electricity produced from them. As always, he was highly enthusiastic and irrepressible …….he gave lectures in the laboratory, he gave lectures to learned societies, he gave lectures to lay audiences …….he was passionate, visionary and presented a frank and fearless description of a future without the traditional sources of energy. He was again 30 years ahead of his time – his 1970 series of lectures on alternative energy sources would attract large audiences today as we face the future David saw so clearly all those years ago.



This is a picture of Dave with Lance Hillen examining a piece of dried Bottrycoccus Brauni, an organism that converts sunlight directly into hydrocarbons – which is now being examined in many parts of the world 30 years after David started working on it.

David always focussed on what was important, ….advancing science for the betterment of mankind was what he was about ….and this meant that often task plans, administrative procedures, time sheets and the public service way of doing things were neglected while he was hot on the scientific trail .

David was, above all, a passionate person ……..when talking about what he saw as important he always gave frank and fearless advice no matter who he was talking to … which often included visiting VIPs, the Director of the laboratory, the Chief Defence Scientist anybody, …..

As a young graduate I saw that, done with respect, people appreciated frank advice and it was something I learnt from David Warren and have used throughout my career. However something

you can't learn from another person is the ability to see and articulate a vision of the future and David had that in abundance.

Recognition of his achievement came late and entirely after he had separated from ARL at the relatively young age of 58.

David was

- made an Officer of the Order of Australia in 2002
- Awarded the Hartnett Medal of the Royal Society of the Arts
- Given the RAeS Lawrence Hargrave Award in 2001
- Awarded the Centenary Medal in 2001
- And the Institute of Energy Medal in 1999
- And Qantas announced that they have named one of its Airbus 380s after him, an aircraft now in operational service.

Time magazine wrote an extensive article on him in their issue of October 1999 under the heading 'David Warren – with an ingenious invention, he helped make air travel safer for millions of people'.

Scientists near the end of their career often assess what they have done and what the impact their lifetime's work has had on society. For nearly all of us the answer is ambiguous and qualified, as we

are but bit players in the grand sweep of science. However, for Dr David Ronald Warren AO, the assessment can only be that the impact of his work was significant and important on a world scale.

Any way you want to do the sums, in a world where the volume of air travel rapidly increases but the number of deaths from aircraft accidents continues to decrease because we can now find out what causes aircraft to crash, David's invention must have saved at least tens of thousands of lives. David is therefore in a very special class of scientists who have changed the world for the better and whose impact continues to this day, past his death and into the future. He will not be forgotten by our Society.

I count myself lucky to have been his student and a friend of his.

Thank you for sharing this with me.