ENGINEERING YOUR OWN FUTURE.

Institution of MECHANICAL ENGINEERS

Jon Hilton CEng FIMechE
Presidential Address 2016

Improving the world through engineering

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Mentoring allows us to pass on our invaluable experience and knowledge, helping to turn good engineers into great engineers and visionaries.

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President

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INTRODUCTION

The Institution of Mechanical Engineers' vision is to improve the world through engineering by inspiring the next generation, developing professional engineers and setting the agenda. In this address, I want to concentrate on developing professional engineers, as well as encouraging those who have already chosen engineering as a career to make the most of their choice.

I have enjoyed a great career in engineering. From apprentice through engineer, chief engineer, technical director, technology entrepreneur and now to non-executive deputy chairman of a plc, I have seen and learnt a huge amount. I will share the key milestones along this route, noting inspirations and reasons for my career choices, while also passing on some key insights that I have learned for myself.

Throughout my career I have been lucky to have my life touched by many really good engineers and a few really good entrepreneurs. Undoubtedly this shaped how I chose to steer my career, and I feel a responsibility to share as much of this learning as possible with others, in the hope that I might inspire a few of my own. Sometimes we all need inspiration, motivation and help, and this professional network is a good place to look for that.

Mentoring is something that the Institution promotes and offers, but I would like to see much more. I believe there is much to learn from the experience of our colleagues, not only at the start of our careers, but all the way through to retirement. As you will see as I explain how my career worked out, the effect of other people on me was significant, and I would encourage each of you to look for this inspiration from others and to give this inspiration to others. The most profound influence on me was from someone I worked with for just five days. It needn't take much of your time to provide or receive that spark of inspiration that can make all the difference. Whatever stage you are at in your career, there will be someone who can help you and someone who can be helped by you. Therefore, I believe every engineer should have a mentor and at least one mentee.

From my motorsport and technology development background, there is a lot that can be usefully understood about how small and innovative businesses get things done quickly on a tight budget. In my experience the key lessons are less about what to do and more about what not to do. Choosing to do something to a lower quality than you know goes against the grain of most engineers. However, most often this is the essence of what is required. Normally you don't need the answer to the last decimal place and +/– 10% will be good enough if it can be done faster and at a lower cost. It is knowing when to take this more pragmatic approach, and when to insist on the full detailed analysis that comes with experience. However, as I will explain, the default position can be fast and cheap and, if the right precautions are taken, the risks associated with getting it wrong can be substantially mitigated.

I also want to highlight the role of entrepreneurs and how well-placed professional engineers are to take up this crucial role. Engineers are essentially problem-solvers and problem-solving is at the heart of entrepreneurialism. If you see everything as a challenging puzzle to solve, are willing to learn about all aspects of business and can maintain your composure under pressure, you could be the next Elon Musk or Sir James Dyson. We have the chance to create more businesses, more jobs and more great products using our unique set of skills, and I would encourage more of you to consider this role for yourselves. As you will see, the journey is not always trouble-free, but the rewards can definitely be worth it.

Lastly, I want to dispel the myth that you need a lot of money or a raft of external investors to build your own successful product-based business. While things would certainly seem easier with more money, I think that the discipline of managing with limited resources is a good one, as it forces you to choose very carefully which things to do and which things to leave for later.

MY FORMATIVE YEARS

My father was an engineer. He was a deHavilland apprentice and worked on the first passenger jet airliner, the Comet. Sadly he died suddenly of a heart attack aged just 31 when I was a baby. In my case it can't really be nurture that persuaded me to follow in his footsteps, but I am delighted that I did. I wish he could have seen how my life worked out.

There were other influential people in my young life. My grandfather Albert, who had toured the world in the 1950s on behalf of his employer Monotype, setting up newspaper printing works in far-flung places such as Mombassa and Nairobi, and who, with his wife, moved in to live with us so that my mother could go back to work. My uncle Peter, who worked in marine engineering and who bought me a second-hand lawnmower engine for Christmas, and my mother Anne, a newspaper reporter, who was very supportive and encouraging in my early-made career choice of engineering.

That I knew what I wanted to do from an early age was really helpful to me. I simply didn't bother with all the things I didn't need to know and concentrated on the things I did need. I managed pass grades at English, Geography, History and French but had no interest in them, and I worked really hard in Maths and Physics to get the best grades I could. At the age of 18 I applied for an undergraduate apprenticeship at Rolls-Royce Leavesden (small aircraft engines division) and after a two-day interview process sitting alongside obviously much more academic students, was really surprised to be offered a place.

With Rolls-Royce sponsorship, I studied mechanical engineering at the Hatfield Polytechnic on a four-year course, with two six-month periods in industry, and worked every day of every holiday at Leavesden. When I graduated in 1986 I had taken only a few days of holiday in four years, but I had a car, a nice stereo in my rented room and no debt.

During my Rolls-Royce apprenticeship I met the person who probably shaped my work persona the most. John Favell was the manager of the factory at Leavesden and was known for being a very direct, no-nonsense manager. There could be no indecisiveness and no procrastination on his team. Once he picked up a piece of paper that required action, he would not put it down until the action was complete. In all, I only spent five days as his shadow, going everywhere he went and doing everything he did. He found it impossible to keep up his external act with me, as on the inside he was a really nice guy, and I discovered how useful it can be to have separate personae for work and home.

I thought a lot about this experience, and every time I changed employer I treated it as a new start and a new opportunity to tune my work persona. Much later in my career, one of my staff told me that he had been warned about me being a really tough boss before joining the company and I smiled on the inside. As I have developed my work persona, I have really carefully managed the separation between work and home. I have very few work friends. I have a LinkedIn network of close to 1,000 people but fewer than 50 Facebook friends. In this way I was genuinely able to choose who I wanted to be at work.

I loved Rolls-Royce, it was a truly high-tech company doing really ground-breaking things. However at that time, and something which I am glad to see has changed within this world-class organisation, the influence that the trade unions had over the business was excessive, and I quickly realised that this was an organisation that would allow promotion only via 'dead men's shoes'. In the few years I worked in engine design after graduation, I got to work on some great projects and learnt a huge amount, but working for a large company like this just didn't suit me. My fellow graduate apprentices were brighter than me and much better suited to the highly specialist roles in narrow technical fields that the company needed to fill. I got itchy feet and after a brief spell working on the design of safety, arming and fusing systems for military weapons, I was invited to interview for an engine designer role at Cosworth, working on racing engines. Here I found my perfect job.

FORMULA ONE

In my career I have been lucky to spend more than 15 years working in the motorsport industry. For me this was the opportunity to play with someone else's multimillion-pound Meccano set. With very big budgets and regular opportunities to test your product against the opposition, Formula One provides the ultimate forum to learn.

On the day I left Rolls-Royce, nothing I had drawn had ever flown. On the day I joined Cosworth the Chief Designer put a broken component on my desk and said, "I want an updated drawing of that part which will fix the problem. I need the drawing by tomorrow night, we will make the part on Wednesday, test it on the dynamometer on Thursday and race it next weekend." This was more like it.

When I started at Cosworth there were ten people in the design office. We drew a Formula One engine over a period of about nine months, did a touring car engine or a motorbike project over the winter, an Indycar engine the next summer, another smaller project over the winter and back to Formula One on a two-year cycle. During my seven years at Cosworth, all that changed. Sponsors spent more and more money, the teams of people grew larger, then split into separate departments and grew larger still. Ten designers for everything turned into more than 70 just for F1 and those few of us who were there at the start had great opportunities for promotion. I had some great years, including leading the engine programme for the 1996 International Touring Car series, which we won with the Opel Calibra, and by the end of the 1997 season I was Chief Engineer of the Formula One engine programme for Ford, leading a large team of people.

My experience with the Opel Calibra programme is worth noting because this was the first time I had been in charge of a whole engine programme from the outset. I drew the initial design scheme, I ran a small team of just five people that created every detailed drawing for a full new V6 2.5 litre racing engine and I supervised the development and race support programme. The first race for the car was at Hockenheim against top-class opposition from Mercedes and Alfa Romeo, and happened to be on my 32nd birthday. As our car crossed the finish line in first place I almost physically changed for ever. No longer did I think I could do it, I knew I could do it. I knew exactly how much technical help I had received from outside my team (none) and that we had built a world-class product.

This was such a turning point for me that I have done my best ever since to give others a chance to realise the same opportunity. The simplest embodiment of this is to allow engineers the space and freedom to do things their own way. It is often easiest for a manager to direct his team to create products the way that they would have done it themselves, it is much more difficult to look at the output of the engineering team and say to yourself 'I wouldn't have done it that way, but I still think that will work'. Every time you ask for a change to the output, however small, you remove the opportunity for the team member to see if their version would work. So, if you can avoid changing anything you should.

Throughout my time in Formula One, I learned many valuable insights. The following experiences I believe helped me develop my career over the years.

Racing to the front

Learning comes in many forms and of course much of it comes from making mistakes. Very quickly you find out that making mistakes is nothing to be afraid of, but making the same mistake twice is forbidden. The key Formula One lesson must be to design your experiments very carefully so that whatever the outcome, you know in which direction to go next. Often this means adding extra instrumentation or performing the test in an unusual way, just to be sure that whatever way it goes wrong you have captured sufficient data to steer the next experiment in a positive direction. Of course, when the experiment goes the way you hoped, you need to be sure that you got the right answer for the right reasons, and again additional data can help to confirm this result.

This all sounds very scientific, which it is, but there was still plenty of room for traditional gut feel and intuition. It surprises many people to hear that we always had a huge list of development projects that we wanted to do, and even with close to 400 people working on the Renault F1 engine programme we did not have enough resource to do half of them. So which ones to do and how to do them? The selection process was relatively straightforward: we would take any new ideas, do a quick simulation study to determine the likely benefits, work out roughly how long it would take to do and how much money it would cost to implement, and then add all the things that looked beneficial to the development list. Every so often we would sort the development list according to weighted priorities and pick the top job to start. Sometimes, in order to balance resource, we would take something from position three or four on the list because it required the sort of resource we had free. However, generally the selection process was pretty robust. How we did those things was more unusual.

The fastest way to do something is to not do it at all

Once we had decided to do a particular development project, we would look carefully at how it might be done. Budget was rarely an issue, so we could use expensive manufacturing methods such as sintered sand cores for castings or rapid prototypes for mock-ups, but the key time savings were made by deciding what not to do. When you have all the computing kit in the world, it is tempting to analyse everything to death and only build something when you have finished many iterations of computer refinement. But in my experience it is really important to actually run something physical as soon as possible, in order to confirm that you have not missed anything and that you are going in the right direction. In my early career I would often look at the early design schemes on a drawing-board and say to the engineers, "Do the stress analysis on this part and that part but just make everything else." In the mid-1990s we genuinely made entire new Formula One engine designs, only analysing for stress one or two parts and with no CFD or other more complicated techniques. Today, the wide availability of computer tools makes it increasingly difficult to avoid analysing everything to death, but I recommend that you try really hard to avoid it. If the answer comes back as you expected, then you have just wasted a load of time and money. Therefore, get brave and don't do the analysis at all.

Another useful tip is to combine together as many experiments as you can with a suitable back-up plan for each risky element. If it all works first time then many of the tests had been completed for free in comparison to doing each one serially. This approach also helped with another development challenge, which was the accuracy of the engine test bed. Basically the test bed power measurement was accurate to 1% of full-scale deflection. However, if you were making 800 horsepower this was 8bhp, which is a lot. By combining multiple experiments into one engine build we were sometimes able to get over this measurement threshold and achieve a clean result. The only other way to be sure was to build a decent number of engines with the new features (10 or 20) and measure the average power versus the old specification. This obviously takes longer, costs more money and may result in unnecessary pass-off testing so that the new specification can be raced in the car, when it provides an as-yet unproven advantage.

Avoid lengthy delays by building ‘Plan B parts’

Another useful trick is to second guess what might go wrong and make in advance the parts that you would use to fix the problem if it occurs. As part of the process you already had to think about what might go wrong (in order to design the experiment correctly), so why not go one step further and make the solution? Often we would spend £3,000 on Plan B parts that ended up never being used. However, if the experiment worked first time everyone was happy so nobody got upset. On the occasion where something did go wrong, swapping the broken bits for the Plan B parts and being back up running again only a few hours later was worth its weight in gold. On average I reckon that this methodology broke-even on spend (the extra cost of components being offset by significant savings that came from saving time), but greatly helped to deliver everything on time, which is invaluable. Obviously it relies upon a strong gut feel for what is most likely to break. However, if you try this you might be surprised to find it is nowhere near as hard to do as you might think.

Continuous improvement

Of all the lessons I learnt during 15 years in the Formula One business, perhaps the most important was the possible scale of continuous improvement. When I started in 1991 the engines made about 480bhp from 3.5 litres. By the time I finished in 2006, more than 900bhp was possible from just 3 litres, representing a year-on-year compound improvement more than 4% against a tight regulatory framework.

People regularly talk about the high rate of improvement in areas such as electronics, but you should never underestimate the scale of improvement possible from mechanical elements. With all of the products I have been involved with, I have never seen any evidence that the rate of improvement was reducing with time.

Teamwork

I have been part of some very successful teams, winning five Formula One world titles, but also part of some much less successful teams. I spent five seasons working with the TWR Arrows F1 team, famously the team that took part in the most F1 races without ever winning one. I honestly believe that I learned just as much working for the unsuccessful teams as I did working for the successful ones, and there are some useful lessons to learn from this.

My period at TWR saw my first encounter with a proper entrepreneur. Tom Walkinshaw was my boss's boss when I joined the company and he had built a substantial empire amassing a personal worth of some £180m. He worked very hard, showed an impenetrably tough external persona that suited his rugby player looks, and was prone to lose his temper in meetings if things were going badly. I liked him, and so did all of the staff. To a man they would follow him to the end of the earth and sadly in the winter of 2002 they did exactly that when the company went bust and Tom lost nearly everything. For me this was an invaluable lesson in quitting while you are ahead.

Always seek goal congruency between you and your employer

If you can find a way to steer the work you are doing, so that what you want to learn personally also meets your employer's objectives, then you can achieve goal congruency. Now you and your team will be happy, because you all feel you are personally moving forward with your own knowledge and you will work hard to achieve the set goals. This is especially helpful if the business is not going very well, perhaps there are staff redundancies or budget cutbacks. However, if everyone's goals are well aligned, you will retain the good people and keep open the chance to come out the other side of the current difficult circumstances in good shape.

In my case, when the Arrows team finally went bust after two redundancy programmes and severe budget cuts, my team and I had kept ourselves busy solving some of the difficult challenges of engine computer simulation. We all arrived at Renault F1 to form its UK-based engine division in March 2003, after team principal Flávio Briatore bought the entire Arrows F1 engines business from the receiver, and just three seasons later we had won both the Drivers' and Constructors' World Championships with Renault. In many ways we had benefited from several years without the continual pressure of racing. It had been an unusual opportunity to focus on the longer-term, bigger picture and we had made good use of the time.

My four seasons from 2003 to 2005 as Technical Director of the UK-based engine division at Renault F1 were fantastic. It was great to be working with such a highly-skilled group of people, where everybody took everyone else at face value and we all trusted each other to do their own bit. An interesting perspective is that nobody looked over your shoulder – there simply wasn't time for that. The pace of life was very high. It was like being on a running machine, where every now and again the speed was clicked up, never down. There was a really short-term focus on the next race weekend, and if you missed a development deadline you could literally see the car qualify lower down the grid.

At Renault I had my next encounter with a great entrepreneur. Flávio Briatore was my direct line manager for much of my time at the team, and was a very busy man. As well as his team principal role, he had a number of other business interests including driver management, hotels, nightclubs and football clubs. He flew around the world by private jet, arrived in a chauffeur-driven car and rarely stayed to the end of a meeting. I once pitched a money-saving idea to him and he gave me just 40 seconds before telling me that if it wasn't going to make the car go faster next weekend he was not interested. But Flávio did pick good people and once chosen he trusted them to deliver with substantively no supervision. He also chose a direction when others sat on the fence, and when he got it right the whole team gained a huge advantage. He can take a lot of credit for the team victories in 2005 and 2006, but also for its fall from favour in the years that followed. He displayed a great short-term focus but limited longer-term vision. I have always tried to stay in a longer-term planning mode for as much of the time as possible, switching to proper F1-style short-term planning only when strictly necessary.

When the F1 engine rules changed in 2006 and the specification was homologated with no changes allowed until 2014, my team and I were all made redundant. In some ways this seemed sad, but in fact I was grateful to get off the running machine. I didn't like the very short-term focus and longed to have the chance to future-cast again.

Outside of my paid employment I had been involved for a number of years with an alpaca farming business. Originally started with my wife to run alongside her work as an orthodontist and my work in Formula One this was another opportunity to find out more about the commercial aspects of business. We bred many national-show class winning animals and kept a herd that grew to more than 65 alpacas. We eventually exited this business after 13 years roughly breaking even but having learnt a lot from the experience.

In my career I have been lucky to spend more than 15 years working in the motorsport industry. For me this was the opportunity to play with someone else's multimillion-pound Meccano set.

When I started Flybrid Automotive with my business partner Doug Cross in January 2007, many of my friends thought it was a risky thing to do. We were putting in several hundred thousand pounds of our own money to develop a business based around a relatively unproven, high-speed, flywheel-based, kinetic energy recovery concept, with an unproven market. But we had looked at the vehicle requirements quite carefully, we understood what was needed and were sure that the existing products were not nearly as well-suited to the requirement as the one we envisaged building. We had both spent many years working on unique development projects that were no more difficult than this, and we had a really good record of success. This should not feel risky just because it was our own money.

In technical terms our technology was quite simple. We aimed to develop a system to harvest otherwise wasted braking energy from a decelerating car, store it for a short time and then release it to help the vehicle accelerate again. By doing this we could reduce the fuel consumption of road cars by re-accelerating the car with less use of the internal combustion engine. Alternatively, we could release the stored energy in addition to the engine power to make the car accelerate more quickly.

When we did the sums for this energy exchange, we had discovered that the requirement was for a high-power system with a relatively small amount of energy storage. The ratio of power to storage required (the C value to electrical people) is about 500. A typical Lithium ion battery, which was how everybody else appeared to be proposing to store this energy at the time, had a C value of 3. Our proposed solution of using a high-speed rotating flywheel connected to the vehicle transmission system using shafts, clutches and a variable ratio gearbox had a C value of 750. Our solution was clearly a much better fit for the intended purpose, and in practical terms this meant we should be able to build a system that was much smaller, lighter and less expensive than an electrical solution with similar performance.

The idea of a flywheel hybrid vehicle was not new. In the 1950s 'Gyrobuses' had been developed using 500kg steel flywheels rotating at a few thousand rpm, and in the 1980s, in a second attempt to popularise the technology, BP had developed a flywheel storage device using a fibreglass flywheel that rotated at over 10,000rpm. These earlier attempts meant that there was a clean route to market, because all of the technology that had been patented was now free for anyone to use, due to the patents having expired.

Our key inventive step was to run the flywheel very fast, up to 64,500rpm and made possible by the more recent development of light and high-strength carbon-fibre materials for the flywheel construction, and then to put the flywheel in a vacuum chamber to reduce coast-down losses. Our early inventions and key patents were around the vacuum-sealing technology that allowed us to pass a high-speed shaft out through the wall of the vacuum chamber, and around other detail design elements that ensured reliable operation of very high-speed rotating machinery and safety of the flywheel. Because energy stored in a flywheel is governed by the equation $E = 1/2JW2$ the reward for running the flywheel very fast was that the required amount of energy could be stored in a much smaller space. Compared to a 10,000rpm flywheel, ours would be more than 40 times smaller and lighter for the same quantity of storage. All the available braking energy from a mid-sized saloon car travelling at 70mph could now be stored in a flywheel that was just 200mm in diameter, 135mm wide and weighed just 5kg.

Our plan was to do the minimum amount of work necessary using our own money, just enough to secure the intellectual property related to the inventions but not enough to develop application-specific sets of hardware. This required us to sell the idea to clients based on paper studies and laboratory demonstration devices, in order that they might pay for the design and development of an application-specific set of hardware. This approach worked well but was not without its difficulties. It did mean that we had a clear sign of commitment from the client before commencing work, as they actually had to sign-off funding, but it did mean there were some jobs that might have more directly met our longer-term objectives, that we had to turn away due to inadequate finance.

Think big, plan big but spend small

From the very beginning of our business, we always thought ahead several years and tried to plan our key business moves with this in mind. In this way we did our best to avoid spending money on things that later became obsolete. Our path was not cast in stone and every small business needs to display flexibility. However, we always had a default direction in the back of our minds, which made short-term decision-making much easier. Doug and I shared an office and used to talk a lot. We regularly discussed the overall direction and made mental notes of adjustments as they were required. It is incredibly hard for any individual to stay motivated all the time and I am very grateful to Doug for his part in our business. Quite apart from the individual skills of your business partner, I think you need at least one other person with you to bounce ideas off and generally help to keep you sane. Every endeavour has its peaks and troughs and every person has their moments of self-doubt, so you need to find someone who can share the burden with you in the hope that they are up when you are down and vice versa.

Developing a new technology from scratch is a great challenge, but also great fun. Being the first to discover each new challenge feels like climbing a mountain: over every ridge the ground rises up again and again until you start to think you will never get there, but eventually you reach the top. Often it takes some time before you realise that you did actually reach the top some time ago. We started saying at Flybrid that we had not failed a flywheel for six months, then for a year and then since 2009, not knowing when the next one would fail. We still have not failed one by mistake since 2009, so that really was the top of the mountain.

If the thing you need doesn't exist, don't give up: make it yourself

There are not many parts of a Formula One engine that you can buy off-the-shelf, cap head screws and O rings is about it for the proprietary parts list. So at Flybrid we were never afraid of making things that others avoided. I think it is really important to have a vision for your product and to stick religiously to delivering on the vision. I wanted the smallest, lightest and most powerful thing we could build. So when an accessory part turned out to be too big, too heavy or inadequate in performance, we resolved to make our own. Sometimes it seems ridiculous that we make our own vacuum pumps, vacuum solenoid valves, hydraulic pumps, hydraulic actuators and clutches, but these components help the overall product to be more competitive.

Ideally you would make it easier to buy your product by offering all of the related items needed to go with it. This is often a challenge for a smaller business and I see plenty that offer only part of a complete solution. In this case they might partner with a company that can deliver the remaining parts, possibly failing to see that they will restrict the choice of who they can sell their business to at a later date and compromise its value. Fighting for the largest piece of the largest pie is most easily done right at the beginning of a new business. Every time you cede control of a sub-component of the complete solution because you are (or imagine you are) unable to deliver it, you give away something for free that would have attracted a fee at a later date. Another important element is the potential for being blocked in the market. If you grow to rely upon key sub-components supplied by a third party, there is the potential for that third party to control your business direction. This is unlikely to be as overtly sinister as it sounds, but can certainly be disruptive and is likely to be the subject of much discussion when the due diligence process starts in advance of a business sale.

To finish first, first you have to finish. It is a famous racing adage, but it is equally true of life in a technology start-up business. From the very start of our business, Doug and I openly discussed what a successful outcome of our business venture might look like and we determined where the finish line was. To use a racing metaphor, you might like running around the track in the lead of the race in front of a cheering crowd, but once you cross the finish line you should throw your arms in the air and celebrate, not keep running around the track, because something is pretty much certain to happen that will lose you the lead eventually. Our principal target was financial. I had worked out how much money I needed to make in order to never work again, and once we could sell the business and achieve this target price, we had reached the finish line. I had learned this lesson from Tom Walkinshaw.

During the key development phase of a new business, it is hard to maintain your own direction and avoid being steered by your clients. It is all too easy to accept every job offered, whatever it is, as certainly you need the money. Doug and I used to discuss the appropriate technical direction for our clients to follow, and based on the outcome we would often start our own development activity, usually comprising mostly computer simulation but occasionally extending to building and testing new hardware. This allowed us to make unique technical offerings that were specifically tailored to our client requirements as we understood them. It also inspired the creation of new inventions, whenever it became clear that the things we had already developed were not ideally suited. This method of operation ensured that the intellectual property in any new invention was clearly owned by us, not by the client.

Choose carefully what to patent, what to keep secret and what to make public.

Patents are expensive and we were spending about £50,000 per year on patent maintenance. In order to minimise spend we determined that we wanted about five strong patent families, each secured in all of the top ten car-making countries in the world. For features we chose not to patent, we did our very best to keep them secret. For many years, whenever we showed flywheel hardware in public it was fake, deliberately manufactured just for show using features that were not the same as the real parts. This is particularly necessary if you want to have something to show but are still in the process of obtaining patent coverage and so cannot afford to make these details public. We only ever showed hardware made from steel and aluminium, believing that rapid prototype hardware just tells all your potential customers that you have not made a real one yet.

Low-cost publicity is good, so despite your wish to keep things secret it does pay to say something and show something. We built a regular presence at a small number of trade shows that we thought worked well. We went out of our way to have something new to show every year, so that it looked like we were making good progress, and we took the engineers out of the office and put them on the show stand so they could evangelise about the technology. Often engineers will shy away from trade show stands or make excuses for why their hardware cannot be made available, but a compromise needs to be struck between short-term technical progress and sales effort, because you do really need to generate sales. By developing good relationships with key magazines, trade shows and trade associations we managed to make a £25k marketing budget go a very long way.

As our business grew, we focused on demonstrating the value in our business. We deliberately looked for opportunities in many different fields, to show the breadth of applications that were possible for the technology. We sought customer-financed programmes to build demonstrator vehicles and built racing cars, supercars, saloon cars, vans, buses and diggers. We showed that the technology was scalable, worked in all of these market spaces, and by doing the projects we learned more about each set of clients. We could determine where the market pull was coming from and how strong it was, including whether it was driven by a desire for performance or total cost of ownership. Understanding all of this was key to the next stage, as we sought to bring products to production.

When the time comes, the best person to sell your business is you

You will know when the time comes. Your business has grown, the staff has grown, and the potential risks have grown. At Flybrid we grew the business from annual running costs of less than £50k to more than £1.5m. We never took any investment and self-funded the whole enterprise with our starting capital and retained profit. We relied heavily on our spouses (thanks Judy and Sjoukje) to support us both financially and morally. Even in our outwardly successful business, we actually made very little money. We built a business with more than 20 staff, a good reputation in the industry, nice premises, good machinery and equipment and no debt, but up to the point of sale we would have earned much more if we had spent the time working for someone else. Eventually you get tired of shouldering the increasing responsibility with little reward and the opportunity to sell looks increasingly attractive.

In 2012 the timing looked good for us. We had two vehicle programmes with JCB and Wrightbus that looked like they were going to production, but we would need significant funding for the set-up of production facilities and for the necessary design validation testing. This was a good reason to sell now and any buyer would understand why we would not be able to fund this investment. Selling a business was something new to us and we spoke to a number of advisers who wanted to sell Flybrid on our behalf (in return for a substantial commission). The more we spoke, the more we realised that they didn't know how to sell it either. There was no formula, no commonly used pro forma set of paperwork, apparently nothing to be learned from having done it before. Everything would be bespoke and created from scratch just for the Flybrid sale, and all that mattered was that we reached agreement with the buyer on the terms. This was just like the earlier discussion about buying proprietary parts or making bespoke ones yourself. So we rolled up our sleeves and got on with it, avoiding the usual sales agents completely.

It was clear that achieving a sale was going to take some time, and it was also clear that in order to achieve a good price we would need to show that the company did not depend completely on the continued presence of the founding directors. We promoted three of our senior engineers into management and recruited a fourth manager, so that the business could run itself day to day while we concentrated on achieving the sale. We told the staff we were going out to find the finance required to bring the Wrightbus and JCB products to production – which of course we were – we didn't talk about a business sale until the deal was pretty much done.

In March 2013 we agreed the sale of a minority stake in Flybrid to Torotrak plc, with an option on its side to acquire the remainder of the company subject to a vote of its shareholders. In January 2014 the required vote was passed and Torotrak took control of Flybrid. Doug and I were both offered roles working for the new parent company and Torotrak raised finance to see the Wrightbus and JCB projects through to production. The finish line had arrived and we celebrated.

Like most Chartered Engineers I had enjoyed a good lifestyle up to this point in my life. A sudden injection of millions of pounds was clearly welcome, but right until the last minute I had refused to let myself believe it would ever come true. Celebrating properly was surprisingly difficult. It took me the best part of a year to really get my head around this and to work out what I really wanted from work.

Now I can equate the finish line we set for the sale of our business to being our first World Championship victory. Clearly a watershed moment we will never forget, but not the end. After a period of settling in to a new lifestyle, you realise that the challenge is still there but the view has changed. Now as part of a FTSE-listed plc the challenge is quite different. At Flybrid we spent many years developing a wide range of different opportunities, but at Torotrak we have to concentrate on a smaller set of applications in order to get these through to production and start generating revenue and profit.

The profile of expenditure in order to achieve technical progress is interesting and worthy of discussion. Using the Technology Readiness Level (TRL) scale published by the Automotive Council, we can see that moving up the early part of the TRL scale is relatively quick and inexpensive. At Flybrid we got from TRL 1 (initial idea) to TRL 4 (prototype running on a test rig) in one year and for less than £1m. To get from TRL 4 to TRL 7 (multiple vehicle prototypes) took a further five years and cost about £10m. To get from TRL 7 to TRL 8 (low-volume production) will take a further three years and cost a further £15m. The final stage to TRL 9 (mass-volume production) could take a further three years and cost as much as £50m.

Did we do the right thing to sell when we did? People often ask how I could sell 'my baby' and assume that I had a huge emotional attachment to Flybrid. I don't have any significant emotional attachment as it was always the plan to sell it, and I was pleased when the plan came true. If we had chosen a different time to sell could we have made more money? Maybe yes, maybe no. Many things have happened in the time since we sold the business that might have affected the appetite of potential acquirers, some positive such as the VW emissions scandal, some negative such as a dramatic drop in the cost of oil. I remain sure that we did the right thing to sell at a time when the business needed a significant investment to bring its products to market, and when the company valuation achieved our long-term goals.

Developing a new technology
from scratch is a great challenge,
but also great fun.

ENTREPRENEURIALISM

I remain really interested in entrepreneurialism: the process of inventing new things and how to commercialise new technologies. Back in 1847, the foundation letter of our Institution stated that we should provide an 'impulse to invention that can change the world', and I hope that by sharing my largely positive experience of being a technology entrepreneur, I might encourage others to follow a similar path.

I see two distinct types of engineering business: those that provide services and those that make products. Service-based businesses provide independence to their owners who might make a modest income while being their own boss, but rarely will the business itself be worth more than a few times annual profit. Product businesses are a very different proposition, with companies that own well-protected products in interesting markets regularly selling for very much higher multiples. We managed to sell Flybrid for more than 60 times annual profit. Given that the amount of effort involved in developing either sort of business appears much the same, I would always prefer the product-based route.

I must say that blue-sky research is not really my thing. The principle of inventing something first and then looking for a problem that required the solution that has been invented seems the wrong way around. I would much rather generate a very clear definition of the problem and then invent something to fit this tight brief. I have found this is really quite easy to do, and often you already know that there is a market for the thing you are inventing. I have not yet come across a tightly defined problem that took more than two people and 12 weeks to solve. If your problem is clearly too big for this, then you need to break it down into bite-sized pieces that can fit this brief, and tick them off one at a time. Seeing and feeling genuine progress every few months will also help to keep up the motivation of your team and your investors.

Key to turning a new invention into a new business, is a vision for where it might lead and a ready market for the product. To imagine that you can second guess all of the potential applications for the underpinning technology is probably unrealistic, but you should be able to think of two or three key applications, and for each of these it is not usually difficult to put some scale to the business opportunity. Most new inventions are a subtle variation on a well-known product that is already in the marketplace. So you can easily find out how many are sold, how much they cost, and start to work out what the potential revenue stream from your idea might be. It is critically important to be realistic about the prospects for the new invention and also about the costs of getting it to market. It is certainly not enough to have invented something useful and patentable. I see very many good and useful inventions that will never make profitable businesses, because the cost of bringing the product to market will never be recovered by the profit from selling it. If this is the case for your first good idea, let it go; you will invent something else soon enough and maybe that will be the one.

CROSS-INDUSTRY TECHNOLOGY TRANSFER

I think there is huge scope for transfer of technology from one industry to another. I see this as an important trend and a great place to look for new business opportunities. I have seen trade body organised programmes for things such as motorsport to automotive and motorsport to marine, but I am sure there are many other examples that would work.

There are some industries that seem to have been left behind by modern technology and these can offer an interesting opportunity. I have a relatively new-found love for the marine industry, as my wife is an accomplished sailor and one of the things we have treated ourselves to is a yacht. Some of the things that sailors put up with in terms of their vessel control systems are truly ridiculous, and would not possibly be tolerated by car drivers. I am sure that we will see a complete change in sailing technology over the next 10 ten years or so as self-trimming sails, navigation systems that actually get you to where you wanted to go and anti-knock-down systems become as common as power steering or ABS on cars.

A key reason why cross-industry transfer works so well, seems to be the lack of pre-conceived ideas about how something should be done. In order for this to be true, it needs to be the people as well as the technology that make the transfer.

THE INSTITUTION'S ROLE IN DEVELOPING PEOPLE AND SUPPORTING INNOVATION

I am really pleased to support the continued move by the Institution into commercial trading activities. In our trading companies we are building valuable assets, creating high-value jobs, doing good work with a healthy corporate social responsibility content, and generating profits that we can spend to help meet our charitable objectives.

With the opening of our Sheffield Engineering Training Centre in 2015, we have created the space for these businesses to grow, and one of our earlier acquisitions is already generating double the revenue it did before we bought it. We have developed a good system for bringing these new companies under our wing, sorting out the inevitable HR issues, successfully handing over the running of the businesses from their owner/operators to professional Institution staff, and cross-selling multiple products to a growing customer base. We are quickly becoming a purchaser of choice for businesses that fit our brief, because the owners know the transition will be handled properly. Our most recent acquisition, Amber Train, has huge growth opportunities and under the experienced Institution team can be expected to realise its full potential. In 2016, our non-charitable trading arm will create employment for more than 85 people and generate revenues of more than £10m; this is something of which we can be really proud.

I have also been pleased to be involved with the Institution's investment in smaller business via the Stephenson Fund. This is an exciting mixed-motive investment opportunity that allows the Institution to more directly give 'impulse to invention' that might change our world. In March 2016 I attended the presentation by one of the companies that has received Stephenson Fund investment, Tokamak Energy, and was delighted to see my enthusiasm shared by a large audience of supporters.

Continuing Professional Development (CPD)

It is never too late to learn something new, and as professional engineers we should already recognise that. CPD is something that we all sign up to when we become members of the Institution and it is something that looks likely to be more strongly policed in the future for our profession – something we should all be pleased about because we do it anyway and therefore might as well be properly recognised for doing so.

It is a little more unusual to find people doing CPD in areas unconnected with their current employment, but I would recommend considering this. Learning about things that you have an interest in, and which may be useful to your future career, but are unlikely to ever encounter in your current role, is an empowering thing to do. It feels like you are putting yourself in charge of how your career works out. Your employer may well be supportive of this, as staff who have the skills to perform multiple roles are useful and those who have worked in many different areas often make good senior managers.

Mentoring

The guidance of a mentor can be particularly helpful in shaping your career and making the most of the skills that you have. Mentors might work for your employer, but I would recommend choosing someone with whom you have little day-to-day interaction or someone who works elsewhere. Of course it should be someone whose advice you trust and ideally someone who has had different career experiences from you.

In my opinion, there is enormous scope for increasing the potential of each and every engineer by better mentoring. I even think it improves the career opportunities of the mentor, by making them think more carefully about their own experiences in order to distil the key influences and reinforce the lessons of their own past.

The Institution now operates the Independent Mentoring Service and is always looking for more engineers to get involved, pass on their experience and share valuable knowledge and experiences with mentees. Under the scheme, the mentors support and encourage mentees, asking them challenging questions so that they find their own solutions and support them in reaching their objectives. I encourage everyone to considering joining the scheme. It is a worthwhile activity, helping others to develop and grow, while furthering your own CPD requirements.

CONCLUSION

In conclusion, I would like to wish you all the very best for your future careers and I hope that there was something for you to take away from this Address. I would urge you to make the most of the opportunities that present themselves, and to help each other to achieve the most that you can. I greatly look forward to seeing what you can do.

Finally, if you have been inspired to change something significant about how you run your business by what you have heard here, or even inspired to start out on your own, I would love to know. You can email me using president@imeche.org and if there is anything I can do to help you further, I will do my best.

ACKNOWLEDGEMENTS

I would like to thank my wife Judy for her support throughout my career and particularly for her faith in me during the formation of the Flybrid business. I also thank Judy for her efforts in bringing up our son Oscar who I am sure saw less of me than might have been ideal but nevertheless appears well on track to become a successful engineer.

I would also like to thank my business partner Doug Cross for his critical contribution to the development of the Flybrid business. I have particularly valued his great technical skills, his ability to work as a true team mate in a no blame culture and his willingness to take a problem away, analyse it carefully and come back on Monday morning with a proper answer.

I would like to thank all my colleagues and the staff at the Institution of Mechanical Engineers for their encouragement and assistance over the years.

Lastly I would like to thank my mentors John Favell, Tom Walkinshaw and Flavio Briatore for their influence on my career direction.

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Institution of Mechanical Engineers

1 Birdcage Walk
Westminster
London SW1H 9JJ

T +44 (0)20 7304 6862
F +44 (0)20 7222 8553

president@imeche.org
imeche.org