# Professor Alison McMillan: Is it too much to ask?

**Professor Maria Hinfelaar:** Ok well good evening everyone, noswaith da, welcome everybody to what is I think third one of our public lecture of the series, they come thick and fast, um, we have a really exciting and interesting and fascinating one this evening, so professor Alison McMillian is going to be addressing us very shortly. Just to introduce Alison, I’m sure many of you know her already, but what she is going to share with us this evening will be quite compromising and quite challenging, shall we say. So, Alison is Professor of Aerospace Technology, she previously worked in the aerospace industry before she joined academia, in recent years she’s been following the research, development, and marketing promises of leading aerospace companies – promises is the key word there – whether they deliver, is of course, another question. Alison has struggled to reconcile those promises of covid safety research and net zero goals. In the last two years, Alison has been leading a transdisciplinary discussion forum called ‘For the relief of our planet’, which has discussed science research, societal equality, and the importance of trustworthy information, so I’m really looking forward to what Alison has to share with us this evening

**Professor Alison McMillan:** Thank you all very much for coming tonight, so first of all I’d like to give some acknowledgements. Many of the ideas and conclusions to be presented tonight arose through the course of discussion during the Bacon2020 project and the follow-on For The Relief of Our Planet activity. This led to a series of ten online seminars, the recordings of which are available on this [link](https://ajmcmillan.co.uk/relief-our-planet.html).

These discussions were of a Transdisciplinary nature, and involved members of staff from across the Faculty of Arts, Science and Technology, some of our Visiting Professors and Researchers, members of the Institute of Physics in Wales and the Institute of Physics History of Physics Group, and a number of other parties as well. I would also like to acknowledge the Global Association for Transition Engineering.

If you consider your everyday life, almost everything you do and use has been influenced or enabled by Engineering or related disciplines. From the obvious things like the car you drive, the bridge you cross, the pervasive electricity and water supply to every home, even the modest stainless-steel cutlery you use, all of this involves Engineering knowledge to provide and to maintain as cheaply and efficiently as possible.

Engineering is more than the everyday: it is central to the development of new machines: medical devices, manufacturing machines, space telescopes, and ... all the wonderful new technology structures and machines that will help us to overcome the Climate Change catastrophe and carry on living in the manner to which we have become accustomed.

Except, that is what the marketing narrative of the big Engineering businesses expect us to believe. The reality is rather different.

Machines that suck Carbon Dioxide out of the air are feasible, but to do it at the scale that would make a real difference is unrealistic.

Aircraft engines that run on electricity or hydrogen are feasible for some specific applications, but not for mass transportation to the Costa del Sol.

We are told to have high expectations of nuclear power, and that Small Modular Reactors will save the day, and perhaps they might give us 30 years here and now, but what is the legacy to our grandchildren?

Meanwhile the technologies and lifestyle changes that could make the necessary impact at scale are being under-developed, mis-managed or are being subjected to dis-information attack.

And the public, you and me, is left confused and bewildered, with no clear idea of planning for the future.

What is required is a new type of Engineering, and we’ll go into this in quite a lot of detail, and that’s the whole purpose of the talk tonight - where we recognise that people, and indeed the biosphere, are part of the machine or structure that we Design.

So I’m not talking now about cars or aircraft, I’m talking about the planet as a machine, and that the humans, we need to be engineering that, and that’s obviously not the skillset of engineers, not just the skillset of engineers, but we have some skills that can come to that.

Designing the changes in lifestyles and the way we use machines and structures to support that is called Transition Engineering.

Even this is not sufficient: we have to re-think what we mean by Economy and Government as the simplistic drivers of money (profit, wages, and taxation) will not ensure that the needs of the common good are met.

In conclusion, Engineering can and will play a large part in tackling the challenges ahead, but it cannot do this in isolation.

There will need to be some radical changes in societal leadership and a far more honest review of the potential of the technologies being developed in the name of "Net Zero".

We cannot afford to play politics: we must work Engineering.

So let me set some context. I’m an engineer, and a large part of my career background is in aerospace engineering. Yet I am here talking about matters that go well beyond engineering. And about matters that are arguably beyond my experience and expertise.

But we all do that, when we talk to our friends, discussing the issues of the day, and trying to set the world to rights.

What I intend to do tonight is to frame the Climate Change issue (and related issues) around my outlook and personality type – as an engineer, and around the knowledge and expertise that engineers can bring in general to the general and specific problems, so general and specific problem-solving.

So People define Engineering or the Purpose of Engineering in different ways, for example, the Institution of Mechanical Engineers describes engineering as “Improving the world through engineering”, the Institution of Engineering and Technology says, “Working to engineer a better world”, and the Royal Academy of Engineering says, “Harnessing the power of engineering and technology to build a sustainable society and an inclusive economy that works for everyone”. Even Sir Francis Bacon, writing 400 years ago, set out an imperative for the advancement of scientific knowledge: “For the relief of man’s estate”. In modern times, given the extent of our knowledge and the impact our way of life is having, the “estate” can be understood to mean “our Planet”.

Personally, I rather like B’Elanna Torres’ comment (from Star-Trek Voyager), “It may be the warriors who get the glory. But it’s the engineers who build societies.

In each of these statements, there is goal that concerns the world or the society that inhabits it.

And in a similar spirit, my definition is, “Engineering creates the infrastructure that enables a civilization”. So, I’m thinking beyond the usual confines: Engineering isn’t only

* Designing and manufacturing things like cars, aircraft, and the infrastructure for washing machines or space telescopes…
* Or building structures like bridges, railways, tunnels and towers…
* Or mining…
* Or generating and distributing power…
* Or creating chemical products and food at scale…

Although each of these does require a specialist engineering expertise.

These are the nitty-gritty details of engineering. These are the skills and knowhow needed at the detailed end of the process: the “How to do it” side of making stuff. And I know I am here speaking as an Aerospace person, many of you here are expecting to hear about aerospace engineering, specifically, in this talk. But it will come. But, first I want to set the scene and say some very generic things about engineers and about people, and how we all view the world that we live in.

So coming back to this, we mustn’t reach straight into the details: first we need to decide, as a society or civilization, (and that means all of us – all of you), what it is that we need the engineers to make or build?

I’m pretty sure that for most of you, who have read the flyer for this talk, and have come along tonight, the one over-arching question is this one:

How should Engineering (or we as a people) rise to the challenges of Climate Change to preserve our Continued Existence?

So, I’m setting aside all those other questions that we see and read so much of, like

* Should I get an electric car?
* How and when will Hydrogen be introduced as a household fuel?
* What needs to be done to enable renewable energy sources like solar and wind provide a sufficiently continuous supply of electricity?
* What is “Net Zero”? Does off-setting really work, or is it a gimmick?
* And, yes, we might believe that any one of the ideas and concepts that appear in the media or in advertising material is technically possible as a one-off, but is it feasible or even sensible at scale? And by at scale I mean all of it, pervasive, everywhere.

These are details questions, and specialist engineers will address them. For example David Sprake who’s here in the audience is going to be speaking here at Wrexham Glyndwr University next Tuesday, 6th December, as an IMechE hosted public lecture, and again on 19th January as part of the Glyndwr public lecture series. He’ll be speaking this sort of aspects.

But I want to come back to the General Point: if engineering creates infrastructures for civilizations, what sort of infrastructure do we need now?

* Can we imagine it? Each of us might have a different vision, but if we share our visions and share our questions, then maybe a shared vision will emerge?

But I am worried that this will not be the case, because there is very little “society level” framing being done. What do I mean? Well, let’s take a “for instance”

* There was a change to the petrol supplied on forecourts about a year ago (September 2021). The change related to the percentage of added renewable ethanol (10%), and the new grade of petrol is called E10.
* Yes, there was information on this on the [www.gov.uk](http://www.gov.uk) website.
* Yes, there were media articles about it, if one searched, but
* No, I didn’t see much of a campaign to inform people about the change in advance,
* Nor did I see any educational information about the reason for the change,
* Nor about the implications, like the change in fuel economy or pricing.
* Yet petrol vehicle engines have been designed to run on E10 since 2011, so there has been plenty of time to provide public awareness. It just hasn’t been pervasive.

It was as if communicating with motorists was not a matter of importance. If one thinks back to the years leading up to 2000, when leaded petrol was banned. I recall the argument about the dangers of leaded petrol since my earliest childhood, so I’m going back to the mid-60s. Unleaded petrol started to become available in the late 1980s, and it became the “done” thing to insist on buying a car that could run on unleaded as soon it became affordable to do so.

* It was a necessary period of transition. And an inevitable one too: there had been 20 plus years of public narrative about the evils of lead in petrol.
* The change was coming, and everyone knew it (even small children), even me in 1970, everyone wanted it, and everyone was waiting for it.
* Affordability is an important point: not everyone can afford a new car, but some can. So, it takes some years for new cars to enter the second-hand market, and eventually all second-hand petrol cars ran on unleaded.

What I do not see now, in regard to Climate Change related actions, is this level of expectation. I think there is a failure of leadership and a failure of imagination and we can all wonder why.

We all wait for a realistic understanding of how we are going to phase out fossil fuels, but:

* Actions taken seem to be piece-meal, and it is unclear, at least to me, whether they are scalable,
* Actions that are taken by individuals (like installing solar panels) have been incentivised, but only up to a point, and there’s a lack of transparency about the future direction,
* The same can be said about house insulation, and heat pumps, etc,
* Yet, given that new build houses, which can, surely, be designed to maximise the value of all fuel-saving features, are still being built without proper consideration of insulation, or solar panels as standard.
* Why not? Because there is a lack of legislation? A lack of empowered demand – I mean, people buying houses insisting on that?

If, at governmental level, there is little evidence of forward thinking, and addressing significant problems, then what messages does that send to us?

Throughout the course of this talk, I shall speak about

* Engineers,
* and about “us”: you in the audience and me,
* and “us”: members of the Bacon2020 and The Relief of Our Planet team
* and “us”: human beings on Planet Earth

I’ll avoid too much engineer-speak, and I’ll refer to fiction (books, films and TV series) – stories that help us to imagine different realities and different futures, inhabited by people (not necessarily human) but who remind us of ourselves.

I think it is important to feed that imagination, after all, “Too much work and no play makes Jack a dull boy!”

But we silo education, particularly at tertiary level. Students study science or engineering, and students study the arts. Here at Wrexham Glyndwr, we have a Faculty that straddles both: not STEM (science, technology, engineering, maths) but STEAM (science, technology, engineering, ARTS, and maths). One of the important aspects of transdisciplinary teamwork for me, was to have the mirror held up, so as to see other peoples’ perceptions of the things I knew about as an engineer, and to find a way to understand and communicate the human-facing aspects and consequences more effectively.

So what are engineers? Well, let’s move on and think about Engineers. And here, I really want to focus on the core aspects of Engineers – not our individual specialist knowledge, but what characterises us.

There are some pretty obvious characteristics of engineers. Given that our educational formation is strongly based in maths and the sciences, and our field of activity is practical and tangible, it is to be expected that Engineers are:

• Logical and analytic: they recognise essential details; they are

• Knowledgeable about science and its applications, and are

• Problem-solvers.

But there are other aspects of mental make-up that tend also to go hand in hand with these types of skill, such as

• Introspectiveness,

• And even an almost excessive focus on precision and attention to detail.

And as well as this I’m talking about aspects of a person that come under the heading of neurodiversity. In designing safety critical machines, precision and attention to detail are an absolute must. And people (like engineers) with a strong capacity for identifying patterns, or with an affinity for numbers, can also be introverted, prefer their own company, and have other personal preferences that seem unusual to other people. This can include, diagnosed or not, traits such as Autistic spectrum, Dyslexia, and so on.

The issue is that while the “doing” of the engineering job requires the kind of mind that does engineering well, there is a communication, or a leadership, need to present the engineering work to a wider audience.

Further, that the characteristics of engineers, being what they are, it is rare that the engineers themselves have the opportunity to communicate directly.

This is what I mean by Compartmentalised.

That Engineers are told things like, “you’re such a talented designer, or stress engineer, or whatever, and it would be a waste to have you as a manager”, and from there, the engineer’s personal development is channelled, and limited, to the development of their particular skillset and away from developing comfort in leadership and communication which is a loss.

I need to say some more things about Compartmentalisation. If you read the old adventure or sci-fi books, by people like Nevil Shute or Robert Heinlein, the skilled engineer is often described as one of the “backroom boys”. In other words, the brains that develops the essential piece of equipment, but who is kept “in the backroom”, and not encouraged to speak to anyone influential.

These story lines inevitably find a way for the backroom boy to interact with some disastrous situation and save the day, but not without having some kind of diplomacy *faux pas* and that’s necessary to the storyline to add some tension and interest.

In reality, and all the engineers here would probably agree with me, engineers are often very good team players, extremely helpful and supportive to each other, and nurturing to younger members of the team. And very many engineers answer the call to be STEM (Science, Technology, Engineering and Mathematics) Ambassadors, and give their time freely to encourage young people to study sciences at school and university.

It seems to me strange that Engineers, on the one hand, recognise the need for increasing the number of future science and engineering professionals. Even to the extent of giving their time free, to engage and convey this message. And remember, this is a political message, it’s the stuff of white papers, and the importance of manufacturing to the UK economy.

And yet, I’m not so clear on how effectively the communication from Engineers is passed back to industry leaders and government.

Well, to be honest, I know something of the process: each of the Professional Engineering Institutions will decide, separately or together, to write a lobbying statement. Such a statement has to be written very carefully, because any mistake of judgement could have disastrous consequences. There might be a survey of opinion from the membership of the institution, but there are bound to be conflicting opinions, and minority views might be missed out or simply not understood in the context. In doing so, the strength and the richness of opinion is filtered out.

Let’s come back a bit and think again about richness of opinion. This has been one of the more significant arguments for Equality, Diversity and Inclusion. For a long time, this has focused on increasing the number of women in engineering, because if there were equal numbers of women and men in engineering, it would almost double the number of engineers. These days, there is greater focus on the value of diversity in “lived experience”, and removing barriers for those not just for gender, but for BAME, LGBTQ, neurodiversity, disability, and socio-economic circumstances. As a University, Wrexham Glyndwr is a stand-out example of this, again for the fifth year running I think, ranked number one in England and Wales for Social Inclusion.

So, the idea is that in increasing the diversity within a group of people, there’s a possibility of a richer outcome. Let’s take another example, this time from the fantasy literature.

In Tolkien’s “The Lord of the Rings”, most of the protagonists are male; however, they represent different species: Men, Elves, Dwarves, Wizards, Ents, and Hobbits. The Hobbits are frequently overlooked as being the smallest, and weakest, but ultimately turn out to be the greatest heroes. The Nazgul King is second only to Sauron as the most evil being in the story, and is under a spell of protection so that he cannot be killed by a Man (a human).

There were two warriors at the battle who were expressly forbidden to take part in it: Éowyn, a (human) princess, and Merry (a Hobbit). While Éowyn’s slaying of the Nazgul King looks, at first glance, as a victory for Womankind, she is still a human. The blow that broke the spell of protection was made by Merry, the Hobbit. This victory was a team victory; a team victory enabled by diversity.

So, now I come to thinking, not just of Engineers, but of all of us, and all our opinions.

“We”, as a population, are even more diverse than the “we” that is me and other engineers, we that is everyone here in this room

• There is a far richer “lived experience”,

• And a far richer set of knowledge and skills.

If we return to the question previous posed, and now slightly modified, How should **we** rise to the challenges of Climate Change to preserve our Continuous Existence? Well, isn’t this just like a customer-supplier discussion:

• The customer specifies what the product needs to be able to do

• The supplier presents options that might fulfil some or all of those requirements

• And there is a two-way discussion about the feasibility and cost of options – not as a battle field – but to ensure that the customer understands and makes an informed decision.

And it all comes down to this:

• What does the new infrastructure for civilization look like, and

• How do we get from here to there?

Do I know all the answers to that? No, I know some of the answers. Do politicians know all the answers? Industry leaders? Nobody knows all the answers, but each of us knows some of the answers, or can imagine what some of the answers should look like for us individually.

Now, most deliberately, I want to show you a blank slide.

I would like you to stop and think: to take away every preconception that you have about how your daily life works, and how it could work. The place we are trying to get to is a daily life that uses less energy – less fossil fuels, obviously, but using less energy would lead to this. Also consider your happiness. What are the things that give you greatest pleasure? Do these require energy to be expended? What gives you satisfaction in your life? What gives you dissatisfaction, and can that be changed? Would changing it impact negatively anyone else?. Give you a few moments to think.

Because when we set out the ideal civilisation, this is what we should be aiming for I think. Ok. I’m introducing here Maslow’s hierarchy. We can talk about the very basics of life, in terms of Maslow’s Hierarchy of needs. I imagine that most people here would consider themselves in the upper categories? I think this model summarises quite well what we would want for everyone? It could be a validation test for whatever we might imagine for our new infrastructure for civilization.

I mentioned before that one of the core skills of engineers and there’s a tool called “The Five Whys”, and it’s’ thinking tool, and it originated in manufacturing process improvement area, but is a good tool for challenging fixed ways of thinking.

The process of “The Five Ways” is to use the question “Why?” to challenge assumptions. Let’s take an example. Let’s look at electric cars. We start with a statement, “I want a car with an electric drive instead of a petrol engine” – so, a like-for-like replacement of the car that I might already have. This is natural, and probably every car driver is having a similar thought. Then we challenge it with a question:

Why? And most people would answer along the lines of the need to cut CO2 emissions, use less fossil fuel: in other words, Climate Change, and then we might ask Why there is a cost incentive. Obviously to drive this behaviour.

I don’t want to go into huge detail here, but you can imagine Whys asking about the source of electricity to charge the car, and the source of materials for manufacturing the battery. There could also be questions about the configuration of the car regarding engineering factors like centre of mass, and how the wheels are going to be driven.

But let’s keep this focussed on the needs of the driver. Why does the driver want a car? Obviously, because that person wants to be able to go to places. We can ask why?

And the likely most significant answer is to be able to go to work. The use of more Why questions, would probably yield the usual answers: having enough money to live, job satisfaction, etc. But there are already trends emerging, with a greater demand for Working-From-Home, and much of that has been enabled by the challenges posed by COVID and addressed in the last couple of years, but I don’t want to think about that, I want to go to another opening question: why travel alone?

About the idea of personal transportation, rather than public transport. More and more people are asking this question of themselves, about making a transition from using the car, to using public transport, for regular journeys like going to work. Yes, some people will walk or bike, and some will switch to public transport. But for a large number of people this is simply not feasible. Either the distances are too far, or public transport is inadequately joined up to make the journey possible.

There are many other sides to personal transportation that could easily be explored, but here’s a really important one:

A few years ago, I signed up for the National Highways alerts about road closures. Here’s an example. It’s not unusual to receive half a dozen such alerts in a day. Some are closures for scheduled repairs, and sometimes for “a police led incident”. But mostly it is because of a collision or vehicle fire, or for emergency repairs of the highway after that. It is depressing reading: daily collisions, some with loss of life, and all implying 60, 90 minutes journey time lost by thousands of drivers caught in the tailback.

By comparison, rail and air travel is significantly safer. Is this an inconvenient truth, that we never speak about? It brings me back to the question of planning appropriate infrastructure: infrastructure that serves the needs of a civilization. I mean, all people within the civilization, not just the businesses, not just those with money, not just those who can afford to make choices. Don’t we all deserve a well-designed-in level of safety in our civilisation infrastructure?

Now, I’d like to pause, and consider again, the reasons why we do the things we do.

I imagine that almost everyone here believes that Climate Change is an issue and recognise the imperative for a reduction in CO2 emissions to contain the extent of change to remain within limits. We don’t need to be climate scientists to believe the general messages, and we recognise that “doing our bit” is the right thing to do, necessary limit the number of species extinctions, and fair to other people in other places and countries that are more susceptible to the effects of climate change. Indeed, we probably all recognise that it is necessary for the survival of our own children and grandchildren.

Yet…

* We still drive our cars – and whether they are fossil fuelled or electric is by the by, as the energy to build and ship them, as well as the electricity to power them, still must be generated. And even if all of that energy were renewable, that is taking renewable energy that couldn’t be used for something else.
* We still run our heating, take baths, and wash our clothes – perhaps to an extent that is more to do with comfort than need?
* And, coming back now to the Aerospace Industry, we all expect to go on holidays, the same sorts of holidays that we have got to having: weekend city breaks in Europe? A week in the sun; Greece, on the Mediterranean, or the Canary Islands? Or long-haul to the Americas, Australia, etc.

So, on the one hand, we know and understand the Climate Change messages, but on the other hand, there are still the societal expectations that drive us to continue to use energy. And this leads to Cognitive Dissonance. We are presented with conflicting narratives, which we are not empowered to resolve. We all live as members of society, a civilization. And we all have an awareness of social signals.

* These include official rules (the Law) and official pieces of information (for example, Governmental policy and incentives to follow policy), and
* These include the social narratives: our “peer pressure”, the collective beliefs and habits of “people like us”. Within any society, there will be a multitude of “communities”, and these will overlap with each other.

The important thing about the official channel is that the stronger and more pervasive the messaging, the more seriously one will take the message. Introducing fuel rationing would be a strong message. Setting up apprenticeship training for home insulation fitting, and making a public register of those suitably qualified, would also be a strong message. We’ve had strong messages about COVID behaviours, so we know what strong messages look like. I don’t believe, and maybe you don’t either, that we have had strong messages about the route to “Net Zero”.

The important thing about narratives is that:

When we associate ourselves with narratives, they become a kind of descriptive form of meaningfulness for our lives. The why we think what we think and why we do what we do. The narratives are a short-cut statement of our ethics and who we are.

* Of course, we can challenge and change our narratives: and the process of moving into adulthood is precisely the process of developing and validating the narratives we adopt that are different to those of our parents. This is wrapped up in the saying, “It takes a village to raise a child”: the child needs access to a multitude of narratives, and to know that it is OK to be different.

The lack of strong official messages, and conflicting narratives, means that we have a problem with resolving the conflict in our understanding. Not being able to resolve conflict is a source of stress.

We need an Official narrative to tell us what the future looks like, and we need to be Involved in discussions, so we can Plan without fear, for what that future looks like for Us. So we need to plan our future, individually.

* In other words, it is for Government, and other leaders in powerful positions, to set out a credible shape for the direction forward.
* We need to be involved in this, to shape the details that impact on us, and to provide the benefits of our knowledge, insights, and needs, to make sure that the shape of the future is going to be fit for purpose. So, we do not fear the future, but recognise its coming and how the threats of potential changes will be resolved.
* And any future shape will have a multitude of niches, so we might want to think about aligning ourselves to a particular one. For example, making a career choice based on a good understanding of demand for that career, and the locations where people with that career can live and work. Other factors might be the availability of renewable energy for large scale manufacturing, or a need to de-populate areas where frequent flooding will become inevitable. So we need to think about our futures and what we’re going to do and how we’re going to adapt towards those futures. And that’s the bit I think is absolutely missing at the moment

I’d also say that we should each forgive ourselves for our feelings of guilt and inadequacy.

* For many, this cognitive dissonance is enough to deny belief in the Climate Change issue: as after all, if the government isn’t seen to take it seriously, then can it be serious?
* For those of us that take it seriously, understanding our feelings and those of others can be helpful. May it can help us individually to formulate more effective actions.

I’d now like to come back to the question of what the Engineering profession can do. And I’d like to introduce the concept of Transition Engineering. With the level of infrastructural changes that are going to be required, and the speed at which they will need to be implemented, this doesn’t look like an incremental transition. Small change is not going to work, it’s going to have to be big and soon.

* Yes, new central heating boilers are “hydrogen-ready”, and
* Renewable energy is feeding a substantial fraction into the grid, and
* There is some investment in the railway infrastructure and city transport systems

But, if we think about The Five Whys again, we might recognise that some of these preparations don’t get right down to the root question, for instance

* Why do we see Hydrogen as a housing heat source at national scale? Is it safe, is it the best way, what are the alternatives?
* To maximise the utilization of renewable energy, the key enabler is going to be energy storage. What are the developments on this front?
* It is great to see improvements in the rail infrastructure, but how well does this join up with the rural transport needs? What is being planned?

But instead of asking these nit-picky questions, perhaps we should go right into the basics.

So let’s go to transition engineering. The concept of Transition Engineering was developed and championed by Professor Susan Krumdieck and Daniel Kenning, among others, and it’s been going for about 10 years on with the view that it should a recognised discipline spanning Engineering and engaging in a transdisciplinary manner beyond Engineering.

* They cite the precedent of the discipline of Safety Engineering, which was developed a hundred years ago, in response to a factory fire in which many employees lost their lives. If Safety Engineering could be developed so quickly in response to such a need, then so too can Transition Engineering.
* There’s a textbook, and Masters level programmes at the university of Canterbury New Zealand is being developed and is beginning to be offered at various institutions. As a discipline, this sits well alongside other aspects of Engineering Management and Innovation, like Systems Engineering, Process Improvement, Design innovation, and so on, because it challenges the basics of Why, and places importance on solving the root problem.

The main tool of Transition Engineering is the InTIME tool. We start with a schematic graph of resource use (or CO2 generation) over a period of time. We can place history on that graph, and the passage to the present. Now then can think of scenarios for the future.

… but these are not the futures that we want, the ones with the scary levels of CO2. So let’s plot the Ideal future.

The question is, of course, how to get to the Ideal future, and we can use a technique called “Backcasting”. Backcasting is about working backwards from the Ideal Future, so we can work out what preliminary steps there might be to reach that future. It is an activity that requires imagination and intellectual freedom. An ideal area in which Transdisciplinary facilitation could play an important part. Having established the steps, and identified technology or infrastructural gaps, it is possible to start planning the projects that provide the Enablers. Each of these could be self-contained projects, or they could be concatenated. But that’s a matter for detailed planning by the expert engineers, scientists, industrial leaders and politicians – to determine the costs, the timescales, the project risks, and so on. But as that is put in place, then the transition process can happen.

So, finally, after having introduced a lot of ideas and concepts, I’d like to turn to the future of Aerospace. I don’t want to go into details about hydrogen or synthetic fuels, lots of specialists are working on assessing the obstacles and developing plans for the research and development that would need to be undertaken, and there are many aspects here, and each can be a lecture in itself, but I want to go back to the 5 whys and intime thought processes, and there are three particular things that come to mind.

Why do we want to fly? And this is a very simple questions and you’re probably thinking I’m out of my mind. Flights have been grounded for temporary issues like 9/11 and volcano eruptions and even covid and these did an immense amount of interruption and I’m not proposing anything so abrupt. But what I am wanting to do is to question the growth of the aerospace industry; the industry wants the growth and people like being able to fly. But it’s an artificial bubble, driven by cost differentials between flight prices and rail for example short haul flights within country and perceived benefits for foreign tourism which currently outweigh those for internal tourism. And perhaps the recent surge in air travel is the short term results arising from covid restrictions – people are so glad that they can finally go and take their holidays. In part, I wonder whether the bubble will burst because of political pressures or consumer ones, or a combination of both, but I do think that if people think about their carbon footprint then they will increasingly think more carefully about their decision to fly and unless or until there is a clearer narrative, there could be a downturn.

Then there’s a question of the narrative, and are narratives true? And let me explain what I mean. The industry wants continued growth, and people are hungry to fly with a clear conscience. The messaging coming from the marketing, the social media feeds about new propulsion systems and new air frame concepts, they feed that hunger, such messages are true in the sense that the information provided is true when read and understood by an expert, but how are those messages understood by others? The first flight of a single seater electric aircraft might be the first step of a new class of air ambulance for example, but it doesn’t readily scale into an electric powered 150 seater commercial flight to Benidorm. And I think there is an ethical responsibility, to ensure as far as reasonable possible that the received narrative, not the one that is presented but the one that is received by the listener, that the perceived narrative the industry creates are just are true for the non-specialist audience

So if we do fly, why can’t we continue to use fossil fuels? The fly in the ointment is the terminology net zero. At one point carbon offsetting are viable and realistic approaches to reducing fossil fuel or at least reducing carbon dioxide. And in the aerospace industry, up until 10 years ago, when I left the industry, the drive was to improve efficiency by improved design and more capable materials, and it was predicated on the idea that flying was a special case and represented only a small percentage of the current carbon dioxide production, so I’m going to go out on a limb and you’re going to question my sanity, but hear me out. If we consider aerospace as one part of a total system and that is a system of civilisation rather than a system of its own self-contained system, then the argument of special case makes more sense. Taken in the context that aerospace is deemed to be an essential part of a civilisation, if that’s a civilisation that we want to design, what is more important, the overall efficiency or cutting the carbon dioxide production of one place in that system, one sector in the system? So for non-specialists in aerospace, you should note that in the fuel tank is a large fraction of the take-off weight of an aircraft, it’s the limiting factor, so when you think of batteries, batteries are, so for an electric aircraft, batteries are so heavy that electric aircraft that are large and long distance flight, this isn’t’ viable; there would need to be a huge leap forward in battery technology to be able to do this, and in theory, hydrogen has high energy density, but by the time you think about the storage and the safety systems that are required for the use of hydrogen as a fuel in aircraft, the increased weight of the aircraft would remove the weight benefit of the fuel. Then thinking about synthetic fuels, there is an energy cost in producing the fuel and how does that compare with the fossil fuels that are used for the special case of flying? So I’m trying to say that there is balance here that the narrative is pushing us to expect net zero in aerospace but I’m not it is the best way. In the long term, yes of course, but we have to stop using fossil fuels but can we buy time to do better later.

In terms of transition engineering is an analogue for what this could look like, for example if we wanted to build a complete public network we would need to build some more railway lines ,and that would take time, so as part of the transition, so that there is an equivalent infrastructure in place, we could run buses on existing roads to fulfil the needs of the network, and this would mean that people can move to using public transport and make their personal transition despite the fact that buses are slower less efficient, but they meet the infrastructural need for the present time. And so enable the process of transition to begin.

So for air travel, do we need to plan for a transition to an air transport, this is perhaps only for people and urgent goods, do we need to look more towards future realistic means of travel, so nuclear fusion powered aircraft, or change the idea completely and look at something like luxury airship holidays. And whilst all this unfolds, remember the aerospace industry is full of manufacturing, engineering, and design and leadership talent and these are very transferable. So there’s going to be a market for rail vehicles, infrastructure, renewable energy equipment, nuclear power, environmental protection structures and so on. And the example of this is the way in which Rolls Royce repositioned itself as a power company and entered the nuclear power business. Companies in aerospace could develop sideways in this way and build skills and maintain their profitability and be ready to generate the next generation of solution.

My honest view about the aerospace industry is that I don’t know enough, and all I can do is watch from the outside. I image in that there are some considerable commercial sensitivities and in the fullness of time the logic behind all this will become to make sense, but these are difficult times, and in difficult times, people will ask difficult questions. And that and is the question that I posed right at the beginning: is it too much to ask for a transparency about the direction of travel and we all need to know where we’re going before we can feel confident about getting on board.

So finally I’d like to bring up an appendix and talk to you about why I worry about hydrogen. Hydrogen is currently seen as the next fuel source, it’s going to save our bacon, and the logic goes as follows: excess power generated by renewable energy sources can be diverted into splitting water into hydrogen and oxygen, and the hydrogen is then a form of stored energy and it can be burnt, recombined with oxygen to give water vapour and heat and it’s a cycle. And this is a very nice narrative, hydrogen burns creating carbon dioxide and it can be a by-product of overproduced renewable energy, but there are some serious practical concerns. So safety and storage, the volume and pressure of storage, the problem of leakage and the efficiency of the cycle, the cycle of splitting it, burning it, and producing the water vapour and so on. And there’s the problem that um from the point of view of the aerospace propulsion fuel although there’s no carbon dioxide produced, there will be water vapour produced and this is another greenhouse gas, and it’s being pumped out into the atmosphere, so the upper atmosphere. And there are some obvious engineering problems that the engineering problem solvers will look at and address, but there’s one more fundamental problem that I think isn’t getting sufficient attention. Any hydrogen that leaks as gas into the atmosphere will eventually leave the planet, and hydrogen leaks extremely easily through all materials because it’s such a tiny molecule, so how much you try to store hydrogen, it will leak. And planet earth is a very small planet and its gravity is insufficient to hold onto any hydrogen gas in the long term. We know that hydrogen is the most abundant element in the universe, and yet there’s very little hydrogen in the earth’s atmosphere are gas. And the consequences of that is that if hydrogen is used as a fuel at scale, then, eventually there will be a loss of water on the planet because hydrogen will not be burnt, it won’t recombine to form water. And one would like to think that that would be an insignificant amount, but I don’t believe it is. So If we think about our population trajectory over the next 1000 years or so, and our power usage, and remember that the first world uses far far more than the third world and the population statistics for the first world are much much smaller than the third world… so even then, if we assume the population and power needs remain constant, only of course they will not and we assume hydrogen leakage rates are not improved, and we assume all future power is generated through burning of hydrogen, the I would estimate, and this is a back of the envelope calculation and I need to do better, but I estimate a loss of water equivalent to about two thirds of a centimetre that’s three eights of an inch on sea level. And to be clear, this isn’t water tied up as ice on polar caps, it’s water lost from the earth.

So, I’d like to summarise, I asked is it too much to ask? And I asked, how should engineering rise to the challenges of climate change to preserve our continued existence? And by this I meant that we should all have a role in specifying and validating plans for civilisation and infrastructural changes that engineering could enable. And my intention was to ask for transparency and better social inclusion with the issue of climate change and to present some reasons why that is important. I see that all of us, all humans on earth, have skin in this game, it matters to all of us, and some of us have the answers and we might be engineers, we might use transition engineering as a tool, but we can also be artists and storytellers or people who have different lived experiences or who lived in different parts of the world or as first nation people have ancient knowledge handed down. And so, don’t leave this to the experts, we all have a role to play in designing, building, and planning a sustainable and equitable future for all. Thank you.