advancing business through people

Next steps for the Aerospace sector post pandemic decline, achieving net carbon zero and how companies like Reaction Engines can help

On 3rd November, Katie Ann Poxon, Director at Holmes Noble, had the pleasure of hosting a cohort of senior leaders from across the aerospace industry to explore the future of the industry and the role of innovative technology development in achieving Net Zero. The event was held in partnership with The Worshipful Company of Coachmakers and Coach Harness Makers.

We were delighted to have two guest speakers for the event, Rear Admiral Simon Henley MBE CEng CHPP FRAeS FAPM, Business and Industry Strategy Adviser to Reaction Engines; and Dr Emma Ryan, Product and Additive Manufacturing Lead at Reaction Engines, who imparted their knowledge and views across a range of topics impacting the sector. These covered themes ranging from the impact of climate change to Government policy and how innovative companies such as Reaction Engines are playing their part in ensuring the industry adapts to change and therefore, remains successful.

This review is designed to capture those thoughts and share the answers to many questions that were posed on the evening and provide a framework for further discussion between Holmes Noble and attendees.

An industry facing headwinds like never before

Aviation has probably never faced such challenging circumstances, as over the last few years. This, as a result of a combination of Covid, the 737 MAX grounding and the increasing focus on climate change and the emissions that come from the sector.

Covid has shaken the economics of commercial aviation to its core. The Boeing 737 issue has undermined public trust and shone a spotlight on the regulation and certification process and the frequency of extreme weather events as indicators of climate change has shone a spotlight on sectors that are considered by some to be luxury or discretionary travel, but which contribute to the global carbon footprint.

At the moment, aviation stands alone as the one sector where emissions are still scheduled to increase year on year to 2030. The predicted sector growth outstrips the ability to decarbonise over that timeframe despite improvements in efficiency. In net terms growth will increase emissions faster than efficiency improvements decrease them by 3%/year.

The impact has been unequally felt in different quarters

It's easy to believe that the economic headwinds facing commercial aviation have been felt equally, but it should also be remembered that the aerospace sector has many facets and not all have been as adversely affected in the same period;

- Business aviation, i.e. corporate jets, suffered a downturn during Covid, but levels of activity have now returned to pre-Covid levels and may well grow faster than previously anticipated as a method of conducting necessary business travel while avoiding the risk of Covid infection
- Defence has largely been unaffected by Covid and indeed the incredible achievements of air national forces, working in conjunction with civil cargo aircraft, to distribute PPE and vaccines as well as the recent evacuation of people from Afghanistan in the face of the collapse of the existing regime, can only have served to highlight the role that aerospace has to play as a force for good

There is no escaping however, the pressures on the most visible and largest portion of the industry economically, commercial aviation. Prior to Covid, commercial aviation was on a relentless treadmill to produce enough aircraft to satisfy demand. This was exacerbated by accelerated fleet replacement with the availability of better fuel-efficient models, with their accompanying lower operating costs. Some would say that that trajectory has taken a bit of a dent but that it will return back to growth and in a few years' time no one will notice anything much has changed, but that is open to question.

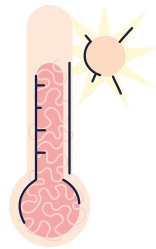
Covid has caused a pause and re-evaluation from society and the industry

Prior to Covid, Airbus and Boeing were locked in a battle to satisfy demand, competing with each other on cost with products that were a broadly similar offering, at least as far as passengers were concerned. However, safety and regulation were taken as a given and there was very little dialogue in the media or elsewhere other than how quickly the manufacturers could ramp up production of Hydrocarbon fuelled aircraft to meet burgeoning demand, particularly in developing nations. If there was any conversation about emissions, it was largely around how efficiently the latest or the next generation of engines would consume Hydrocarbons with options for passengers to solve their environmental consciences by purchasing carbon offsets.

Suppliers were almost always established companies selected for their track record of hitting delivery targets of traditional components with years of in-service experience, making qualification and certification not much more than a marginal consideration. Barriers to entry for new companies were high and new technologies only won their way onto a programme on the basis of either lowering the initial purchase cost or by improvement in through-life costs. That forced technology development to be largely incremental.

As ever, there were a few exceptions that proved the rule. With breakthroughs such as the fly-by-wire and sidestick architecture of the Airbus aircraft; or more recently geared turbofan; or the aerodynamic advantage which has been achieved by the use of advanced materials and highly developed aerodynamic modelling being clear examples. But in general, the evolution of the commercial aircraft as a tube with engines on the wings, burning carbon-based fuels through gas turbine engines has been a relentless succession of incremental improvements amongst the same players.

The new reality – climate change has impacted industry's priorities



The prospective scenario today though is very different. At the ADS pre-COP26 summit the CTOs of Airbus, Boeing, Rolls-Royce, GE, Pratt & Whitney, Safran and Dassault all appeared together, which itself is unusual. They reaffirmed their commitment to working together to deliver the Net Zero targets for aviation by 2035 and 2050. Their views which were notable for their differences in emphasis as much as their similarities on the ways to achieve those goals and were also quick to acknowledge that the need to deliver Net Zero has spawned many start-ups bringing step changes in approaches and technology to compete with the more established players and their more incremental approach.

Broadly put, the aerospace sector's approach to meet it's Net Zero targets today relies on sequential and parallel application of the following changes;

- First and foremost and right at the heart of the current approach is the widespread adoption of sustainable aviation fuels (SAF) as a drop-in replacement for fossil fuels along with improvement in the conduct of aviation, i.e. better navigation and air traffic management to optimise flight paths and reduce wasted fuel in holding patterns or more efficient routing. Included in this is the need for a massive ramp up in the supply chain for sustainable fuels.
- The second part of the strategy is the continued application of the incremental technology approach (notwithstanding that some of these, such as UltraFan, can actually achieve double-digit reductions in fuel burn), to continue the past trend of improvement which was roughly 1.5% improvement in efficiency at fleet level year on year and that's not predicted to change massively.
- The third piece is Net Zero ground operations through initiatives such as electrically powered ground equipment, electric taxi on aircraft, improved public transport to and from airports etc. For example, Bristol Airport has confirmed its ground operations will be Net Zero as soon as the end of this year.

In the background, game changing technologies are emerging such as hybrid propulsion, (basically the combination of a thermal engine with some form of electrical system, burning either SAF or a zero-emission fuel), pure electric or pure hydrogen. All are being researched but are considered to be unlikely to make much of a change in terms of overall carbon footprint for the sector, by 2050 and that is demonstrated in both industry's predictions and in the Climate Change Committee figures where they make little or no allowance for hydrogen penetrating the market by 2050.

How can Net Zero be achieved and will it arrive soon enough?

This step-by-step approach by the aerospace sector is both pragmatic and problematic. It assumes that the public appetite for flying will continue and that forecast growth of aviation, driven largely by developing markets along with more modest growth in established markets, will be socially acceptable. The issue is that, even according to the industry's own figures, this approach will not achieve the Net Zero targets that we've set without significant reliance on carbon offsetting, accounting for as much as 35% of the target. The whole approach is also reliant on SAF being regarded as a Net Zero fuel which accounts for a further 20% of the reduction required to meet the target.

SAF is a generic term and it covers everything from fuel made from bio feedstocks, fuel from waste, fuel from algae, through to synthetic fuel created by combining carbon captured from the air with green hydrogen. It is believed that synthetic fuel is the only practical way of creating the volumes of the fuel needed given the projected growth rate. It is also probably the only one which takes carbon out of the atmosphere with obvious equilibrium benefits.

Whatever the capture mechanism, SAF is the cornerstone for both the industry's plan for NetZero and also part of the Government's recently published Net Zero strategy for transport. There isn't really a viable alternative, at least in the near term. SAF is the only viable way to reduce the net carbon footprint of the existing generation of aircraft, including the very newest ones only just entering fleet service.

All new fuels and architectures remain some way off

There is no practical alternative to kerosene, synthetic or otherwise, to power long haul flights until an all-new hydrogen powered aircraft is developed, along with the attendant regulation, supply chain, handling expertise and the availability of hydrogen in the first place. All-electric aircrafts will at least for the foreseeable future have only a very small impact on the sector's emissions as they will only be suitable for short-range, low-capacity aircraft.

Hydrogen fuelled aircraft are still a long way off – the industry view is that even a narrow body, medium-range hydrogen replacement isn't viable before at least the late 2030s, maybe even 2040s and long-haul is even further off. This causes some concern about the continuity of social support for flying in the period beyond 2030 if it's still emitting carbon regardless of whether or how the carbon has been captured earlier in the process.

If the rate of climate change continues as is, or even accelerates, and the consequences become ever more obvious in terms of extreme weather events, raised temperature and radical adverse changes to our ecosystem, then there is a danger that aviation will be seen as an ever bigger contributor to global emissions and will have growth limits imposed on it. The industry itself sees carbon taxation as inevitable, and that will likely have some impact on growth, but it is difficult to reconcile a projected growth of 4% p.a. with the expectation in terms of direct emissions reducing by 1.5% and still believing that unfettered growth will continue.

But technology disruptors are coming to the fore and their time is now

And that's where disruptors such as Reaction Engines come in…

Reaction Engines is well known due to its work on the SABRE space engine, but what most people are less likely to be aware of is that the technology developed for SABRE is being applied today to enable an acceleration of Net Zero in a number of sectors, most importantly in aviation. Reaction Engines is not alone, but what is important is the approach taken by the many disruptive companies and that they at least in part hold the key to how aerospace survives into the future.

The SABRE space engine came about because three engineers believed that space access didn't have to continue on a relentless path of vertical launch, single use rockets and that key to opening up space was the development of fully reusable space planes, capable of making space launch operations more akin to commercial aviation: regular sorties to and from runways with passengers and cargo in safe, lower cost operations to open up space access to humankind. Now many others have followed part of that dream and arguably Jeff Bezos, Elon Musk and maybe Richard Branson have moved the dial much more quickly in the recent past, but all of those companies have just made incremental changes to the current vertical launch model.

SABRE remains true to the dream of 100% reusable space plane which will entirely disrupt space travel. Making that work involves creating an air breathing rocket because if you take your oxidiser with you, that you need to get out of the atmosphere i.e. whatever you combine with the fuel to make it burn, then you're stuck with a maximum payload of single digit percentages of total vehicle mass. Typically no more than 6-8% is available for payload. However, if you don't need to lift all that oxygen because you take it from the atmosphere then that payload fraction goes up to 25% or more and that is the key to unlocking the economics of mass space access.

So why has no-one done it before? Because at Mach 5 the air coming into the intake has to be slowed down to subsonic and in doing so it heats up to 1,000^{0}C – you can't work with air at that temperature as a) it won't compress and b) it will melt your engine if it does, so you need to cool it.

In a world first in 2019, Reaction Engines ran a cooler which could breathe air at the rate required to feed a rocket or gas turbine engine and cool it from 1,000^{0}C to ambient temperature in 1/20th of a second. Since that date, Reaction Engines has followed that same principal of thinking out of the box and going beyond the perceived art of the possible to apply that technology and others to achieve a step change and disruptive effect to tackle some of the challenges that are preventing or slowing the decarbonisation of aviation and other sectors.

People as the driving force for technology advancement

The technology is important, but probably more important are the people who thrive on solving the unsolvable and for whom defining something as impossible just means it takes a little longer to crack. Dr Emma Ryan explains what it is to be part of that and how technology can help solve aerospace's dilemma.

Reaction Engines goes about achieving the seemingly impossible by not being willing to just "make do" – SABRE is the perfect example of this. Reaction Engines has been around for more than 30 years however, it hasn't really got going until about 5 or 10 years ago when it grew from a company of about 8 people to a company of 50 and now stands at more than 200 people. The way this was achieved was that the original three engineers didn't make do. The technology that they needed to allow them to do what they wanted to do wasn't actually possible at the time. The thin microtubes that are used in the precooler which makes the technology viable, couldn't be manufactured 30 years ago – it's only a very recent development. These tubes are about a hair's width and absolutely miniscule. What the company did was it waited – the founders knew that the technology would become available and so they waited for the technology to catch up with the company's ideas so that they could proceed with SABRE. That mentality and philosophy continues at Reaction Engines and customers have also aligned with that.

A company with a different ethos and approach

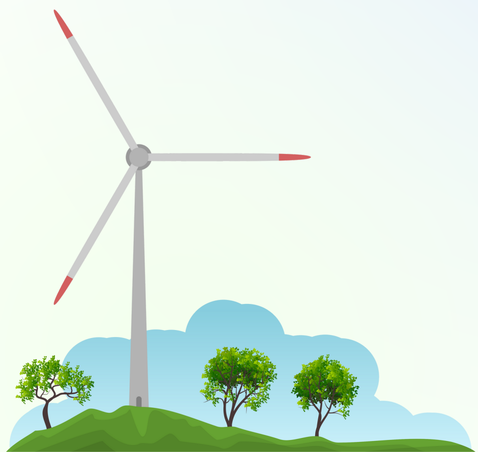
When Emma joined the company it had a really different feel to compared to others – more like a start-up. The average age at Reaction Engines is 33, so quite a young organisation which is very different from many other more traditional aerospace organisations with a completely different dynamic.

Emma joined the Applied Technology team which was about 6 months old at the time, so she was part of the new guard of Reaction Engines but is considered in the old guard of Applied Technology. Applied Technology were trying to take the technology from SABRE and apply it to other industries. The group branched out into aerospace, but also energy and motorsport. In fact, in the motorsport example the customer wasn't willing to just make do – they wanted a more efficient intercooler, a lighter intercooler, they wanted less of a pressure drop and what was available didn't do that. Reaction Engines managed to make it happen.

Examples abound of making a difference to a sustainable future

Touching on the key products that are helping the industry be more sustainable and work towards Net Zero:

1) An annular radiator – Reaction Engines recently released news that they are working with Cranfield Aerospace on a project called Fresson and the annular radiator was the only viable solution to enable the use of hydrogen fuel cells. This is going to fly very soon – next year, and Reaction Engines is making radiators to go on Cranfield Aerospace's products as part of their heat exchanger system and thermal management system on their hydrogen fuel cells.
2) Foils which are going to be useful for Electric Vehicles. Initially in automotive, but also in aerospace. Currently, one of the issues with batteries, and why electric aircraft aren't yet viable at this point, is that the batteries can't hold enough charge and power and they also don't charge very quickly. One of the reasons behind this is the non-uniform thermal gradient across the batteries which causes ion plating where the ions build up to create hotspots, making the charging a lot slower and also reducing the efficiency of the battery. The foils are used as a heat exchanger to create a uniform distribution of heat across the battery and make long-haul travel more likely. It's also relevant for electric cars as you can therefore charge a lot quicker as well.



3) Work on ammonia. At the moment this is focused on maritime applications, but there are possible applications in aviation as well. You can "crack" ammonia it to create green hydrogen and that hydrogen can be used as fuel. One of the current ammonia limitation is how much heat can be transferred to the ammonia to initiate and help with the cracking to allow you to store a significant amount while you're flying. Reaction Engines' heat exchangers were again the only viable option to make that happen. News was released at COP26 that Reaction Engines are working with the Science and Technology Facilities Council (STFC) who have a catalyst for the cracking process, to get the most efficient ammonia engine possible once again it's the thin wall heat exchanger technology that makes it viable. Equally impressive has been the speed at which this development has occurred – only a few months from concept to test. This rapid proof of concept approach is driving innovation and progress which can then be utilised in different applications.

4) There are also a number of other products that are being developed for use in areas outside aviation:

a. a super-critical CO2 heat exchanger which is going to connect to the national grid to help with electricity. Super-critical CO2 has properties of two phases, both liquid and gas - at the same time. The benefits of using super-critical CO2 is that you can reduce the space required from a traditional steam-powered power station by 90%, significantly reducing the installation footprint and thus make it easier to retrofit into existing systems.. The team managed to produce a heat exchanger that works in that power station that can transfer the heat to the super-critical CO2 and generate electricity in a more sustainable way.

b. Another exciting area is waste heat recovery. For example with NAMMO, who test rocket engines where the plume is coming out at 2,000^{0}C, need to lower that temperature so the sensors can pick up information about that plume and detect what's going on. The subsequent data can be analysed to make sure the rocket engine is working correctly. A heat exchanger is therefore needed that can cool the plume down from 2,000^{0}C to ambient in less than a second and the bespoke heat exchanger designed by Reaction Engines achieves that. What can then be done with all the excess heat energy transferred to the water within the heat exchanger, is to use it to power the rest of the plant thus it's a very efficient and effective way of using heat that would otherwise be dissipated to the atmosphere, reducing energy consumption.

The role of Government in setting direction

So where does Government policy point to and provide guidance? The implementation of policy is all about action and there's a bit of a divide between the two.

The Government policy has set out how we are going to decarbonise transport and we must distinguish between popular soundbites and policy that's backed by significant funding. A quick perusal of strategy documents released recently very much reinforces the approach to aerospace decarbonisation previously discussed with an emphasis on SAF, including investment to ramp up SAF production.

Hydrogen is still regarded by the Government as a long way off and the jury is still out on whether scarce green hydrogen will be directed towards greening domestic heating or whether tackling the hard to decarbonise markets of transport will take priority. In reality, UK funding of hydrogen is still dwarfed by funding by other Governments such as Germany, Norway and others.

It is reassuring for the aerospace sector that there is a guarantee of funding for the Aerospace Technology Institute (ATI) envisioned in the last budget with funding until 2031 with an additional £800m for the establishment of the new advanced research and innovation agency (ARIA). So Government is serious about innovation, or at least as serious as can be expected in a post-Covid economy, but the thinking around transport beyond SAF is not as mature in policy terms.

What is for sure is that it is in the hands of industry to ensure that the money is spent wisely to deliver the maximum impact in terms of reduction in carbon footprint, both in the immediate Net Zero world and, in the longer-term, zero emission technologies. The policy initiatives clear a path for the UK Government to support many of the R&D programmes which will help shape the industry to meet its objectives. From the recent experience of Reaction Engines, there are lots of funding opportunities globally where large funds will take reassurance from UK Government backing to multiply the initial Government contribution several times over. Rolls-Royce's recent announcement of its partnership with the Qatar Foundation is a great example of what can be done to leverage external funding when UK industry and Government pursue joint goals.

Business models are changing, and the industry needs to adapt

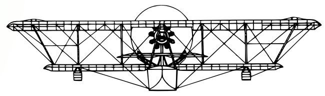
As reassuring as it is, that Government and Industry are aligned, we must avoid the danger of groupthink. If Covid has taught us anything, it is that Black Swan events that hitherto have been seen as so unlikely as to not require planning for, can actually occur. When they do, if we don't have a plan and have made funding provisions, then we'll never get ahead of the drag curve, resulting in very little time or the wherewithal to shape the outcome, the outcome shapes us. The same is true of climate change – just because we want something to happen, because it makes good business sense and allows us to continue on our perceived most favourable path at a comfortable pace, does not mean will.

Different generations may well take a different view as to how much they are prepared to compromise between climate change and the received wisdom that people will continue to fly and accept the growth in aviation. If the current generation already take a different view from those of us who are more senior in age and/or thinking, then the next generation with the likes of Greta Thunberg are more than prepared to challenge the status quo than ever before.

Pre-Covid, investment in the industry largely came from the reinvestment of internal profits of existing aerospace companies, or from funds which were looking to make returns out of the continued growth in passenger numbers. That situation is changing now with significant funding streams available from investors which are dedicated to positive climate impact. As one of the potential disruptors in the sector, that has certainly been Reaction Engine's experience and they have been able to attract investment from areas that would have hitherto been off-limits for a traditional aviation company.

The business model is changing and the potential reduction in carbon footprint per seat mile is now at least as valid a measure of a product's success and return on investment as the more traditional cost per seat mile. Also, in the war for talent which is ever increasing in its intensity, particularly in high value engineering jobs, companies who are seen to be trailblazers in making the industry more sustainable will win out. Reaction Engines is one of those and therefore has no difficulty in attracting talent and actually lose more people when there isn't an aggressive enough pursuit of technological advancement than from people finding the work too challenging.

Small and large companies need to work together to secure the industry's future



While all in aviation, whether that be the traditional aerospace companies or the smaller start-ups, have a passion for making the industry a success, the perspectives can be different. Start-ups work with people who think outside the box and who turn up at work every day determined to achieve things which everyone else says are impossible. When they do achieve unbelievable world firsts, that makes them even more dismissive of the hurdles that restrict the general vision of how quickly we can make a difference through the technology. We all definitely share the same end goal of a thriving and healthy aerospace industry, providing our children, grandchildren and those that follow with the same incredible career opportunities as we have today. What is different is the perspective of the technology path to deliver a sustainable industry and how long we may or may not have to get there. If our scientists can deliver a vaccine for a hitherto unknown virus on a global scale in under 12 months, then we as an industry can do a lot better in delivering true zero emission aviation well before 2050. Game changing companies like Reaction Engines and their truly amazing engineers, operating in an environment that nurtures innovation, fast paced experimentation and sets its sights on achieving the impossible have a great part to play in getting the industry to get there.

Q&A

Q) COP26 – will it become impossible to maintain existing solutions in the future given the focus on the industry's carbon footprint? At what point will it be seen as unacceptable and how will that

A) There may well be different views across the generations as to when it becomes unacceptable. There is no Quick Win here, there is no instant answer to the problem.

SAF has to happen and it has to happen at scale and it has to happen quickly. Scaling up SAF and the synthetic production of fuel in particular because only a process that actually captures carbon out of the air that has already been released so you're not releasing carbon that's already been trapped by something else, you're capturing new carbon as it were and putting that into the process, is the only form of SAF that can genuinely been accepted as at least Net Zero. We have to do that and we have to do that quickly and that requires a great deal of investment.

But we do have to be realistic about how long carbon emissions, whether they're Net Zero or not, will be acceptable. Particularly as other sectors decrease their carbon footprint and aerospace doesn't. It's not predicted to reduce at the moment and therefore aerospace emissions will form an ever-greater percentage of the total global emissions picture. We do think that there could well be an event, potentially around the mid-2030s at which the tide of public opinion could turn against the industry.

We may need to be prepared to look at other solutions rather than waiting for hydrogen to come along in the late 2030s / early 2040s. That sort of thinking is driving the work is being done on ammonia, but ammonia may be one of those things that you need to have in your back pocket for a Black Swan event in case we can't wait for hydrogen. Ammonia may be an easier solution because it probably can be stored in wing tanks in aircraft. Reaction Engines is doing the basic work with the Maritime industry to see if that is viable and produce a solution for a gas turbine to burn ammonia. It's then up to us to look at the runes of public opinion to see whether it becomes a necessary part of the aviation picture.

Q) There was a recent report from IATA where they had assumed that about two-thirds of the carbon reduction is estimated to come from SAF, but there are other studies that have it the other way around, that it will be mostly new aircraft technology or carbon pricing. Do you think there is an answer to this question or is it all largely political and it depends whose view it is?

A) I think it probably is different people taking a different view of the same figures. The optimistic view says, look at the emissions you currently have and look at the growth in percentage of operating legs where the aircraft is operating on SAF and that basically starts to replace the emissions of those legs with effectively a Net Zero figure. Whereas others will take the same data and say well actually you look at the gross emissions and the likely efficiency of the conversion process and see how much carbon actually ends back up in the air that hasn't been captured from a sustainable source so it is probably horses for courses.

The one thing that everyone can agree with is that there is no alternative to SAF right now. We've seen Rolls-Royce engines in the last few weeks and others flying on 100% SAF and in fact certain business aviation customer of Dassault are telling them they want their aircraft only to operate on SAF because it's very important to them. So SAF is real and we need to get it and we need to get it at scale. Less worried at the moment about exactly how you count it than we are about getting it widely available and used on all the major aviation routes and in particular in long-haul, because that is still the biggest single contributor to the overall global footprint.

But also need to ensure that the focus on SAF which is necessary does not distract from the industry's ability to move to true zero emission technology with new aircraft, new engines and new fuels in the medium-term.

Q) As a disrupter pushing technology innovation, how do you see the need for the implementation of that in volume manufacturing to come alongside it and be available for you. Do you think there is enough being done and enough focus on that to create those new manufacturing techniques to support the innovative techniques being developed?

A) We see issues with current techniques on some of the substrates, impacting on the holes for the microtubes, the precision of which needs to be extremely close. Reaction Engines has managed to develop some of the necessary manufacturing techniques in-house as part of the strategy and managed to develop to get to these really high tolerances using traditional manufacturing techniques. It does just take a bit of development, work and a real requirement to do this. Again it highlights the 'won't just make do attitude' – they could have just accepted the looser tolerances that were being achieved by some of the suppliers but they didn't want to. It was worth the effort and energy because they were doing incredible things and needed incredible parts to enable that.

Companies need their own internal development to achieve this, but Reaction Engines also works with externals. In some cases they have had to turn to additive manufacturing because the things that were being asked for simply could not have been made using conventional manufacturing techniques. The necessary tolerances just weren't achievable. There is a lot of support and funding and investment in additive manufacturing which is great to see but more could be done. There is very much a skills gap but the business is very lucky to have a lot of apprentices and a lot of very experienced technicians who know how to put things together and know how to make things but could do with a fabrication shop and skills like welding are becoming lost arts. There were lots of older employees who could do it and then the Government started funding apprenticeships in it but there was a massive gap in the middle when people were being encouraged to go to University rather than take up apprenticeships and skills and trades.

Q) How do you see the position of legacy manufacturers such as Airbus and Boeing versus new entrants to the sector who may be more agile? Who will wield the power in the future?

A) The whole make/buy issue is a really big one for Reaction Engines as a company of 200 at the moment: do we want to stay as a company of 200 and stay at the real cutting edge of innovation and spin out the technologies into others? Or do we want to grow with the danger that as you grow you become a mass producer of the same product and it becomes quite hard to maintain that innovative edge unless you keep that separate. That is a dilemma that all start-ups will go through and it's a really important indicator for the sorts of ways in which the prime and supply chain relationship is going to change to meet the challenges we currently face.

It requires more of a partnership. The technology can be passed to those who are more able to produce them in volume and probably more used to delivering them to the relevant quality standards and it can be done in a way that protects the IP so that they get the returns on the IP that invent the next innovation. In the days before the current innovation , being a supplier into the primes was ruthless. The pressure that came down from the primes to the supplier to keep delivering and knocking cost down was endless. That relationship is going to have to change because the product supplier might have the key to making for example, hydrogen fuel cells for aircraft viable or not. The example in motorsport where the OEM has changed the design of the end product to optimise it around the technology being produced by Reaction Engines is expected to start to be seen more and more in aviation. Therefore, the prime / supplier relationship is going to have to become more symbiotic.

It's really hard however to see the start-ups, even those at the whole aircraft level to rapidly ramp up to reach production levels necessary for the growth targets, even if they were halved. There would still be the need to produce aircraft in significant numbers and therefore the capital investment required to do that, the broad range of skills that's required, the infrastructure, and the knowledge, all resides within the Boeings and the Airbuses, along with the other airframe suppliers. We don't see them being displaced at all – research and demonstrator projects, such as Freson, will then hopefully see their way onto mainstream aircraft with one of the primes. The position of those primes as the big suppliers in the industry will remain, and has to remain for the stability of the industry, but what will change will be that relationship between them and the suppliers such that the technology gets more of a voice in the core design and then the route to market is a shared destiny.

Q) With companies like ZeroAvia taking an incremental step to development in smaller bitesize steps, in year / 18 months increments, partnering with established companies. This looks like a different approach, it isn't a big prime but a small disruptive company working at pace. What's the view on that?

A) There will be some limitations on what can be achieved in that way, using gaseous hydrogen in external tanks on existing aircraft is a quick way to progress but gaseous hydrogen has a problem due to being not very dense in terms of volumetric efficiency. Therefore, you will be limited on range all the time you use gaseous hydrogen. Now that is not to say that for routes that smaller aircraft are taking that will be a limitation and therefore that should be a welcome part of coming into that part of the market and it does raise a very interesting question.

ZeroAvia's ambition was not at the 190 seat market, it was initially at the 19 seat market, was there a fundamental change in the way the short-haul commercial aviation was done that would effectively take a 100-150 seat EasyJet aircraft and break it down into seven, 19 seat loads and fly them point-to-point to smaller airfields rather than fly them to central hub – is there a different model? There were some very positive conversations around that but with the pace of change accelerating and if a 150 seat hydrogen aircraft can be proved then it does not necessarily need that change in approach.

They will have limited range though and therefore there will have to be a change in the way Airlines acquire fleets – currently they will buy the A320 series knowing that it has a range of up to 5,000 miles despite the fact that most of the legs they fly are under 1,000 miles, but the 5,000 miles means they have ubiquitous use of the aircraft across their fleet, they don't need to have mini fleets within fleets to cover particular legs and therefore they can just move aircraft around with demand. It may be that we have to make compromises like that to bring these things into being. But if it means we can start to make a dent in our carbon footprint, by operating true zero emission aircraft on the routes, particularly the holiday routes, then that's got be a good thing for the industry.

The question does return however as to who would be best placed to accelerate that uptake and get those aircraft into the market. Will it be the disruptors or the primes who are set up to deliver such production numbers. That is the point at which there needs to be really good coordination between the innovator and the mass producer to make sure that the right person is doing the right thing for the industry to get the emissions down as fast as possible.

To hear more about the services we provide, please contact:

Katie Ann Poxon
Director & Head Of Practice: Energy, Manufacturing & Infrastructure
m: +44 (0) 7891 549 541
e: katie.ann-poxon@holmesnoble.com

Roger Johnston
Director, Business Development
m: +44 (0) 7557 235525
e: roger.johnston@holmesnoble.com