COMMISSIONER: Good morning. Welcome back. I am sorry for a technical delay. The topic is Nuclear Education and Skills Development and I welcome Dr Addie Paterson, the Chief Executive Officer of the Australian Nuclear Science and Technology Organisation. Welcome Addie, thank you for joining us?

DR PATERSON: It's good to be here, Commissioner.

MR JACOBI: Dr Adrian Addie Paterson commenced as the CEO of ANSTO in March 2009. In this role he has the oversight and responsibility for ANSTO's multifaceted portfolio of activities. He has a wealth of experience in national and international science, innovation and energy policy settings and nuclear fuel cycle issues globally including his role as General Manager of Business Development Operations at the Pebble Bed Modular Reactor Company in South Africa. Dr Paterson was elected a fellow of the Australian Academy of Technical Sciences in Engineering, AATSE, in 2009. And in 2012 he was elected a fellow of Engineers Australia recognised by the Sydney division as the 2012 professional engineer of the year. In 2015, he was elected a fellow of the Royal Society of New South Wales. He is a member of the Academy of Science of South Africa and the South African Academy of Engineering. He holds a Bachelor in Science and Chemistry and a PhD in Engineering from the University of Cape Town and the Commission calls Dr Adrian Paterson.

COMMISSIONER: Dr Paterson, can I start with the technical expertise – we need to understand what the current state of technical expertise is in Australia and what we might need to do in the future, were we to participate more fully in the nuclear fuel cycle. A theme of some of the submissions that we have received over the last six months has addressed the issue of a lack of technical skills in Australia to be able to manage this activity and I saw recently in a press article where you addressed the issue of skills and had perhaps a different perspective. Perhaps you could start with that and then we might want to unpick each particular part of the nuclear fuel cycle and where our skills base are strong and where they aren't. But in terms of the general sense of the skills in Australia?

DR PATERSON: Well Australia fortunately has some very good nuclear skills. The strongest skills base that has been around for a considerable period of time is in the nuclear medical environment. In nuclear medicine there are a range of skills that are required, for instance if one is to undergo a diagnostic scan and you go and have a PET scan at a hospital, behind the room that you are in for the PET scan and the PET machine is a whole series of people who provide safety and assurance that the PET scan will be diagnostic in nature and that the radiological risk is very, very low. So you will have health physicists for example, who are trained to understand the impact of radiation and the doses that are supplied to patients. If those doses are fabricated in a cyclotron, you will have a group of people who can operate cyclotrons. These are accelerators that produce the isotopes to be used in nuclear medicine. The skills that you use to shield and protect the public and the environment from the cyclotron are the same skills that you would use in providing radiation protection in a power environment for example. In addition to that, you have the opportunity then to look at the skills that underpin the support of that. People who can build these types of facilities, people who understand the calculations you have to do in order to have the correct shielding in order to make sure that the doses in nuclear facilities are as close to background as possible.

So the nuclear medicine community, I think has had long and strong tradition of safety; 224 clinics in Australia every week receive a generator which contains molybdenum 99 which is transported from ANSTO to those clinics to provide the basis of diagnostic nuclear medicine. So those long traditions, I think should give us confidence that we aren't without a base line of nuclear skills in that regard. In addition to that, we have had uranium mining in Australia for a considerable period of time. Uranium mining deals with the front end of the fuel cycle and the type of skills that are required there are the safe operation of those mines and as the conversion of the material from the ore to yellowcake which is transported, there are a number of issues in that part of the processing where understanding of where the different decay products of the nuclear chain reaction, which is happening just naturally. It happens in the earth all the time. But once you start to concentrate the ores, obviously you then have to know where those different radiator materials are going.

There is a huge amount of skill in Australia in doing that and it is monitored independently by the regulators and they provide assurance that the public and the environment is not going to be negatively affected and the operating people keep it done safely. So there you have people who can understand the processing parameters, where the isotopes are reporting to, how that can be mitigated if there is higher doses in certain parts of the plant and so on. That is very similar to the type of management of the facilities that are off the nuclear island in a nuclear plant to make sure that there is no contamination of the water for example. So those skill sets apply directly in to the nuclear energy environment and can provide a lot of confidence. In addition, we have the skills that have been developed around the Opal reactor ANSTO site at Lucas Heights, just in the south of Sydney. We operate a nuclear reactor in Australia. It is not a power reactor and it has much less uranium in it for fuel than you would find in a power reactor but everything else about the supply chain for the Opal reactor is essentially identical to the fuel supply chain for a modern power reactor. We have to specify fuel. Our fuel at the moment is fabricated in France; we have to control the flow of the uranium. This is all safeguarded and under IAEA rules and so understanding the transport and fabrication of nuclear materials is something that we have acquired over the period of time that we have operated nuclear reactors in Australia. Once the fuel is at the reactor, we have to put it into the reactor and use the fuel as a source of neutrons. Research reactors are really neutron factories, and those neutrons are used to make nuclear medicine and they are used to provide scientists with neutron beams that they use to understand modern biology, geological samples, the quality of welds in gas pipelines, and so on.

So the benefits that accrue from having nuclear capabilities in the case of the research reactor are to our research community, our nuclear medicine community and some specialised supply chains. But essentially, being able to safely control a reactor, to have the people who can do the calculations - the best computer codes in the world to model reactors have been developed for the nuclear community over tens of years. We have those codes in ANSTO and we use them to model what happens in our reactor, for example. So apart from the benefits of having the reactor, it has created a base of skills for Australia.

Over and above that, since we built the OPAL reactor we continued to develop nuclear projects at ANSTO. For example, at the moment we are building a nuclear medicine facility which will significantly increase our supply of Mo-99. This global supply will be important in the future. The nuclear engineering capabilities that have been developed in order to build that are based on the plant that we had been operating for a number of years. So we partnered with the people who run the most recently built plant in the world, the South Africans, and our own operating experience of our current nuclear plant to design the next generation plant.

So the design and the underlying capabilities are always a combination of what's the best thing that happened in the last construction in the world, how can we improve that and how can we develop it further. So ANSTO has moved over the last seven or eight years from being essentially a sophisticated nuclear procurement engineering capability to a fairly sophisticated nuclear engineering design capability. So the first step is that you do need the procurement capability. You've got to be a smart buyer, and I think that there are plenty of skills in Australia to be a smart buyer.

But really, if you want to make it something that is part of your economy, you need to get that capability to be a player, not just a procurer, and it's there that I think there's a great opportunity, because we've seen it in action in ANSTO over the past seven or eight years. The nuclear engineers, because they are aware of the requirements of nuclear procurement, can start to develop confidence in the use of the nuclear construction codes, understanding how those calculations turn into design and how that design turns into an operating facility.

So I think with practical experience and on the ground evaluation, we've also seen it's not just the engineering capability that becomes strong, but the supply chain around ANSTO has also become more sophisticated. So we have just put in this nuclear medicine project about 420 people who are supplying trades to those construction programs, and we are able to upskill the people in the trades from the quality systems that they are already familiar with, construction, quality and so on, to the more demanding aspects of nuclear construction technology, nuclear mechanical engineering, the instrumentation and control and so on.

So once one starts to invest strategically in having nuclear capacity you get what I call translational abilities. You take people from their existing level of skill, and the top end of town in Australia at the moment is oil and gas, and then you incrementally improve their skills. So the idea that you have to build from the bottom up a whole new chain of people and they've got to go through all of the pieces of that is simply not true, even in the Australian context. We're also a country that imports people to help us grow and develop as a nation, and a country like the United Arab Emirates, which has gone into the nuclear supply chain with no nuclear background at all and not even having a research reactor, is very successfully constructing reactors at the moment.

So the skills problem, I think, is overstated, but the best practice is to be deliberate about the acquisition of skills. Now, the best practice that we've seen recently in the global setting is the United Kingdom. They've got a very clear program to develop their nuclear industry over the next period of time. They developed a skills authority that is dedicated to the nuclear area. They've got training programs at the level of trades. They've got training programs at the level of the early engineering capabilities. They are drawing in people who are familiar with the construction codes. Just in terms of things like the French pressure vessel code, there's a whole focused area for - they're probably going to build the French EPR reactor. They've got a specialised group of people learning about the construction code for that pressure vessel.

So you can get quite detailed about it, but you should only get detailed when you've got an intention to do something. There's no need to do the detail before, and I think because people are not themselves invested in the nuclear supply chain, they look at it and it looks a little bit like a blank wall, but in fact it isn't a blank wall. There's a lot of texture there, there's a lot of experience, and we've seen countries be able to get back into the nuclear supply chain very effectively.

COMMISSIONER: You talked about the skill base in medical transport construction. How do you assess the knowledge in storage and disposal? I notice, having visited ANSTO, you've got a facility there.

DR PATERSON: Yes.

COMMISSIONER: Can you talk about that skill base, how you see that?

DR PATERSON: It's very important. If one is getting benefits from nuclear, one also has to think about the by-products, and one of the by-products is nuclear waste, and so if one is making medical isotopes, for example, the gloves, the goggles, the smocks that the people wear when they are doing that, when it gets contaminated it's classified as nuclear waste. So I think most people think about nuclear waste in terms of lumps of stuff. In many cases, it's things like gloves and things like that. So low-level waste is normally constituted of the associated materials that may be contaminated.

Now, the first rule of doing that is to make sure that you've got a disposition pathway from your production facility to a holding area, because we have a principle called delay-and-decay. Some of the isotopes decay quite quickly and it would be pretty silly to call that nuclear waste if all the isotopes have decayed away. So we have a delay-and-decay principle. We then move that into another environment where it's stratified into different classes of waste. That is then stored safely on the site in the appropriate storage containers waiting for a national waste store and repository for the future.

So we've been doing that since the late 50s and we've got a very well-defined set of criteria which the regulator supports. The regulator is responsible for setting the final guidelines, but ANSTO is responsible for working well within those guidelines. So we never work close to the edge of the guidelines; we work as far away from them as we can to be fully safe and never create any risk from the waste. So we've got facilities that can handle high classifications of waste, intermediate level waste, and each waste form is understood in its own right, classified according to its own set of rules and responsibilities, and we already have the capability to understand that for what are called low-volume waste forms.

The change with nuclear power is that the spent fuel, which many people don’t regard as waste but simply call spent fuel, sometimes is taken directly to a waste repository, that's the United States practice. Other countries reprocess and get much smaller amounts of waste; that's the French practice. So depending on the choices that are made, your final waste management strategy determines the type of skills that you need in order to disposition it. But again, this is all about being able to measure radiation. The good news about radiation is it's very easy to measure. This is physics, not chemistry. And so when radiation is present it's very easy to detect and it's very easy to quantify. So we use the careful ability to measure to stratify the waste and then get it into a form that is safe and able to be stored and ultimately disposed of.

COMMISSIONER: Can I just dig down a bit in the transport scene, because clearly, as you've explained with medical isotopes, the transportation, you're in the middle of Sydney.

DR PATERSON: Yes.

COMMISSIONER: Can we walk through how you developed that experience and what's involved with that in terms of a skill base, how you grow that skill base, and then we might move on to look at the supply chain and your involvement in the transport there.

DR PATERSON: Yes, excellent. So when one is supplying nuclear medicines it's important to recognise that they're standard packages that are used for the transport, and those packages are designed according to principles that the radiation dose at the package cannot cause any risk to the driver, for example, who is transporting them on the road system and so on, and that's all to do with - when it's radiation, it's all to do with shielding, that's your first principle, is you shield the radioactive source, and distance.

Many people don't know this, but if you have a dose, for instance, at the edge of this cup and let's say that it was 20 microsieverts, by the time you have moved a metre away it's a fraction of that, and you go another metre, it's actually four times less for every time you double the distance. So you don't have to be too far away from a radiological source for the dose to go down, and I think, to me, one of the key messages we have to get around nuclear safety is if you detect that you are around a package and the package has got a number on it that says it's essentially safe, you are safe, it's not scary when you see the trefoil sign, it's actually information that tells you that you're basically safe.

So when we transport, we put the packages into the vans. The drivers are trained in the routes that the follow. They take it to the receiving bays at the hospital. The receiving bays at the hospital are organised that they can safely transport the generators into the nuclear medicine facility, and that is a standard practice, every week this is happening.

If a delivery is not made, we then have a process of recovering anything that might have happened. For instance, it could be that there's a massive traffic jam and it doesn't arrive on time. By the time it hasn't arrived on time, the message comes back to ANSTO and then we detect where the traffic jam is, we evaluate the risk which is normally very, very low or insignificant, and make alternative arrangements.

Similarly with the air transport of these packages because they fly by air to different destinations around the country. They're tracked as they arrive at the loading facility in the airports, they're tracked onto the plane, they're tracked off the plane and to the facilities. So there are two levels of integrity. One, inherently it's pretty safe. So you don't have a risk of inadvertent dose acquisition by the handlers and so on, but secondly there's a data flow and an information flow that supports that safety.

COMMISSIONER: In terms of training the staff, is that on the job training, is that some sort of technical qualification? How do you - - -

DR PATERSON: Typically we'll require an entry level of technical capability, and then we have specialised training at ANSTO. So we have - and this is a requirement also by the regulator. For each job category there's specified courses of training that people have to undertake. They have to keep up to date with that and we have a learning management system that tracks all of that. So we basically have a system that if somebody is not suitably qualified and experienced because those are the two things you need, you need to be qualified and experienced, they have lost their qualification because of the time expiry, they are no longer suitably qualified, they may not conduct that work until they have redone the training and been certified as competent. So competence and certification and assurance that that is the case is fundamental to a good nuclear supply chain.

MR JACOBI: One of the issues that we picked up last night in our discussions with professors from the UK was the nuclearisation of trades which I think you have picked up as well.

DR PATERSON: Yes.

MR JACOBI: I am just interested about who is doing the work with respect to nuclearising relevant trades and the extent to which that's something that's generally available.

DR PATERSON: Yes. So in the Australian setting for many years ANSTO has supplied a lot of the training and there are some other private vendors now for that type of training that have developed as the nuclear industry has got bigger in Australia. In respect of the trades, there is a very strong relationship between the needs of, for example, the uranium and mining community and the type of training courses that are developed at ANSTO and which are also available from other providers. So there is a positive and synergistic feedback between the needs and the requirements that are set.

So when that training is conducted, increasingly it's a combination of classroom training, digital training and practical demonstration that people have the skills. The important thing at the level of trades is to move people from where they are to the higher requirements of nuclear training. The higher requirements generally go to awareness. Your awareness level as a tradie in nuclear has to be higher because if you see something that concerns you, it's not just somebody else's problem, it's something that everybody becomes used to reporting.

So the awareness of the environment that you're in, what the requirements are of nuclear construction and so on is one of the training things that takes place. The second thing is quality. The nuclear codes for construction for mechanical engineering, for instrumentation and control and so on, are higher than they are for any other industry. So the quality systems are more robust and it is therefore essential that the quality process and the trades process are lifted to the level where it happens. This is not so much a safety issue as a cost issue. If you have to rework because the trades haven't met the requirement, that's a very expensive thing. So you have to train the people, for instance, with welding techniques to meet the full nuclear requirement.

Now, those are all specified in codes. Those codes are deterministic. You can determine when somebody has reached that skill level and so on. So the first thing is awareness. The second thing is quality, and then the third thing is the openness and transparency of the behaviour, as we call it, where if you think you have done something wrong, you know, it's fairly human instinct to not disclose it. In nuclear we put a lot of work into changing that culture, that people are disclosing when they think they have made a mistake, because if you disclose it and you're not blamed for that, in fact, you're celebrated for having disclosed it, you can then track anything that might be non conforming in the system.

MR JACOBI: To pick up on your reference to oil and gas, is there a model in terms of the training of trades perhaps from that area which I understand involves an upskilling - - -

DR PATERSON: Yes.

MR JACOBI: - - - that can be applied into nuclear that won't put the burden on, I guess, the procurer, as in ANSTO's case, but it might be able to be something that's generally available and provided by third party educators?

DR PATERSON: Absolutely. I mean, ANSTO for many years was in the nuclear medicine training business. We're not in that any more because it's been taken into the university setting and we're very happy about that, because it means that the early work that created the community has now been taken by the community into their own setting. So the reason we do it at the moment is that we have got a small nuclear footprint from the point of view of these nuclear facilities that have been constructed at ANSTO.

My view is that you can in a very practical way partner with good quality suppliers, typically the UK is a good example, which we have talked about before, where they have done all the hard yards of actually developing the protocols, the training curricula and so on, and then import those into the Australian setting, translating it into our educational environment, and I am sure there would be both private and public suppliers who would rapidly acquire that capability if they could see a consistent flow of people coming through in a new nuclear footprint in the Australian setting.

MR JACOBI: You spoke of the mining industry, nuclear medicine, which there's a fully developed industry with respect to those activities in Australia.

DR PATERSON: Yes.

MR JACOBI: The commission is also looking at activities where there isn't a fully developed industry, that is, things like conversion enrichment, fuel fabrication, the operation of a nuclear power plant, and I am just interested to understand in broad terms where you think the skilling is at the present time if you had to look at that capability. Perhaps we might then move to the idea of thinking about the importation of skills.

DR PATERSON: Yes. So certainly if one looks at - if we pick a piece, maybe if we went for fuel fabrication, for example. Fuel is a high tolerance, high precision manufacturing operation. So the types of skills you would be looking for would be people who are familiar with modern advanced manufacturing because that's really the environment that you're talking about, and to do probably a higher proportion of that remotely than you would do if you were just doing it in a non-nuclear setting. So remote operations are high precision manufacture.

There are icons of that sort of manufacturing around Australia. It would be a case initially of finding where those high capabilities are. Some of those have developed a little bit in association with ANSTO as we have set the higher requirement for them and they have met it, they have become, you know, possible touchstones at the start of that. So I think the first thing is then to recognise that you will find at the top end of Australian manufacturing, firms that could quite easily make that transition because they are already meeting a very high spec requirement, particularly aerospace is a good example. So our aerospace actors could very easily migrate laterally into a nuclear space.

Then in terms of importation of skills, the most efficient way to then build out the workforce base is initially to import skilled people, or alternatively take Australians who are close to that skills threshold and inject them into the industries in other countries where they can both learn by doing and acquire the skills in those settings. So it's a brain circulation model, if you will, where

Australians go and learn those skills and then bring them back, and that can be done in a very deliberate way.

In fact, the very early days of nuclear in Australia, that's exactly what happened, people were sent to the UK, they spent three to four years there, they came back, they felt competent to develop the HIFAR reactor, for example, ran really successfully for 50 years, probably was the cleanest, neatest and best operated when we switched it off. So that's the type of thing that can be done really effectively.

Then I think the other thing one can do is if you have got sort of iconic one-off projects, you would only build one enrichment plant, for example, if one was going to go into enrichment. I think you would have a importation of skills but what you want to leave is a very effective operating workforce and that's really important. You know, nuclear facilities cannot be run without deep knowledge of what is happening in those facilities and you would therefore, rather than look for a supply chain type of effect, you would really concentrate on getting the operators, the engineering teams and others, to have the deep skills to operate it for the lifetime.

So I think in each case one could analyse it. I think the complexity is over estimated. It's putting in the time and planning. Project skills, for example. I mean, Australia has got some absolutely awesome project managers, people who run really big projects in Australia and around the world. To add the nuclear component to that, as I say, it's awareness, quality and behaviour. You add those three extra things and you can take your top quality project engineers and people and you can move them into that environment. So the degree of difficulty I think is to do with people's lack of awareness rather than a fundamental feature of nuclear that makes it more difficult than anything else. I don't think that's true.

MR JACOBI: I just want to pick up one other aspect of that, which is the issue of scale, and last night, for example, we saw the graphs for projections of the need in the UK. Now, that's a very large new build program, but there is a question of scale associated with the idea of the scale of a skilled workforce necessary to construct, for example, a nuclear power plant that's large. I am just interested in your views about both the present capability to do that and perhaps how you might move to being able to skill such a particular exercise.

DR PATERSON: I think there's a profound difference between the UK energy setting and the Australian energy setting. The UK is going to build large plants and it's recognised that the existing sites that they have got around the coast, for example, are suitable for large plants, but at the same time they have very recently launched a very dedicated effort for small modular reactor construction. The big difference, and my feeling is that the nature of the

Australian energy grid - it's not just a feeling, it's something I have thought about a lot and studied, to see where you might look at different types of nuclear footprints.

I think Australia by definition is a small modular reactor destination and from that point of view one would have to look at the construction curve, if you will, of small modular plants. The way they have been designed is fundamentally different from the large plants. What you will see with large construction programs is a very big peak in skills when you're at the height of construction, and then it drops off quite sharply, so the trades come in, they spend relatively short durations on the site and then they move out.

The number of the small modular reactor programs are designed on the basis that you expand the plant sequentially as your requirements grow because they're small modules by definition. What you can do there is you can smooth out the requirements for the trades on the site by taking them for a longer period on the site which has the benefit of the skills mix develops and stays for a longer time, but it reduces the total headcount that's required.

Now, that's one of the benefits of small modular reactors that are being talked about in the UK setting, for example, in places like Wales, where, you know, moving in large workforces and moving them out is not the optimal way to proceed. So my sense is that it's difficult because we haven't done the work to really understand what it might mean in Australia, but overall I think it would mean that instead of having 3000 people on a site, you might drop it back to 1500, or if it's a relatively small site, 1100 people.

Just building our nuclear medicine facility at the moment, in terms of the trade numbers it's about 420. The complexity of that plant is it's not as complex as a nuclear power plant, but it's not much less complex either. So, you know, we're building that over a two and a half to three year period, we're seeing the ramp up in the trades now, but it hasn't been a fundamental problem to assemble that workforce, skill it up and get it into that construction project.

COMMISSIONER: Now that you raise small modular reactors, it might be a good time for me to just interject for a moment. It's been put to us by many that this concept is vapourware, it doesn't exist, it's many years from being commercialised and that it's not really on the immediate horizon. You have mentioned that you have studied small modular reactors. I would be interested in your view of what you have seen around the world in terms of development, particularly in terms of commercialisation and also the cost effectiveness of what you have seen.

DR PATERSON: Yes. It's a very rapidly developing area. I mean, even as much as a year ago when I started this study phase of trying to understand exactly where we are, there was a series of projects that had, you know, a profile that they looked like they would take a long time to get to market. I think in the last 12 months we have seen some things that were quite speculative drop away, but some things that were more substantive really move forward in quite an important way.

Small modular reactors really have a fundamental difference from the large plants. The large plants look at economy of scale. You build them big because it reduces the costs of the electrons because you can get more of them out of the same sort of kit. Small modular reactors are built not on the economy of scale, but what is called the economy of multiples, by making a lot of them smaller you can get a different type of economy.

One of my colleagues in the UK, Giorgio Locatelli, compares an ostrich egg to normal hens eggs in a tray, and says if you're getting some people coming around to dinner and you have got an ostrich egg and you get it wrong, it's going to be a really bad dinner, but if you have a whole tray of eggs, you can actually build up the capability of having lots of people suddenly arriving for dinner, which is our energy equivalent argument and it's a different way of thinking about it.

So many people felt that it would be too difficult to reconceptualise power reactors that had emerged into third generation and Generation III+, to downscale them and to turn them into small modular reactors. That's proving not to be the case. For instance, in China there's a project, the ACP100 project, that's 100 megawatt electrical reactor, that's a tenth of the size of an AP1000, that project is being built and is likely to be completed in 2017 or 2018. So that will be, if you will, a demonstration reactor, it will demonstrate the capability.

Now, these reactors are rather different, they don't have lots of pipes coming out of them, they are called integral reactors, so everything that normally would be outside the pressure vessel goes into the pressure vessel. Because they're smaller you can fabricate much more of them in a factory, that means that your quality issue which we have been talking about is managed in factory settings, not in site settings. All of those things lead people to be able to do quite refined calculations as to where the savings might come and what the benefit will be.

The underlying principle becomes the learning curve. Can you get down the learning curve fast enough in order to acquire the savings without taking too long or not getting down the learning curve. Now, my view of that is that projects like the NuScale project in the United States has got a good opportunity to get down the learning curve because they have got a very small module, they have got a 50 megawatt electrical module. If you have got a

50 megawatt electrical module, by the time you have built a 600 megawatt plant, you have got 12 modules. You're well down the manufacturing learning curve if you have built 12 modules. So there's one argument that the smaller small module reactors might be more efficacious for the factory based fabrication and we'll get down the learning curve quicker.

At the top end of time, if one looks at, for instance, the Westinghouse small modular reactor, that has a different benefit that all of the work that was done for the AP1000 and the previous AP600 is enveloped in that 284 megawatt electrical design. So you can take credit for a lot of the engineering safety features that are in those bigger plants and therefore have a lower regulatory burden to get these into the marketplace. So these are the sorts of arguments that I think are proving very helpful in the discussion at the moment.

The UK last week launched a paper in which they are going to make specific investments to develop the small modular reactor market. I had the opportunity to spend three days talking to people about the NuScale plant during the course of August. I went there somewhat sceptical. I came away really, really interested. They've got 500 engineers already committed to that project. We always say a paper reactor needs about 40 engineers. You can do quite a lot of engineering on paper with 40 engineers. By the time you've got 500 engineers, that's a real project. They've got a real client. They've got, I think it's now, over 700 documents lodged with the Nuclear Regulatory Commission. That looks real to me if you're putting in substantive submissions. And I think recently they announced that they're going to go for a design certification during the course of the next calendar year.

When you go to design certification, that's a very important signal that this is a real project. They are bankrolled by Fluor. Fluor is a very big company. It's in the real market and it's on the US stock exchange. They are saying very positive things about it. These things make me feel this is a real project, and they are talking about 2023 for operation of a plant. Now, I think that if they’ve got their costings to a reasonable level of precision, maybe they can still drop it by 10 to 15 per cent or have an upside of 25 to 30 per cent. The stage they are at at the moment, I would regard that as a mature, in effect, project. So those are the sorts of tests you can apply.

I recently visited China and visited the demonstration reactor that was built at Tsinghua University in the INET facility. The reactor itself is a very small reactor, a 10-megawatt reactor, but it demonstrated all of the safety principles for that pebble-bed reactor. It actually made electricity in the demonstration phase. Much more interesting to me was to visit their test and evaluation facility that's built next to where the reactor building is, where they develop all of the key components and safety structures and operational structures, full-scale test rigs; cold-test rigs, as we call them, because they are not nuclear in nature, but they're getting ready to build a nuclear program.

Now, if you see a test and evaluation program that has been operating for 10 years, and then you know that they are also out of the ground in a large-scale pebble-bed project on the coast of China, that's a real project. It's undeniable that that plant will be built, and that's about a 250-megawatt steam-generated plant based on two modules that will be pebble-bed module reactors. Now, that is a challenging technology. I was involved in the pebble-bed project in South Africa, but it's got massive upsides in terms of quality of heat, the ability to deliver both electricity and potentially also things like desalination. That's an absolutely real project.

So I think that there are some fast followers. The smart reactor in South Korea has recently announced a partnership with Saudi Arabia. The way that I read the partnership documents - and I haven't studied this in detail, but what I have seen so far - is that the intention of that partnership is to upscale the engineering capability. That's a key signal. How many engineers are on a project turns it from being pre-conceptual design and scoping into conceptual design and design and realisation.

So I think rather than generally feeling that sweeping statements are important, it's to get ground truth. You've got to go and see these projects and you have to evaluate the extent to which they are real, and my sense is that a number of the projects are now very real and they don’t yet have absolutely deterministic time scales, but they've got timelines that I think are practical and are realisable from my experience of our own nuclear facilities and builds and the awareness of what has happened in other projects.

So I think it's not correct to say that these are vapourware or paperware. Some of these projects are real. Some of them will change the nature of the nuclear industry from an economy of scale industry only to two options, economy of scale and economy of multiples, and I think that will transform the nuclear industry globally starting with the decade from 2015 to 2025 that we are already in, but then will accelerate in the back-end of that decade and the decade after that, I think. Many countries which are now currently not nuclear actors will consider it, because countries with small grids or long, thin grids, which characterises Australia, are automatically going to be attracted to baseload power that is low or zero emissions and can be built predictably. That's really, I think, not unrealistic in the 10 to 15-year time horizon.

MR JACOBI: You spoke about the reality of the projects. Do you think there are any key points that are going to emerge when we might be in a better position to be able to judge cost, particularly the cost per unit of electricity generated?

DR PATERSON: Yes. Well, I always say that there are two things in nuclear: there's cost and there's economics. Cost is what it actually costs you to build a plant; economics is how that rationally connects to a market. I think it's quite difficult to do economics back towards emerging technologies, because the underlying costs are not well known yet, but if one looks at those cost envelopes, I think if you can see projects with a real client and they go to first concrete, those are the projects you want to have people standing next to and watching. It's the ones that are being built that are real.

Let's take the pebble-bed project in China. That would be an interesting one to spend time analysing, because once one gets a sense of what the real costs are of that and what the value proposition is at that reactor, or in fact the bigger ones that they're now proposing, will have for different uses, you will know the costs are rational because China is building a lot of nuclear plants and they do have a very keen understanding of cost. For example, when I visited the Vogtle plant in Georgia and met with the senior team there, they are bringing their project management experience from Chinese projects to manage the construction of those plants, and so there's learning that will take place in the global supply chain about the costs.

The studies that I've seen around the manufacturability of these small modular plants and the possibility of realising the cost goals, I think has two advantages we haven't seen in large-scale nuclear projects. The first one is that you do have the opportunity, subject to your regulator's approval, to start making electricity while you're still putting in further modules. That changes because you're getting cash flows early and you're not as exposed to the full capital cost. The second thing that may change this, and this is, I think, one of the key points that will really tell us whether these plants will achieve all of their cost objectives, is if the emergency planning zone is the fence as opposed to being 10 miles.

You will change public perception about the safety of these plants, not just the perception. The reality that the public does not need to have a big emergency planning zone will allow us to not have to have evacuation plans and all the other things that have to be in place with a large-scale plant. I think there's a reasonable prospect from two of the projects that I've seen that the emergency planning zone can be at the fence, but that would have to be demonstrated in front of a regulator.

MR JACOBI: Yes. That in turn, though, depends on the extent to which they're either inherently or passively safe for very long periods.

DR PATERSON: Yes. So that's a very important concept. In my view, there are two classes of small modular reactors: those that are inherently safe - basically that means that under all the design base stats and conditions, there is no immediate requirement for operator intervention. That's what we call a passively safe plant. But in order to protect the asset and, indeed, to secure the longer-term safety within 24 to 72 hours, there's normally a requirement for operator intervention. Now, that's a long time but it's not an infinite time. And so the passively safe reactors, I think are genuinely 1,000 to 10,000 times safer than Generation III plants and that will be demonstrated from the probabilistic safety analyses. If you want to go to inherently safe, the Indesign basis accident have to allow no operator intervention at any time. Now that is a high bar. In aeronautical terms that would mean that the pilot doesn't have to fly the aircraft and that's a significant bar. And I think that probably it means that your modules have to be below about 60 megawatts electrical to get a truly inherently safe – unless there is some other breakthroughs in the physics or the fuel management which can happen and more accidents are on fuels for example. These are somewhat further out and down the chain but as we stand with core established mature technologies today, the NuScale plant is intending to go with a design basis that is inherently safe. So their design certification will be an interesting thing to observe and should be keenly watched because if they do achieve the regulator agreement that this is passively safe, I think that will be a new threshold for people entering the nuclear industry.

MR JACOBI: Can we come back to skills and I just want to pick up, in terms of skilling, I just want – we have dealt with I think trade skills and construction skills and I am just interested in the extent to which we might need to build regulatory competence in Australia?

DR PATERSON: We have an excellent regulator in APARNSA. I think that the structure of our current legislation for nuclear safety provides a clear separation between the responsibilities of the regulator and the responsibilities of the operator and it does in a way that the regulator is genuinely independent and the regulator can genuinely enforce all of the actions required to get a licence holder to do the right thing. So our current structure of legislation could be made more streamlined if we integrated the safeguard safety and security in to the regulator in a predictable way. The skills required by the regulator is mainly massification, getting more people who have got the right skills for the part of the fuel cycle that is envisaged. So if one was to have a pathway for example towards a waste management and reprocessing capability, one would concentrate on the type of skills that have developed around long term repositories, the calculation of the safety of those. Waste acceptance criteria, the different types of waste packages that would be brought in to these facilities and you would skill up around that.

If one was to go to the enrichment side, you would really be strengthening your safeguards capability, your materials accounting, but the regulatory requirements are so well known that skilling those regulators would be very much in exchange of views between regulators and people learning what is done in the Netherlands and other places. So my feeling is that if we had to upgrade the skills, you have got three pathways. The one would be to avoid any risk of an aging workforce, you would want to bring in young people who wanted to be part of a regulatory authority and you would train them in university courses both here in Australia, there now is a nuclear engineering course at the University of New South Wales that has development over the last two years. You would have people seconded, post qualification for additional qualification in other jurisdictions that were more focussed on those outcomes. And a number of them you would take through PhD programmes in other places where they could meet and learn to network with peers who were working in that environment. So I think depending on where you are in the fuel cycle, it's a massification issue. How long would it take? Well, one of the quickest ways to do it is to take competent regulators, who have got a chunk of the skills already and then put them through post graduate programmes because that is a way of translating them from their own discipline in to a nuclear discipline.

So one could imagine for the non-PhD component, that is three to four year type of period that you could reasonably do that and be confident. And then for the PhD component you're probably looking at more like six years to get a cohort of people coming through who can do that. And then you have got the recruitment possibility. So I think there is a good mix, so I wouldn't feel that there would be any downgrading of the skills of an already very competent regulator in the form of ARPANSA but there would have to be a skill strategy as we said, it's a case of planning, it's a case of knowing where the needs are and of course once you are in the back end of the fuel cycle as an economic case, or perhaps fuel fabrication or nuclear power, you are not going to be looking for public purse to pay for that because they are economic actors and they generate revenue. And so as a result of that, and I've had discussions with regulators about this, the actual core appropriation of the regulator probably would stay about the same. It might grow a little bit during the training phase but the fact that the people who are being regulated pay in this marketplace, means that there would be expansion of the regulatory workforce but no additional cost to government.

MR JACOBI: You spoke of the idea of cross-skilling, that is from existing regulators, do you think that there are pockets of existing regulators in other areas in Australia that you could borrow from if you wanted to up skill?

DR PATERSON: Yes, I think you would go to the aerospace environment and you would go to oil and gas. So you've always got to go closest to the top end of town and I think there are good competencies there and that would be a good place to go and then you often get people who have – are moving in to a phase of their career where they want to be less operational and so, subject to a kind of cooling off period, you can put people out of the operational and then they end up on the side of the regulator and they understand how these plants work and that is always an important component.

MR JACOBI: I just want to pick up on – I think it's probably wrong to – given the discussion, describe Australia as a new entrant but do you think that there are any key lessons for – in terms of – particularly in terms of skilling and education for a country that is considering the idea of potentially expanding in to these areas?

DR PATERSON: I think there are. I think that if you look at some of the programmes that are going on around the world, not to underestimate the requirement for your engineering workforce. I think what often happens is if you are new to a domain, there is a feeling that it's a procurement action as we were discussing earlier. You know, I'll buy one of those, it will be a black box and then we'll operate it. That is never going to be true of nuclear. You have to have deep understanding of the nuclear operations, you have to be able to asset manage them through their lifecycle; you've got to deal with aging plant issues. All of those things mean that your engineering workforce is very sophisticated and the earlier you start developing it, the better off you are. Now we have got small templates for that but I would say that if I was looking at countries like the UAE or Jordan, which is going to have projects; potentially other new entrant countries that have got no base line, every dollar I put in to a science oriented person, I would probably put 10 to $15 in to engineering capability. Because I think it is the engineering capability that would give the public confidence in nuclear because you have got people who are practical, they have seen what works in other parts of the world, they have seen what doesn't work in other parts of the world and you would bring those capabilities in.

So engineering is very, very important. I think the second thing is, in building public confidence you would want to have a strong regulator. If there is a strong and independent regulator the United Arab Emirates has done an excellent job of bringing in some well-respected skills from around the world and meeting what a number of actors have called the gold standard. They have gone beyond the basic requirements and built something that is a little bit richer in terms of the model, in terms of getting the regulatory environment they need. And I think that has been incredibly positive. I mean I have spoken to people in the UAE programme and they've really, really created a regulatory oversight of the supply chain and the quality management of the supply chain and how that is going to turn in to really good reactors, which I think is genuinely world class and people can learn from these experiences. So it is about rigour, it is about planning but I think these projects we are seeing around the world, say that's eminently achievable. It is not a multi-decade thing. With strong focus it is a decade.

MR JACOBI: In terms of, you spoke of the university courses in Australia, I am just interested whether there's any particular preference for perhaps in terms of sending engineers overseas to be experienced in particularly universities that might be associated with development programmes or build programmes?

DR PATERSON: Yes. I think it really is interesting. I mean the programme in New South Wales has been developed in association with Imperial College and Imperial College is part of the three major centres in the UK with Imperial, the Dalton Institute at University of Manchester and then Sheffield University and they each do slightly different pieces of the puzzle and I think that is a really smart strategy. So the fact that the Imperial core material that is up to date, that is about modern reactors, not historical reactors and is looking at a build programme, coming in to Australia just really reduces the overhead of getting the programmes going. So I think if you then look at build programmes, very logical place to be at the moment is some of the UK programmes because they are going to build. Typically, for example, Oregon State University has been sort of the brains trust of NuScale. If one was looking at small modular reactors, that is an interesting place to look at how that developed, how the momentum developed, where the engineering is. And that is an interesting thing as well because Oregon State University was contracted for many years by the US Department of Energy to develop the tests and the evaluation programmes that they use to certify the AP-1000. So this is not just people sitting at computers and doing engineering training, they are actually working on the tests and evaluation programmes for a real reactor programme.

So I think there is no substitute in nuclear for getting close to what is real, or coming from an industry that is close to what is real and so on. Because nuclear practice is continuously evolving and being close to the programme where things are happening will get you the best international practice.

COMMISSIONER: Dr Paterson, I thank you very much for your evidence this morning and the preparation that you took to help us think about these issues. It has been very useful and I wish you well for the future.

DR PATERSON: Thank you very much.

COMMISSIONER: We now adjourn until next Thursday.

MATTER ADJOURNED AT 10.12 AM UNTIL THURSDAY, 10 DECEMBER 2015