



STATE DEVELOPMENT, NATURAL RESOURCES AND AGRICULTURAL INDUSTRY DEVELOPMENT COMMITTEE

Members present:

Mr CG Whiting MP (Chair)
Mr DJ Batt MP
Mr JE Madden MP
Mr BA Mickelberg MP
Ms JC Pugh MP
Mr PT Weir MP

Staff present:

Dr J Dewar (Committee Secretary)
Ms N Mitchenson (Assistant Committee Secretary)

PUBLIC HEARING—INQUIRY INTO JOB CREATION OPPORTUNITIES IN QUEENSLAND ARISING FROM THE ESTABLISHMENT OF AN AUSTRALIAN SPACE INDUSTRY

TRANSCRIPT OF PROCEEDINGS

FRIDAY, 19 OCTOBER 2018

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The committee met at 9.00 am.

CHAIR: I declare open this public briefing for the committee's inquiry into job creation opportunities in Queensland arising from the establishment of an Australian space industry. I acknowledge the traditional owners of the land on which we gather today. I also acknowledge Professor Chen and the other senior University of Queensland executives and thank them for the great support the University of Queensland has provided the committee in hosting us here today. Thank you for your attendance at this hearing.

The purpose of today's hearing is to assist the committee with its inquiry. My name is Chris Whiting. I am the member for Bancroft and the chair of the committee. The other committee members with me today are Mr Pat Weir, deputy chair and member for Condamine; Mr David Batt, the member for Bundaberg; Mr Jim Madden, the member for Ipswich West; Mr Brent Mickelberg, the member for Buderim; and Ms Jess Pugh, the member for Mount Ommaney.

The committee's proceedings are proceedings of the Queensland parliament and are subject to the standing rules and orders of parliament. The proceedings are being recorded by Hansard and witnesses will be provided with a copy of the transcript. To assist with clarity, please identify yourself when you first speak and speak clearly and at a reasonable pace. All those present today should note that during the proceedings it is possible that you might be filmed or photographed by the media and images may also appear on the parliament's website or social media pages. The media rules endorsed by the committee are available from committee staff if required. I ask everyone present to turn off their mobile phones or turn them to silent mode. I also ask that if witnesses take a question on notice today they provide the information to the committee by 10 am on Friday, 26 October 2018. The program for today been published on the committee's web page and there are hard copies available from the committee staff.

SMART, Prof. Michael, Chair of Hypersonic Propulsion, School of Mechanical and Mining Engineering, University of Queensland

CHAIR: For the record, could you please state your name and the capacity in which you appear today?

Prof. Smart: My name is Michael Smart. I am a professor in the School of Mechanical and Mining Engineering at the University of Queensland. I am also one of the founders of a start-up company called Hypersonix.

CHAIR: Thank you. I invite you to make an opening statement, after which committee members may have some questions for you.

Prof. Smart: I would like to thank the committee for the invitation to present to the inquiry about opportunities for Queensland in the space economy. It is a very exciting time. The space industry worldwide is growing faster than almost any sector of the economy. There is also significant disruption occurring around the use of small satellites, a so-called Space 2.0 revolution. Just like many other industries, new players have a significant advantage over established ones that have business models built around the status quo. However, the space industry is very competitive. For new players to succeed, they must innovate and bring new technology and know-how to the marketplace. This is true of all levels of the space supply chain, from small satellite launch to earth observation analytics.

Today I will talk about a Queensland start-up called Hypersonix that is working with local SMEs to develop a small satellite launcher that does not dump rocket motors into the ocean. Later today you will also hear from Professor Stuart Phinn about the formation of a national earth observation analytics hub to expand the use of earth observation data into the business sector. The state government has a role to play, of course. If it leads with strategic investments, this will give industry investors and other investors the confidence to follow. The success of the South-East Queensland aerospace manufacturing sector is a perfect example of this succeeding. I recommend that this committee bring about strategic investments in space that will enable Queensland to be a producer in the world economy, not just a consumer.

However, first of all, I would like to particularly make the committee aware of the significant opportunity for small satellite launch that exists right now and into the future. A small satellite is generally considered to be one that weighs less than 200 kilograms, so something that would be quite a bit smaller than the size of the table that I am sitting in front of here. Due to the rapid development of microscale low-power electronics, like in the mobile phones that we all have, these small satellites can supply high-quality imagery of the earth and high-speed broadband anywhere on the globe. That is the future. In the near future, broadband will not discriminate between the city and the country or between New York City and Africa. In terms of satellite supplied services, every part of the globe is the same.

A 2017 survey predicted that 6,200 small satellites will be launched between 2017 and 2026. The estimated cost of the launch of those 6,200 small satellites is US\$13.6 billion. That is the cost just of the launch—not of the manufacture or the operation but just the launch. That demand is driven by the needs of customers like the company OneWeb, a US company, that currently has Federal Aviation Administration, FAA, approval to operate a constellation of 648 small satellites. These are the satellites that are going to bring to the world the high-speed broadband I have already mentioned. Australia has the potential to tap into that US\$13.6 billion market.

How does the market work right now? At present, almost all small satellites are launched on a rideshare with a larger service. In those instances, both the orbit and the date of launch are set by the customer—the main customer. The small satellite operator has no control whatsoever. This situation going forward is just not satisfactory for commercial means, for defence or even for scientific activities. Therefore, there is a significant commercial opportunity for the development of what are known in the industry as dedicated launchers. That means launchers that are designed to launch something as small as 100 kilograms into a specific orbit, so each one of those 648 small satellites can go into a slightly different orbit. That is the opportunity that is there.

In response to that opportunity, numerous small satellite launch systems are now under development around the world. The most mature is by Virgin Orbit, one of Richard Branson's companies, and also a company called Rocket Lab. Rocket Lab is based in New Zealand but is a US company. Both those launch systems and others that are being developed use fully expendable rocket technology. That means that the entire rocket system is thrown away each time a launch is made.

I am not sure if the committee or the audience is aware, but almost all space launch systems are expendable. That means that, once the fuel is used up, the rocket motors just tumble into the ocean to a watery grave. The only thing that survives is the payload, or the satellite in orbit. This method has not changed since the 1960s. As you might expect, throwing away a space launch system each time it flies will always be inherently expensive. That is why going to space can cost as much as US\$50,000 per kilogram. For a 100-kilogram small satellite, that corresponds to a launch price of US\$5 million. That is just the price for the ride into orbit; it is nothing to do with manufacture, operation and the other things.

What can change? The thing that can make the difference to economies of space is re-usability. By 're-usability' I mean a space launch system that operates like an airline, so a space launch system where the vehicles are used many, many times over. Instead of throwing away the ride each time, those systems fly back to the launch site and land like a plane. They can then be refuelled and launched again. It is a completely different business model to the current one.

UQ researchers from the Centre for Hypersonics have joined with local Queensland SMEs to develop re-usable aeronautical technology. The re-usability that we plan is based on aeronautical technology, and that aeronautical technology can make re-usability happen. This capability has grown out of more than 30 years of hypersonics research, funded by both the Queensland and the Australian governments. Earlier I mentioned the opportunities in the space economy and how it is very competitive. It is innovations such as re-usability that will enable Australia to earn its share of that competitive space market.

What is this technology that I talk about? Many of us are familiar with SpaceX. They are a US company and they are able to re-use their first-stage rocket boosters by slowing them down, using rocket motors, to a controlled landing. Once they land, those rocket motors are transported back to the launch site and they are used again.

UQ has developed a small satellite launch system called SPARTAN that re-uses not just the first stage but also the second stage of the system. In a break from tradition in the space industry, it does it using aerodynamics, including hypersonic engines called scramjets. With the SPARTAN system, we call the fly-back first-stage rocket booster the Boomerang, because it flies back to base

and lands right next to where it was launched. The hypersonic stage that is powered by a UQ designed scramjet—which, by the way, can heat up to 1,500 degrees Celsius on the way to space, before returning to base—is the second stage of the system. The only part of the system that is expendable is the small upper stage.

I could talk all day about the technology, but I will not do that here unless the committee asks me to. The main thing that you guys are interested in is how Queensland can become a producer in the space economy. International satellite operators will bring their satellites to Australia to be launched into space by SPARTAN because the price will be half that of other launch systems—not because it is a high-tech system but because the price will be halved. The price is halved because it is re-usable. Re-usability is the key technology. The development of a commercial small-satellite launch capability based on locally designed and manufactured vehicles would deliver a multitude of benefits to Queensland. It would also raise the profile of Australia internationally as a genuine player in the space launch sector.

What about the business numbers? SPARTAN is designed to supply a dedicated launch of a satellite of up to 150 kilograms. A detailed business case indicates that revenue of \$125 million per year would accrue from 25 launches. That is a conservative launch rate of one launch every two weeks. That is only a small percentage of the predicted market. Over a 20-year period, a business such as what I have mentioned would amount to a \$2.5 billion industry.

Scale-up, meaning increased flight numbers, is also much simpler with an aircraft-like system like SPARTAN as opposed to an expendable system, where you have to keep launching new rockets. Each one of those rockets that you launch ends up in the ocean somewhere on the earth.

How many jobs would be expected to be generated by the operation of SPARTAN? A good model for the benefits that would accrue to Queensland, for example, is Rocket Lab in New Zealand. A detailed economic analysis was conducted in 2016 of Rocket Lab's contribution to the New Zealand economy. Benefits included high-tech jobs at Rocket Lab and its suppliers and jobs associated with the operation of the launch site. There were also induced impacts like space tourism and cluster effects, which I will explain in a moment. In 2017 Rocket Lab had 200 direct employees and it plans to expand to 300 employees when it is fully operational.

Cluster effects, which I mentioned, are very important. A small-satellite launch capability would create a centre of mass about which Australian space companies could operate and grow. Having a close connection between launch services, satellite manufacturers and end users of satellite data can create synergies that promote commercial competitiveness in all areas of the supply chain. A system like this would require new advanced aerospace high-temperature composite avionics manufacturing capability to exist, and this manufacturing capability has a significant crossover with defence programs and could be built upon the strong aerospace sector that exists already in Queensland. Also, SPARTAN is an autonomous system. There are great synergies between the technology needed to fly SPARTAN and that being developed in the Queensland based centre for trusted autonomous systems.

How can the government help? Both the Queensland and Australian governments have invested over \$70 million into hypersonics research over the past 30 years at UQ. This is what has led to UQ's leading position in hypersonics and scramjets. Remember, in 2002 UQ beat NASA to the first flight test of a scramjet with a fraction of the research budget. A start-up company that is called Hypersonix was founded in 2017 to commercialise this technology for space. Hypersonix seeks to remain an Australian company. It is currently pursuing phase A funding, where significant pressure is applied by venture capitalists to control ownership, operation and structure. Seed funding of as little as \$10 million from the Queensland state government would enable Hypersonix to begin to mature SPARTAN without giving away control. Local control of the company will enable us to stay in Queensland. This would be a highly leveraged use of seed funding, where a \$10 million allocation could result in a \$2.5 billion industry for Queensland.

Finally, I would like to discuss the issues associated with a Queensland launch site. Hypersonix is a high-tech company and it could really launch from anywhere in the world, but what about Queensland? These modern satellite constellations that I have talked about require orbits that range between what is known as equatorial orbits—so orbits that travel around the equator of the earth—and polar orbits that go from pole to pole. A whole range of different orbits are required.

Launch sites that are close to the equator suit low-inclination orbits. In fact, they are the only place where you can launch low-inclination orbits—equatorial orbits. Launch sites that are far from the equator are more aimed at polar type orbits. A general purpose launch site can benefit from being in between. This is the case with the Kennedy Space Center in Florida in the US.

At present, to my knowledge there are two commercial companies that are developing launch sites suitable for small satellites in Australia. The first and most advanced is Equatorial Launch Australia, which plans to launch from Gove in the Northern Territory. This site is close to the earth's equator. It is aimed at equatorial launch, hence the name of the company. There is also another company called Southern Launch, which is planning to build a site on the south coast of South Australia.

A launch site situated in regional Queensland would provide significant economic benefits to the surrounding community. These flow-on economic effects have been shown to have a large multiplication effect in the wider community. For this reason, any launch site that we construct in Queensland, I believe, should be based in an area with an already established population base. A coastal position would be ideal. However, a launch over the Great Barrier Reef may be problematic. The coastal area in the Gympie region—launching easterly over the ocean—would be an ideal place for a number of reasons. The first is that it is suitable for a wide variety of orbital inclinations due to its latitude—similar to the Florida site for the Kennedy Space Center. It has a clear and safe path easterly over the open ocean. The airspace in the area is under Defence jurisdiction and could be easily controlled. It is well south of the Great Barrier Reef and it is a great place where launch site staff and families could live. It would also bring tourism to the Sunshine Coast. I will finish my preliminary remarks there. I am happy to answer any questions for the committee.

CHAIR: I would like to hear a bit more about Hypersonix—the ownership structure, the capital put in and certainly the ownership of, for example, the intellectual property. Could we have a bit more background on what Hypersonix is and what it does?

Prof. Smart: It is a start-up company that has been developed through UniQuest. UniQuest is the commercialisation arm of the university. The means by which the intellectual property goes into the company is through a licence from the university. There is a well-established process within the university for doing that. For that, through UniQuest, the university gains equity in the company.

The other partners in the company are a company called BMT WBM. They are an SME in Queensland. They have been in Queensland for 40 years. They do high-tech mechanical and automation work. They have seen the opportunity of this and wanted to get involved. They are a contributor. There is also another small UAV company called Australian Droid + Robot, which has some IP that is very useful for our first-stage rocket booster. My position in the company is affected by working at the university, so we are still trying to sort out the details of that, to be honest with you.

CHAIR: Thank you. Their headquarters are here at the university?

Prof. Smart: Its headquarters are at the offices of BMT WBM in the city.

Mr WEIR: We occasionally see footage on TV of failures with rockets. With the size that you are talking about—these smaller ones—what is the failure rate, because that would come into consideration in terms of where you are going to locate it?

Prof. Smart: The failure rate is always highest when you are developing new technology. That does not really change with the size of your system. If I use SpaceX as an example, they did their first successful launch in 2008. They failed a couple of times first, but now they launch 18 to 20 launches a year and they have not had any problems during flight for many years. They have had one or two problems on the launch pad. There is always the risk of accidents, but as time has gone on those risks have reduced significantly. I could not put my hand on my heart and say that there will never be a problem.

Mr WEIR: All of those things will obviously come into consideration when you are looking at a location. You mentioned the Gympie area. There is already a Defence area on Tin Can Bay Road, as I remember. It is not heavily populated.

Prof. Smart: No, and it has clear access to the ocean. Almost all launch sites launch over the ocean, because it is a much more easily controlled space for safety. Whenever you do a launch there is a thing called a safety template, where you have to look at the possibilities of problems and how big an area you need to clear out. What is interesting about the re-usable system is that, because it does not drop rocket motors into the ocean, there is no place where something will definitely fall. It makes the safety template and all the planning quite a bit easier than a traditional expendable system.

Mr MADDEN: Professor Smart, I would like to thank you for coming in today and presenting to the committee. The questions that I have relate to the SPARTAN small-satellite launch system, this very innovative system that you have. I presume this is an automated system that does not require pilots.

Prof. Smart: It does not require pilots, no. It is not big enough for pilots.

Mr MADDEN: That is a great initiative. It involves two vehicles returning to earth. The first vehicle is stage 1. I am curious about the fuel. You say that it is a propeller driven vehicle. Would that just be an avgas standard sort of aeroplane but pilotless?

Prof. Smart: Yes.

Mr MADDEN: Could you explain how the fuel will work with regard to the scramjet? I understand that there is some innovative technology that means that it has to carry a lesser weight of fuel than other comparable vehicles.

Prof. Smart: Yes. A scramjet is a hypersonic air-breathing engine. It works on the same principle as a jet engine that flies on aircraft every day. It uses the air to generate its thrust. There is oxygen in air. A scramjet, or any air-breathing engine, uses the oxygen in the air to combust with fuel to generate thrust. An air-breathing engine only has to carry fuel. A rocket system has to carry both an oxidiser—usually oxygen—and fuel. Oxygen is very heavy. The advantage of an air-breathing engine is that you do not have to carry oxygen. That means that you can carry a lot more payload. That is where the efficiencies come from for a scramjet.

Mr MADDEN: The fuel is hydrogen?

Prof. Smart: The fuel is hydrogen—for a space system, yes.

Mr MADDEN: Is hydrogen a relatively inexpensive fuel?

Prof. Smart: It is relatively inexpensive, yes.

Mr MADDEN: Compared to, say, avgas or something like that?

Prof. Smart: I suppose, on an energy basis, it is. Per kilogram, it is a little bit more expensive because it has a low density, but it is not an expensive fuel at all.

CHAIR: I note, too, that, with hydrogen supplied from the Gladstone area, there is a possibility for future linkages.

Mr BATT: You were talking before about the launch sites. What is the size of those sites? Are there so many square kilometres that need to be around it for an exclusion zone, or is it only a small area?

Prof. Smart: The launch site itself can be quite small. The launch site itself could be 100 metres square—so really quite a small area—but there would have to be a controlled corridor where the launches occur. Interestingly, if you have a traditional expendable system—the point-and-shoot type devices—if you want to go in an orbit that has a certain direction then you will have to clear a corridor in that direction, so that could vary depending on which orbit you are going for. With the scramjet based system, we can do manoeuvring and things and change the direction. We could launch the system and it could then change its direction and align itself with the orbit, so it would give it more flexibility in that respect. The launch site itself geographically could be quite small, but it does need a clear pathway essentially.

Mr BATT: Yes, but is there an exclusion zone surrounding that? Do you need a certain amount of space before someone is living there and that sort of thing? Are we needing kilometres?

Prof. Smart: Yes, the launches would be quite noisy but also would attract a lot of tourism, I think. Yes, it would need perhaps a couple of kilometres, I would say, for an exclusion zone.

Mr BATT: There is quite a bit of air traffic along the coast of Queensland. Do you have to advise everyone that there is a rocket going up?

Prof. Smart: Definitely, and CASA is the organisation that would manage all of that. For any launch system, I believe it is CASA that will, along with the Australian Space Agency, manage all the airspace. The interesting thing about the Gympie site is that, as an example, to my knowledge that is Defence controlled airspace already, so that makes it much easier to manage the airspace.

Ms PUGH: I read in your submission that you managed to beat out NASA with a fraction of the funding. Can you expand on how you were able to do that? Obviously that is a very impressive achievement.

Prof. Smart: It was really about need. We wanted to accomplish a really big thing. I was not directly involved; it was some previous academics and staff who now work for Australian Defence. In fact, after that period Defence wanted to grab them and so they moved to a group that is called Applied Hypersonics Group, which is in Pullenvale, so still in Queensland. It was about need. It is interesting with science: you do something for a very specific reason and then it actually has a lot more implications than you think about. The reason that we wanted to flight-test a scramjet and we then ended up beating NASA was that we have a facility here at UQ where we can test scramjet

engines, but we can only do an experiment for a very short time—in the order of three milliseconds, so way shorter than the sound that I just made clicking my fingers. We produced a lot of experimental data that showed good performance in scramjets with our facility, but there was always this question: does it really apply to real life? We had this need to prove—to justify—our research to the community and the only way to do that was to flight-test.

The group came up with really quite a simplified experiment that did exactly what it needed to do, but we did not include all the bells and whistles. It did not fly back to base and it did not land; it just proved the scramjet engine. The NASA work that was going on at the same time was much more complex, trying to do lots and lots of things. It was about need and then about ingenuity, about making it happen, and very talented people who, if they did not know something, went out and found out what it was for themselves and then questioned it—that is, do we believe that? It was really a combination of need and ingenuity, I would say. Australians are well known for that in the scientific and engineering communities.

Mr MICKELBERG: Continuing on with the launch site conversation, you mentioned the training area at Wide Bay. Would you envisage the launch site being inside the existing training area or abutting it, just in the general vicinity?

Prof. Smart: I am not 100 per cent certain of the details on that. One of the later speakers today will be able to help you out a bit more with that. That is Nick Green from PFI. Perhaps you could ask him.

Mr MICKELBERG: Could the launch site coexist with things like a high-explosive impact area? Obviously it would not be at the same time, but is there technology that is so sensitive it could not be affected by, for example, an explosive in the general vicinity?

Prof. Smart: I do not think so, because the rocket is sort of a higher explosive thing as well. I do not see any problems with that, no.

Mr MICKELBERG: Are there any alternative locations outside of Queensland and/or other proponents, excluding those that you have already mentioned, that have a tangible project underway? Are there any alternative solutions out there?

Prof. Smart: Now that you have asked me that question, there was some talk about a site in Western Australia, up on the North West Shelf—a commercial site up there. There are lots of opportunities for Australia just because of our open airspace compared to other parts of the world—particularly Asia, where there is so much population and it is hard to find a straight line where you could launch a system. There are many places in Australia where you could launch a rocket system. The great thing about the east coast is that the earth is spinning easterly, so when you launch easterly you actually get a kick from the earth and you can launch more payload for the same rocket. Going westerly is just more complicated and you can get less performance, essentially, from the same rocket.

Ms PUGH: Just to be clear, westerly would be launching from, say, Florida? Would that be right?

Prof. Smart: No, Florida is easterly as well.

CHAIR: Obviously we had the flight in 2002. Have there been any test flights since then, including the re-usable vehicles? You have obviously done a lot of research and a lot of experiments.

Prof. Smart: Yes. There are two flight programs that we have been involved with. The first one was HyShot, which was a UQ managed program under which this first flight of a scramjet was done. That program went from about 1997 to 2006. Then, as I mentioned, part of our Centre for Hypersonics moved to Defence and we then went into a second program called HIFIRE, which was partially funded by the state government under a NIRA proposal. The partners were Defence Science and Technology, the US Air Force, the University of Queensland and Boeing. That program was called HIFIRE. The plan was to do nine flights in five years, which was very aggressive. In the end, the program went from 2007 to 2017 and we did seven flights in that period—mainly scramjet flights but also some other flights—looking at different aspects of hypersonic technology. None of that was re-usable. In 2015 UQ did a flight based on the fly-back rocket booster that I mentioned that has a propeller motor and wings. We did some small scale take-off and landing testing of that system, which was piloted from the ground but not from in the vehicle. That was really just to prove the ideas—that is, you could actually fly an aircraft that looked like that, because it is a pretty strange looking aircraft. That is all the flight testing we have done so far.

CHAIR: Where did the HIFIRE flights take place? Were there a number of different sites?

Prof. Smart: There were a number of different sites. The original plan was that all of the flights would take place from Woomera, which is Defence controlled. HIFiRE was a Defence managed program, so it enabled us to get access to Woomera, which is not easy. Access to Woomera for commercial activities, for example, would be very difficult just because it is so busy and it is all controlled by Defence. I think three of the flights were undertaken at a space range in Norway called Andøya Space Center. The reason for that was that we were not able to launch from Woomera because of an issue with the rocket motors. We were not able to import into Australia the rocket motors that we needed for a short period. The German company that supplied our service launches from the site in Andøya in Norway many times a year, so we went up there to do some flights.

CHAIR: We are talking about a technology that essentially we have captured here in Brisbane. From the sounds of it, from around the world, if we are talking about this technology here, where we are sitting is the base of that technology in that nowhere else has developed it to the extent that we have in Queensland; is that correct?

Prof. Smart: That is correct, yes.

CHAIR: We have captured that in terms of not only the intellectual property but also the capacity of the people to work on and develop this technology. They are all based here in Queensland.

Prof. Smart: They are not based here at the moment. In our Centre for Hypersonics we have graduated more than 130 PhD students, and they are all over the world in different places doing very exciting things. We would love to bring them back and bring back what they have learned as well. They are out there doing really exciting things and we would like to take advantage of that and give them opportunities back here in Queensland.

CHAIR: Just to recap, about 130 Queenslanders with PhDs in this field are all around the world. I would think they would be very keen to return to Queensland.

Prof. Smart: Many of them, yes. Not all of them were from Queensland. We also have overseas students as part of our PhD program. We had some fantastic overseas students. Having overseas students builds up connections, because when they go back to their home country they end up becoming important people in their own country. It has been a fantastic thing to have them through—not just our local Queensland and Australian students.

CHAIR: You have talked about the Gympie site. Have you been up there? Have you had experience there? Have you looked at the possibilities of the actual site itself?

Prof. Smart: I have not actually been to the site, but you could perhaps speak to Nick Green about the site. He is fairly familiar with it. No, I have not been to the site. We have looked at sites in that area for quite a while, but in terms of the site at the moment I should not speak in too much detail.

CHAIR: No, that is fine. Feel free to talk in general terms.

Prof. Smart: Right at the moment there is an existing business there that flies a light aircraft. There is an airstrip and it flies tourist flights around the area, so there is quite a bit of infrastructure already in place.

CHAIR: You have talked about \$70 million over 30 years and 130 PhDs, and there is a lot of development that has gone on. In a general sense, is it time to take this to the sky?

Prof. Smart: When we talk to businesspeople about the funding that is needed to take this all the way, that is a very important thing for them. We have a five-year plan to get to commercial launch. It is a three-phase plan, but at the end of five years we would be launching commercially.

Mr WEIR: I do not profess to be an expert on this subject, but I am curious. You are talking about 6,200 satellites that are to be launched between 2017 and 2026. CASA obviously oversees the skies, but when you get up into space how do you work that out?

Prof. Smart: There is an international organisation that manages space navigation and where everything is. It used to be organised through the US Air Force, but recently—I am not sure if it has actually happened yet—it has been made into a commercial organisation because it is not just doing things for US companies; it is doing things for everybody around the globe. There is a group that manages everything, and anytime you do a launch you have to get approval from them. There is quite a lot of process, as you might expect. You do not want to launch something and hit the International Space Station. Not only that, there are also questions about spectrum. When you put up a satellite, what frequencies can you transmit on? There are a whole series of regulations and there is an organisation to manage those things as well.

Mr WEIR: That would have to be secured before you went any further?

Prof. Smart: If we wanted to do a launch, we would have to tell them about it and then confirm with them that our plans were acceptable. There would be some sort of qualification process to do that.

Mr MADDEN: Professor Smart, you mentioned the criteria for determining an ideal site in Queensland being near the water, you mentioned about it being a populated area and you also mentioned the importance of a controlled area with regard to aviation. Can you just explain why that is so important?

Prof. Smart: In order to do a flight, obviously an area has to be opened up where no other aircraft can fly during a period. That period might be as little as half an hour, but it might be longer than that. There are a whole lot of other businesses operating that use airspace, so it just gets more complicated to control the airspace if it is commercial. If it is currently used by Qantas 100 times a day landing in Brisbane, it is going to be pretty hard to use that airspace, so that is the advantage.

Mr MADDEN: It is not just controlled by Defence: it is also a low-use area?

Prof. Smart: It is a low-use area, yes.

Mr MADDEN: That is what I was getting at.

Prof. Smart: Sorry, yes, it is a low-use area, definitely. That is very important.

Mr BATT: Professor, with regard to launches, you mentioned there are two others already—one in South Australia and one in the Northern Territory. Who controls how many of those would be made in Australia or around the world? Is it just a business decision or would it be the Australian Space Agency? Who is it that would say, 'Yes, you can do that'? Could we end up having 100 of these in the next 10 years because businesses decide they want to put rockets into space?

Prof. Smart: I think the agency would say that they do not want to dictate how many sites there are; however, I think they would feel they would like to have it manageable so there are not 100 sites between Brisbane and Sydney, for example. I think in the end it will come down to business decisions about the market and how practical the site is. It will definitely come down to that, yes.

Ms PUGH: You talked about your re-useable technology, and I note that you also refer to SpaceX. They have a similar concept; is that right?

Prof. Smart: Yes. SpaceX is the first company to introduce re-usability into the space industry; however, it is not involved in the small-satellite market.

Ms PUGH: Is it correct to say that you and SpaceX—this is what I am picking up from the submission—are basically the only two that have moved into that re-useable space?

Prof. Smart: Yes.

Ms PUGH: That would make us the only one in the Southern Hemisphere?

Prof. Smart: In the Southern Hemisphere, yes.

Ms PUGH: Fantastic. Obviously the New Zealand company Rocket Lab has been sold to America. Can you walk us through the drawbacks of that sale for the New Zealand government and the New Zealand economy? What are they losing out on by allowing that to be sold overseas?

Prof. Smart: All the operating profits will go back to the US; however, there are a lot of jobs that are created in New Zealand, so the fact that it is an American company is not all doom and gloom. It is creating new capabilities, but it is basically about all the profits. All the business benefits will flow back to America. That is really the main disadvantage of that situation. Also, much of the board is made up of American venture capital people. The board of a company makes all the decisions, so lots of the business decisions are made in the US. The rocket motors that Rocket Lab uses are all made in the US as well. I do not know the reasons for that, but that could have been a decision made by the board, or maybe it was to do with technical reasons. I do not know.

Mr MICKELBERG: I am interested to continue the conversation around the practicality of the launch. Are there particular times of day when the orbit is superior or there are fewer satellites in that particular part of the orbit so that, for example, you would be launching more during the day or more at night? I note your comments with respect to noise. By way of context, I have spent a fair bit of time at Wide Bay in the training area and I know all of the constraints that already exist from a Defence perspective with respect to noise. I am just curious as to what the practicality would look like with time frames.

Prof. Smart: It comes back to when you launch: you do not want to hit anything else. That is one of the constraints that you have. In terms of going into an orbit, the time of day is not so critical. A lot of times you would like to rendezvous perhaps with another craft that is in a similar orbit, so the

timing would be set by that. There is no particular time of day, per se, that is dictated by the orbital mechanics or that type of thing. You notice when you see space launches that some of them are at night and some of them are during the day. It is more dependent on what is happening in orbit than on the ground.

Mr MICKELBERG: How long would that process take? If you were closing airspace, is that just for the launch or do you need to close from the point you start to—

Prof. Smart: No, just the launch.

Mr MICKELBERG: So half an hour?

Prof. Smart: It could be as little as half an hour. The launch itself only takes 10 minutes.

Mr MICKELBERG: You mentioned in your submission and your testimony that a launch over the Great Barrier Reef may be problematic. What does that relate to?

Prof. Smart: It relates to dumping rocket motors into the Great Barrier Reef. In my personal view, I do not think we want to be doing that. It could be managed. From a scientific point of view, I would say that you could manage that and make sure that if you did dump rocket motors into the reef they were in a particular place. Maybe you would require companies to remove them. The system we are suggesting does not dump anything, so it has a great advantage from the perspective of sustainability and not putting junk into the ocean. I do not think a launch over the Great Barrier Reef is an insurmountable problem, but it may be a problem that you do not want to take on. Maybe that is the best way to put it. In Queensland we love the Great Barrier Reef and we really want to protect it, so I think that comes from that—

Mr MICKELBERG: It is just an environmental consideration.

Prof. Smart: Yes, there are environmental considerations.

Mr MADDEN: You said that under this system nothing would be dumped into the Great Barrier Reef area.

Prof. Smart: Or any area.

Mr MADDEN: Or any ocean. I am just looking at the diagram you have with regard to the scramjet. It talks about the thermal protection system being discarded. Is that discarded at an altitude where it would be burnt up on re-entry?

Prof. Smart: Yes. That is right. There is a heat shield that will be discarded, but it is travelling at such high speed and at such high altitude that it just gets burnt up.

Ms PUGH: I am going to ask the money question. Right at the front of the submission is the outline of the strategic investment, which I would think would come from government. Can you expand on the benefits the Queensland economy would see from that seed funding over the next 20 years?

Prof. Smart: The \$10 million is seed funding, so there is a lot more money required to bring the system commercial in five years but, as I say, once the system is commercial, based on 25 launches a year the revenue to Queensland would be \$125 million. Over 20 years—multiply that by 20—that is where the \$2.5 billion comes from.

That is the revenue. That revenue employs Queenslanders but it also builds up capability that could be used in other areas. There is a lot of crossover with the technologies needed to build those vehicles. For example, there is a lot of crossover to Defence programs and general aerospace. There is the autonomous systems activity—these are autonomous vehicles—so there is significant crossover to many other products, essentially, both in aerospace and manufacturing.

There is the direct benefit, the \$2.5 billion, but there is also the multiplication effect that is talked about. The space capability survey, which was done in the lead-up to the opening of the Australian Space Agency, talks about multiplication factors depending on the type of activity. I think there was some data from the UK Space Agency that direct revenue to space was more than doubled in the broader community in terms of the number of jobs created. For direct investment in space there was a much higher factor, of at least seven, on the investment. That was mentioned in that space capability review based on some European Space Agency data. The direct revenue from the investment would be \$2.5 billion over 20 years but the broader benefits would be much larger than that.

Mr MICKELBERG: Are you able to quantify the cost to commercialise it?

Prof. Smart: The cost to commercialise is \$150 million. The \$10 million is just seed funding for that.

Ms PUGH: You have said in your submission that you are pretty confident you could attract private investment—once you get that seed funding—to get the rest of the funds required to get to that point.

Prof. Smart: We have been in a lot of detailed conversations with investors to get the seed funding. If the seed funding is supplied by the state government, as well as that money it points in a direction that gives investors confidence to get the rest of the money. It is really about making strategic directions. Yes, the \$10 million would definitely help us.

CHAIR: Thank you very much. The time allocated for this session has now expired. There are no questions on notice. Thank you very much, Professor Smart, for sharing with us your knowledge and pointing out what may be a very exciting future.

Prof. Smart: Thank you very much for the opportunity.

WILLIAMS, Dr David, Executive Director, Digital, National Facilities and Collections, CSIRO

CHAIR: I now welcome Dr David Williams from CSIRO. For the record, could you please state your name and the position in which you appear today and also give us a precis of where you have worked in the past?

Dr Williams: Thank you for inviting me. I am Dr David Williams, Executive Director in the Commonwealth Scientific and Industrial Research Organisation. I think CSIRO is well known around these parts. We are a national agency doing science and innovation. We have about 5,500 staff. About 30 per cent of those report to me. I look after what you call the large facilities. I look after the research vessel. I look after the biosecurity level for the research lab at Geelong. I look after the 50 million or so biocollections we have in the country. I also look after the radio astronomy program, which is in Narrabri, Parkes and on the west coast, as well as the whole of computing including supercomputing for CSIRO. Finally, I look after Data61, which is an organisation created by merging NICTA, which has a footprint here as well. It is quite a broad-ranging group of things.

In addition, because of my personal background, I also look after space for CSIRO. My personal background goes back to postgraduate days. I am a geologist by training. I used satellites in my PhD. I went into university. I went into industry. I worked in Germany building and operating weather satellites for 10 years. Then I took over what was the British National Space Centre and turned it into the UK Space Agency in 2010 and became the first CEO. For the last two years before I came here in 2012 I was chairman of the European Space Agency. It is quite a challenge to cajole 20-odd countries to do one program rather than 20-odd programs.

CHAIR: Thank you for that outline, Dr Williams. I ask you to make an opening statement after which committee members may have some questions for you.

Dr Williams: We have submitted a document, so I will take that as something that everybody has read and I will take out a few highlights. CSIRO has quite a comprehensive program in space. We do not have a space section, per se. It is spread across all the businesses. We do research in manufacturing, agriculture, minerals, mining and radio astronomy. We have a strong technology program across all of those and we have a strong application program. A lot of what we do is across the business. We also have a very strong data analytics group with supercomputing capability.

One or two of the highlights are that we operate in Canberra all of NASA's deep missions that go to the rest of the solar system. We operate all of the satellites—about 50 of them—for about eight hours a day which is an interesting program. At the end of this year, one mission, Voyager 2, is set to leave the solar system. Australia is the only place that can monitor it as it leaves the solar system and look at the heliosphere. There is some very interesting science that goes on as a result of managing satellites.

We also look after a number of calibration validation sites around the country. They allow other operators of satellites to verify the accuracy of their data. It is an earth-observing satellite. They look at the earth. We have sites that we calibrate so that we can understand exactly the signal conversion from the electronic signal on the satellite to the geophysical signal that they need to use on the ground. That is quite an important piece of work.

We also build a few of the new CubeSats. Historically, in my lifetime, satellites have gone from being very large beasts that did one or two tasks to small beasts in terms of constellation flying. We have moved a little bit into that to look at some of the technology of hyperspectral work. Perhaps the most interesting thing is that last year we bought a share of a radar satellite known as NovaSAR. This will be the first time Australia has full control of an earth-observing satellite. We bought the data rights over Australia so that we could look at this radar satellite, which is all-weather, and allow scientists and operators to understand how it could benefit Australian business and industry and science. It is a particularly interesting one for the Queensland area because it is an all-weather system, so it can do the tropical zones. It can do water offshore. It is quite a broad-based satellite. Our purpose there is not per se to have the satellite, but it is to enable structured understanding of the value of this type of data in a range of applications.

We do all of those things and we support industry. The 'I' is in CSIRO for a purpose. We do excellent science. We do innovation. We try to help industry do better things and we try to help government improve the way they work. We do that through the science program we have. We also have an interesting innovation program, which Larry Marshall introduced, which is known as the ON program. That allows scientists from CSIRO and universities to go on a course to understand what it takes to move from a good science idea to a business proposition. What we have found is that we

have a lot of good ideas but transitioning to a business proposition is difficult. It is a challenge for many scientists understanding the business dynamics. There is also a gap in the market in terms of who can train you in that field.

We also have a separate venture fund. CSIRO has its own venture fund now called MSV. It has about \$240 million in it. The purpose of that fund is specifically to help small starts and new starts to get beyond the point of a good idea to a point where the series A funding can take over. There is a gap in the market there. The emphasis on the innovation program is to go from CSIRO, and universities for that matter, undertaking work on the scientific risk and the technical risk and reducing that to the point where the market risk will take over in terms of a business model. We can do all we want on the science and innovation, but any good idea that goes into industry has to survive the market risk and a business proposition, and that is the boundary we try to cover in that area.

Space have been quite successful. Gilmour Space Technologies on the Gold Coast has recently got money out of that. I think they got about \$19 million in total for a launcher, and the MSV fund put in about \$4 million or \$5 million. There are three or four of the companies we are funding around the country because we are a national footprint. We do all that work. We try to help move from the science to the innovation. This transition to market risk is a very important step. I think we call it a business plan but it really is going there.

Why do I think Australia is a good place for space? It is a large country. It is undermapped. Almost two-thirds of its economic zone is offshore. We often forget that two-thirds of the economic zone is the 200- or 300-kilometre radius around the land mass. There is a lot there. There is a lot to manage, both environmentally and economically. It brings a new dynamic. If it is an earth-observing satellite, it can bring a new dynamic to moving from what I call postcode management of information to spatially referenced management. It is not just the satellite data; it is how you integrate it with other data and how you do the modelling of that in computing capability. We talk these days of big data and data processing. That is where Data61 comes into the picture. They can do a lot of work. They can help companies and organisations and governments change the way they do business with the data they can get access to in the future and the volumes of data.

That is where we are going overall. I could spend a long time talking about different projects around the country. For example, one of the more interesting ones from a farming perspective is fenceless management of livestock. It is working with beef cattle now where they have a transmitter around their neck. You can not only manage where they are but also control where they go through that mechanism using satellite signals. That to a farmer is quite a big benefit because it avoids fencing, but it also allows pasture to be managed in a better way. It is that economic benefit downstream where the real benefit is, as I think we have already heard.

In the UK we did a lot of work on this. For every dollar that you spend on a space activity you probably can get a return of \$4 on the added value of the data if it is earth-observing data or geophysical GPS data. Then there is the spin-out to the community in general. It is a value chain of how the value flows back to a country. It is not a simple thing of putting up a satellite and getting value off it; it is that you put a satellite up and you have a business proposition about how you change process, how you create new jobs, how you make things more effective, efficient and productive. That is a big challenge for the whole system.

I will dwell briefly on a little bit of my background on launches. It is a market that will emerge. In my first period there were half a dozen launches a year with a big satellite on top, or maybe two big satellites if it was Ariane. We now have constellations of 300 or 400 satellites being launched. For example, Planet Earth recently launched 90 on one satellite. That presents, when it is successful, a good way of doing it and, when it is not, a big risk. Small launches can spread the risk around. It is a risk issue, not a capacity issue.

How do you spread the risk? If you have 400, you probably need to replace somewhere between 50 and 100 every year through the natural cycle. You need to do that in a structured way, and small launches allow you to do that. Then there is a defence need for on-demand launch of small satellites for very particular purposes. The market has changed. It is a different market than 15 years ago. There is an opportunity, but you really have to do it in a cost-effective way. Solely state launches, the traditional sort, will never have a payload of more than two per cent of take-off mass. It is almost a physical impossibility. Most are at about 1.7 or 1.8 per cent. The one per cent of the total mass on take-off is useful payload. The idea of a single stage to orbit—I did some work on that in the UK—changes that dynamic and allows you to have a bigger payload mass, therefore bringing the price down. I am happy to take any questions. I am happy to continue to tell you all the things I have done in space, but I think I will stop at that point and take questions.

CHAIR: Thank you, Dr Williams. I appreciate that. You talked about Gilmour Space Technologies. I note in your submission that you talked about the earth observation capability hub. They are two things that you could expand on. Perhaps you could tell the committee a bit more about these particular things that CSIRO are involved with.

Dr Williams: With Gilmour some of it is technical-in-confidence, but we are helping them with some of their technology. The catalyst to ignite that they currently use is silver. We are looking at alternatives. We are helping them with 3D printing. In Melbourne we have a big titanium printer. CSIRO was the inventor of titanium printing, which is a good printing mechanism. A lot of the 3D printing in Australia can benefit from our open lab in Melbourne, where we allow countries to go in, learn how to do things, learn how to print and then go away and buy their own machine to do it themselves if they have a business. It is the same with on-board processing of data on a satellite. We can work with Data61 to assist them with that sort of processing—how you can do it better and how you can do it more efficiently. The downlink from a satellite is a big power consumer and it is also a big time constraint—so if you can improve the way you do it, it is a benefit.

We are also looking at reception. With our radio astronomy program, we have something called a phased array feed technique, which allows you to look very distant into space—when I say 'distant', I am talking five or six billion light-years out—and with a very faint signal against a very noisy background extract that signal. We see advantage of that in small satellites to become a receiver for the satellite where you allow the satellite to have a small signal coming to earth and you have a system that extracts it from the background noise. There are a whole range of technologies where CSIRO has parallel skills and where our ambition with industry is to say to them, 'Do not start from scratch. Come and have a look at what we can do to help you, where you can pick up from what we have and then go off and do your own thing,' so to speak.

We have done that through a relationship with industry. We have had now two meetings and a third meeting where we called together 30 or 40 small space companies. The first meeting was quite astonishing. You do not realise how difficult it is for SMEs to find out what is available in a country from a nationally funded organisation, so the first challenge was just explaining the range of capability we have. We are now moving into helping individual companies address the problems they need to solve as they go forward. We are not trying to interfere and we are not trying to upstage them; it is really a matter of trying to say, 'Well, you don't need to do that because we can do it. We have people skilled in data analytics.'

I will give you an example on data analytics. On the west coast we have just built the new ASKAP telescope. When that comes fully operational next year it will receive 120 terabits of data a second, which is the same of the rest of the internet globally put together. We process all of that data in real time in the desert on a battery solar system power base. We have massive technology capability that we can demonstrate to other companies and let them get on with it. The data processing involved in that is enormous and powerful, and it has a translation to other parts of any business, let alone the space business.

CHAIR: From what you have talked about here and in the submission, it is very clear that CSIRO has a very broad spectrum of activities and that you are present, shall we say, in all steps in the space industry. In every opportunity to open up jobs you already have a presence?

Dr Williams: That is correct. We have a national footprint, so we are talking to all of the states that are interested in space. We do not intend to stop doing that. What we would like to do is help each one, stay confidential with industry where we need to, be open where we can and ensure that collectively Australia does better things. I think one of the challenges for space is that it is not about Australia competing with itself; it is about competing with the world. We have to realise that the market is the world. The competition is the rest of the world, not Australia. Therefore, we have to be very honest and very open about how we do it and we have to be as collective as we can within the constraints of business.

When it comes to creating jobs, I think we do a lot in the application side which will lead to jobs. We have people in Brisbane in several sites. We do a lot with governments to help them improve processes. One of the things I am looking at for space—I will not name the companies—is to persuade some of the big internationals to set up research in Australia. They tend to do that offshore in their own country. I would also talk to them about which part of their supply chain can come to Australia. It is one thing to build your own satellite and one thing to build your own rocket, but there is a very big market in the supply chain. You do not need to be a big piece in a big supply chain to have a very nice business.

I have talked with these companies and said, 'Let's be realistic. Space has defence connotations. Which parts of the supply chain are you prepared to release to a "five eyes" country?' and then looked at how CSIRO can help relevant industries get up to the standard necessary to bid into those supply chains and become part of the supply chain. I think in that way we can create more jobs within Australia. That is a long-term game because big companies will not take suppliers they do not have full confidence in and they will not take suppliers who do not have the full capability, so there is a task whereby CSIRO can help industry to get through that gate once the companies have identified where they are prepared to work with us as a country.

CHAIR: Certainly the message is a strong one about collaboration throughout Australia in this industry at all steps of the supply chain, as we have heard already as we have just started this inquiry. Certainly your role in that collaboration, from what I have seen through your submission as well, is that CSIRO is open to partnerships and collaboration across all opportunities and all supply opportunities within the space industry chain? Would that broad statement be correct?

Dr Williams: That would be a broad statement and a true one. We are primarily interested in this case in supporting the Space Agency, which is a policy group at the moment, be the voice of Australia and we see ourselves as the national technical arm to help industries across the country. In doing that scientific work, it does not need to be in a particular state for a company to take benefit from it. We have capability around the country that we can share and help them with.

Mr WEIR: As you may or may not know, farming is my background. I have seen great advances in agriculture with GPS navigation and many other things, and obviously the mining industry is looking at driverless machinery. With these satellites, the technology that is already up there would be becoming outdated like my mobile phone, would it not?

Dr Williams: It is the old adage that if you want to do things properly on a small scale large area you need data. Yes, the phone is an application tool to use things and to access the information, but in the background you still need the processor. For example on a phone, if you use Uber it is not the app; it is the background work that they do to have a map of the country with everything in real time that can deliver to you in real time. It is that background work. The platform to deliver the service is the one that we have to go for.

In the farming world I will give you a different example. We are looking at provenance of food. If you want to sell high-value food into Asia, which Australia does, the problem of substitution of inferior product is a challenge. How do you prove that the beef is the beef of the quality it was stated on the package, so to speak? We are looking at a platform to try to improve that process so that we have a provenance chain of food. Some of that will involve satellite. Not much of that one will.

In terms of your apps, yes, a lot of the people who use the data will use it on an app on a phone, an iPad or a Surface Pro, but the background platform that supplies it is the one that creates jobs—big jobs—in the tech industry, it is the one that has the big data crunching and it is the one that requires the largest data sources. You could translate that to the Barrier Reef. If we want to manage that as a holistic system, we need to be feeding good quality data into the model all the time to understand what changes, how it changes and why it changes.

Mr MADDEN: I was very interested to hear you talk about fenceless grazing. I am curious about two aspects. Firstly, how do you control the movement of cattle through this?

Dr Williams: It is basically a little beeper that creates a sonic noise and turns them around. As they move through the boundary condition it gets worse and they turn around.

Mr MADDEN: Is it a beep or is it a zap?

Dr Williams: It is not a beep; it is a sonic beep. We would not hear it.

Mr MADDEN: It is through sonics that you control it?

Dr Williams: I will be honest with you: I do not know the exact technology, but it is linked to a GPS tracker. You set the boundary conditions that you want them to stay within and as they approach the boundary there is a sonic noise. The sonic is based on techniques that exist, for example, for family pets where you put a wire around the property and it has the same impact.

Mr MADDEN: Previously you raised the issue of CSIRO developing technology and that technology being commercialised. Using that as an example, can you explain the process by which technology has developed and is then commercialised and CSIRO benefits from it?

Dr Williams: There are several parts to taking something out of CSIRO into a business form. One is that a company may come to us and say, 'We have heard this is possible but we don't know how to do it. Can we work with you to do it?' If it is sensible we will put a team in, we will understand

how we share the costs and, dependent on that sharing, there will then be some sharing of the benefit. The benefit can come in many ways for CSIRO. It can be direct cost recovery of the effort we put in, it could be an IP stream—if the technique is successful they pay on an IP stream—or we could take an equity share in the company they have. In the case of the one we are talking about, a company has been set up, it has taken the technology out and it is running it.

Mr MADDEN: Did that company approach you?

Dr Williams: I do not know the particular details of that because that came through the agriculture business. With CSIRO it can come in from many directions as well.

Mr BATT: For how long would satellites stay up in space? Is there a time expectancy?

Dr Williams: The big telecoms ones that run in geostationary orbit—the ones that, for example, do satellite television and satellite communications—these days probably have a lifetime of 15 years, maybe pushing out to 20 years. They are big satellites. What has changed with those is not only the longer lifetime but also the way you can control the beam forming so that you can look at different parts of the earth at different times. When I started, the earth observation satellites historically run in an orbit of about 700 kilometres, they had altitude and they had a lifetime of three years. That has been pushed out to eight to 10 years. From a technology point of view, there is a massive saving through changing the lifetime from three years to 10 years, but the small CubeSats have to be in an orbit that deteriorates back to earth very quickly. They tend to run at 300 or 400 kilometres, and some of those may have a lifetime of only six months. Some may stretch to two years. The reason is that many of the CubeSats do not have a propulsion system. You put them up and their orbit just decays naturally over time and then they just come down.

Mr BATT: What happens to them?

Dr Williams: The CubeSats are small enough to burn up.

Mr BATT: And the bigger ones?

Dr Williams: For the bigger ones, since the mid-1980s everybody has to have a mechanism to either put them into deorbit—that is, bring them down safely, and we hear from time to time talk about whether it will come down where they said it is coming down—or send it off into deep space. For example, if it is a geostationary orbit, which is 36,000 kilometres, the normal process is to push it out, and once you push it out so far it just starts drifting away.

Ms PUGH: I notice that you have your space education and outreach program operating in 239 schools in Queensland alone. Could you expand on the program a little bit? Obviously, some of the people who will work in this industry in 10 years time are still in school. How are the schools selected? Do you work with particular students or more with a particular school?

Dr Williams: I will start by saying that, in general, STEM is not part of CSIRO's formal remit—there are other organisations that do that—but we recognise that a lot of things we do are interesting for schools, so we do quite a lot with schools and we have this group that do science education. We do it across a range of subjects. I would have to get more information sent to you on the specifics of how we do it in Queensland, because we have a team based in Melbourne and Sydney that coordinates all the activity but it is usually done in conjunction with the education authorities. It is not a matter of somebody knowing a school and going to it; it is a more structured program.

Mr MICKELBERG: In your submission you talk about spectroscopic technology in sensing applications. Could you outline some of the commercial applications of that? From a public policy perspective, I think of something like the PFAS issue. Could that sort of technology be used to identify a PFAS contamination issue in a water source or something like that?

Dr Williams: The sensor technology is important. Basically, you have the spectrum that you can use to look at the earth, and different parts of the spectrum respond to different elements on the surface. At the end of day, you usually have a 16-bit electronic signal. With the hyperspectral, for example—the hydrogen, the oxygen and the water bands—you can filter those out so that if you want to detect a particular feature and you can correlate it to a particular part of the spectrum you can develop a sensor to specifically do that job.

Mr MICKELBERG: Is that within the realm of possibility with current technology? Is that on the radar?

Dr Williams: Yes. In the early satellites, because of the limitations of bandwidth and the technology of sensors, you would predefine the bandwidths that you looked at. Most of the early ones had a red, a green and a blue so you could make a colour picture and maybe an infra-red to look at the edge and a thermal to look at temperature. Now we are moving to what we call a hyperspectral,

where you can look at any part of the spectrum but you have on-board processing to choose which part you look at with any particular application. If you are flying over water, you may change the boundary conditions compared to over land. If you wanted to identify a particular mineral, you would hone in on those very narrow bandwidths that would allow you to identify—assuming you can do that of course. I am not saying you can for everything. You would change the frequencies you observe in almost real time on the satellite with hyperspectral to look at the bandwidths you wanted to look at.

It is a changing dynamic of how satellites operate and work. It is brought about by advances in sensor technologies, in data management handling techniques and also in software—the way you can now change the software on board a satellite. In the early satellite days it was hardwired and then you had read-only memories. I have known satellites where the read-only memory was emptied when it went through a particular zone of turbulence in the atmosphere, shall we say—a storm. Once that happened it was dead. With the modern satellites you can reprogram them and recover most of that capability. I could tell you a few stories about how that is being done and how some have been lost.

That is the benefit of modern technology. It sounds like space is at the frontier of science, but it is actually a very conservative business because once it is in space you tend not to be able to fix it. It does pick up on technologies that operate elsewhere. With a lot of the sensor technology you just have to harden the system; you just have to make it suitable for space. It does draw from all the other developments around technology. That is why the price has reduced dramatically in the last 10 years, because the amount of off-the-shelf hardware and software with suitable capabilities has changed so dramatically.

Mr MICKELBERG: You talked about the large communication satellites, which is historically how things have been done. Is there scope for these smaller CubeSats to replace those large satellites over time?

Dr Williams: There is, and a lot of people are looking at that. The first issue is that the geostationary telecom. satellite can only look out to about 60 to 65 degrees, so the polar regions do not get coverage. You have to have different satellites for that anyway. There is a system where you fire a constellation in low earth orbit and it becomes a network of communications platforms that talk to each other. It is a bit like the web that mobile phones work in: a mobile phone talks to a base station; that station talks to another one; it talks to another; and it goes up and then comes down. They have a management system which is not massively different in conceptual design but massively more complex in the way it has to operate. There is a chance to change that. That will be a dynamic which will be driven by market force.

Mr MICKELBERG: Do all those satellites operate on different bandwidth? If so, how do we go about managing the competing demands with respect to the bandwidth required? Obviously the government sold or altered the allocation of bandwidth for different applications between defence and commercial applications in recent years. Is that an issue? How do we manage that?

Dr Williams: Bandwidth is a big issue. The bandwidth is fixed and limited and there is an increasing demand for it. The way it works is an international telecom. union—and internationally there are no hard or fast rules and laws. I think every country has understood that it is in their interests to work together to ensure that the bandwidth is sensibly used. There have been some problems. No matter the applications assigned to you, you can have an uplink bandwidth and a separate downlink bandwidth. You can have it allocated to you, you can have an uplink and downlink. You can have it allocated to active use or passive use and you can have primary and secondary use. We used to spend a lot of time—and countries need to do this at country level, not at subject level—in working out how you can sensibly talk about allocating bandwidth to satisfy defence, commercial operators and what I call the government operators who want things for social and environmental reasons. Different countries put different weights on different elements.

I think India changed the bandwidth. In one case they changed the bandwidth and all the satellites in the world had a problem and they had to take it out of use. I was involved in building a satellite that was looking at seawater salinity. It spent its first six months identifying rogue transmission stations around the world that were using that bandwidth illegally and were just swamping the signal of the satellite. After a while they all got cleared out and then you could use the satellite for the purposes intended. Bandwidth is a big issue.

Mr MICKELBERG: You talked about the angle of your communications satellite, for example. Is bandwidth a greater issue the closer you get to the equator, where there are more population centres?

Dr Williams: Bandwidth has two meanings. One is the frequency in which you operate, which is the bandwidth of the satellite. That does not matter as long as you have the power. Then there is a bandwidth of transmission, which is a power driven issue. You can have a satellite transmitting with very high power that will swamp lower power signals. Conversely, you can have one transmitting at very low power and get swamped by other signals. Getting that balance right is always difficult. That is what I was talking earlier about the phased array feed being a tool to allow a lower power downlink, which saves power on the satellite, but still recovering the full signal. It is a constant, consistent and ongoing technical issue.

Mr MICKELBERG: I am interested in the fidelity associated with open-source imagery and how that would be used for commercial applications and where that technology is at now. Is it ocean that has a four-by-four-metre fidelity? Correct me if I am wrong. My question is: how can that technology be applied now? Also, what advances are on the radar with respect to that technology and how it can be applied?

Dr Williams: When I first started, the satellite resolution was about 30 metres. You can now get centimetres and millimetres even. The difference is that the higher the resolution, the smaller the area on the ground you look at in any one moment because of the data rates and issues around that. The challenge is whether you charge for the data or make the data open source. Europe has gone open source. The US primarily in the government sector is open source and the commercial operators are trying to go closed source. The challenge there is that the data itself has a value but you cannot just pick it up and use it. It is the modelling and how you integrate it and how you perceive it that gives it value.

When I worked in Europe we spent a lot of time, first of all, moving the UK government to open-source data and then moving the European Union to it on the basis that that was the best way to create the big market. You could try to sell a bit of imagery, but you are much better off allowing industry and commerce to take the data, add value and use it in a true economic commercial sense. For example, all the European data is now open source. CSIRO and Geoscience Australia have agreements to bring that data down to Australia and that is now open source. Earth-observing data, unless it is very proprietary, will be open source. Some companies will try to do a vertical market—so have the data and do the applications. Whether that works is yet to be seen, but I think we are in a phase where open source is probably the way to go for a while to allow the bright people who understand the satellite data and understand the application area to develop real applications which they then sell for a value.

Mr MICKELBERG: It sounds like what you are talking about there is that we are duplicating the imagery itself. We have the high level—the highest fidelity is used for defence purposes. I do not know if that is the case or not, but presumably it is. Then we have commercial operators duplicating the same patch of dirt in order to use it for commercial applications. Is that a fair comment?

Dr Williams: There has been a bit of that. I do not think there is a lot of that at the moment. For example, in the agricultural world, if you want to monitor a crop yield, we are still at the point where getting the right data at the right time in the growing cycle is still an issue. That was one of the reasons that drove us to NovaSAR; it is all-weather. If you want to see how the crop is doing on this date, it does not matter what the weather is like; you can have a look. Whether it makes sense is still to be determined, but that is a scientific challenge for CSIRO. If it works and we find industry in Australia that takes advantage, there is a market.

Mr MICKELBERG: Do you save that data?

Dr Williams: That data will always be saved, yes.

Mr MICKELBERG: In 20 years time, when we identify there is some trend we did not think existed, you can go back and interrogate it?

Dr Williams: Yes, we can go back into it.

CHAIR: Dr Williams, you have headed a national space agency and a multinational space agency. What do governments have to do to initiate and grow a space industry in their jurisdiction?

Dr Williams: Historically it was about sovereignty. Space business was a Cold War issue, full stop. The origin is entirely in the Cold War of the fifties and sixties. It was probably only in the late seventies and eighties when anything except Cold War stuff was done with space, and the first time it was weather forecasting. From that point of view, weather forecasting now is heavily dependent on satellite data and it is moving out into other fields. It depends where you wish to be. The question is: do we as a country need to be in the space hardware business or do we stay in the good-user, the consumer, business of using the data for value added? That is a big question. It always will be.

CHAIR: That is a question perhaps that governments need to determine as a policy issue.

Dr Williams: That is the government's issue. If I was looking at a parallel, the decision was made not to stay in the car manufacturing industry. The reason was that most of the value is in maintenance, running and operation and the value of the vehicles to the economy and not in actually building them. I do think that as a country Australia has a big opportunity to go into niche markets. Australia will never be the global leader in space hardware, but there are some niche markets. What we have heard today about launches and other companies doing that—that is a valuable market. They will need some support to get through the science technology risk to market takeover of risk. That is the way I would like to look at it. It is how you get from that good idea and get through the science and technology boundary to the point where market risk will take over. Supply chains will be the same thing in sensor technology.

The way it has worked in the past is if you want to be a country with a good, high standard of living and high population, you have to be on the front edge of all industrial waves. We are in the digital wave. We have to ensure that Australia gets the right skills into the system and the education system out of it and that we support the establishment of the right infrastructure to allow a digital world to emerge. I think the skills are there. If you do that, you keep the value added of a high-value country. Australia has been in that market and wants to stay there, and that is what we have to do. I think there is a role of government, but they should always be looking for the exit point when they enter and not see it as a long-term position.

If you want to change anything, you need extra money for the change. It does not matter whether it is decorating the house or redesigning a multibillion dollar business; the change itself needs money, over and above the day-to-day operating costs. It is that change area that I think governments can step into to help industry get through that little wave of uncertainty to a point where they can look to the market. The markets are prepared to back risk if they understand (a) the market and (b) that there is no technical and scientific risk involved.

CHAIR: What you have talked in relation to change is an opportunity, but in the supply chain a number of different opportunities or niches have been identified that would suit Australia.

Dr Williams: Yes.

CHAIR: Do you have an opinion on what has been identified so far?

Dr Williams: On the hardware side, I think we have a lot of software expertise in managing systems. We have potential capability for on-board software to run and operate satellites and change the way they operate. We have a lot of high-tech sensor performance. I think they are key areas. I think we have extremely good GPS digital—what I call the geosphere capability—in Australia, mainly through Geoscience Australia and some others where we understand the sphere that we are in. Because Australia is moving north at several centimetres a year, you have to understand that movement to be able to do things and manage things. I think with some of the emerging rocket companies there is a market there. We will do what we can to help them with the technology that they need, but we cannot do everything.

CHAIR: We have talked about launch sites and locations or bases. Has the CSIRO done any work on this? Is that information that they can share?

Dr Williams: No, we have not done any work on that. A number of people are looking at different launch sites, but for me that is very much a market issue.

CHAIR: In your submission you talked about turning those ideas into viable business opportunities and then further developing those. One of the things that we have done in Queensland with our Advance Queensland program is exactly that: turning ideas into businesses and developing those businesses further. Has the CSIRO formed a relationship with Advance Queensland?

Dr Williams: That would be a good question for me to take back and find out. We did the study with Data61 for Queensland, and we are in Fortitude Valley with our data team. We are involved, but I am not sure how structured that relationship is. We do get a considerable amount of funding from the Queensland government, which we then turn around into postgraduates and we turn around into data driven technology and science.

CHAIR: That may be something that your organisation can take on notice and come back to us on—that is, the relationship with Advance Queensland.

Dr Williams: Sure.

Mr WEIR: You state here that you have a partnership or a relationship with Boeing. Is that in IT or in the rocket space? What is the relationship with Boeing?

Dr Williams: Boeing is one of those companies that has a good international footprint. They build part of the 787 down in Melbourne, the trailing edge wing on the rear wing. They have a research group down in Melbourne. We formed a relationship with them to help them with their technology. Historically, it was probably more in the physical things. CSIRO has been Boeing supplier of the year three times. The first time was for paint, oddly enough. It is an interesting story. When you paint a jumbo jet, it takes several tonnes of paint. What you want is the paint to be very even. To do that you want a spray mechanism that gives you a very uniform drop size as you spray. CSIRO invented a technique to give them a very uniform drop size. We have moved on from that.

We are doing a lot more on the digital side, because they understand that going forward a plane is basically a—I should not say a ‘tin can’, but it is really a tin can with electronics these days, because everything inside it from all the lights, which are managed by wi-fi, to all the seats are electronic. It is really an electronic system that carries passengers within a tube. We do a lot of work with them. It is moving from being hardware to being more software driven.

Mr MADDEN: Dr Williams, once again you have told me something wonderful about CSIRO that I did not know, which is your good work with Boeing and reducing the amount of paint on their planes. I am aware of your great success with wi-fi. Can you give me one example where CSIRO has made a major advance with regard to space technology?

Dr Williams: On space technology, in the 1980s, a long time ago, they did build part of the satellite that I was building in the UK. It was a long-track scanning radiometer, which was to precisely measure sea surface temperature. They only built one of them and then Australia backed out, but that technology travels on and is still around in those sensors. That is a very historical one. That was one piece of space hardware.

Through the company Sabre Astronautics we have some control software that flies on satellites. There are little packets of software. I would not say it is massive in that we have not built a rocket but, in terms of being a niche market where they do a very particular high-tech job, there are a number of little examples around.

Mr MADDEN: It is in those niche areas that CSIRO excels?

Dr Williams: When you look at the big companies—the Lockheeds, the Boeings, the Northrop Grummans—they control the program, the airbuses. What you have to do is really get in their supply chains.

Mr MICKELBERG: At our hearing the other day we heard that the broadband cable between Australia and presumably the west coast of the US is really important with respect to the pipeline for getting data back and forth. Can I get your thoughts as to whether or not that is the case? Aside from a reliability question, does additional cabling provide additional capability, as opposed to just additional redundancy within the system?

Dr Williams: There are two or three answers to that. I sit on the board of a company called the Australian Academic Research Network, which provides the broadband connection across the academic network of Australia. We just agreed to fund two new cables—one into Singapore and one into Guam. The purpose of that is to improve the way data can move around the world on cable. It is point to point. Once you are into Singapore, you can go across to Europe; once you are in Guam, you can cut across to the USA or go into Japan and Asia and down to Singapore. Therefore, you are getting much better redundancy around the system.

It is an important tool, because certainly the European satellites now have gone to on-board storage. It is storing the data on-board and downloading over Europe rather than downloading locally, so you do need to bring the data down. You do need a link. There is still a lot of volume on a lot of links when it is the downtime. When it is overnight in Australia a lot of businesses do not run, so there is a lot of downtime.

With some of the weather satellites and other satellites, you still get downlinks into Australia. It is a matter of whether you downlink in Australia or whether you downlink in the host country and move the data down. With NovaSAR, the initial phase of the downlink will be in the UK and we will ship the data down. We are going to, hopefully, put a couple of ground stations in to receive in Australia, but we control where it looks at. It is different with different systems, and it is different for different countries, and it is different for different operators, but there is no doubt that good cable broadband out from Australia, both scientific and commercial, to Guam and to Singapore as the two hubs to get to the rest of the world is important.

Mr MICKELBERG: Currently, is all the data from a satellite that might be applied in Australia downlinked somewhere other than Australia and then shipped in?

Dr Williams: No. There are ground stations, like at Alice Springs. There are five or six ground stations across Australia that collect data. It is just that some of the more modern satellites switch to storing on-board and downlinking at one site, because it is more efficient. It is a better cost capability.

Ms PUGH: I note that you have supported Australian SMEs such as Puzzle Precision and Innovation Composites. You note that they have difficulty getting information. Is there any insight that you can share with the government around any role that we can play in making sure that they have access to better information, with regard to programs that already exist or funding opportunities from government?

Dr Williams: I do not think it is much of a funding problem. I think it is the old classic of extracting the information from the noise. You have all searched the internet to find something. How many sites do you go through before you find the thing that you want? One of the challenges is identifying the group that you are working with, in this case the SMEs interested in space, and then, in CSIRO's case, allowing them to understand the range of capability in CSIRO that is available to help them.

At the Queensland level, do all the companies know what all the universities can offer and what all the small industries can offer? It is really focusing the information exchange, not to say 'buy this' or 'buy that' but simply to understand where they can start from if they want to do something novel. It is a little paradoxical, but the more data and the more channels you have for data to be transmitted down, the more difficult it can be to find that needle. Sometimes it is really like looking for a needle in the digital haystack.

Mr MICKELBERG: I was just going to look it up on the internet, but since we have time I will ask you: what is quantum Monte Carlo materials?

Dr Williams: You really have me there.

Mr MICKELBERG: I will look it up.

Dr Williams: I will try to get somebody to send you a note.

CHAIR: There being no further questions, we will close this session. Thank you again, Dr Williams. We appreciate that you have travelled some way to talk to us today. We really appreciate what you have shared with us. We thank the CSIRO for letting us have you here today.

Dr Williams: No problem.

Proceedings suspended from 10.55 am 11.18 am.

O'SULLIVAN, Ms Rhonda, Principal Research Fellow, Sustainable Minerals Institute, University of Queensland

CHAIR: I now invite you to make an opening statement after which committee members may have some questions for you.

Ms O'Sullivan: I thank the committee very much for the opportunity to speak today; I really appreciate your time. Today I am going to discuss and elaborate on the space resources submission that I previously made to you.

In Queensland we are already world leaders in many facets of mining, which places us in an ideal position to make an impact in space resources. By partnering with earth and space mining, we could create complementary benefits which include providing a new era of high-tech growth for the Queensland economy and help improve resource discovery rates for our already strong resources sector. Before discussing Queensland further I would like to set the global context for space resource activities. I do apologise for starting with the heavy topic of international law, but I think it is really important to specifically understand why globally now is an opportunistic time to invest in space resource activities and develop this industry.

In addition to recent reductions in launch costs due to the development of re-useable launch vehicles, national legislation has been enacted in the USA and Luxembourg to promote the private space resource sector. International law relating to space resources is ambiguous. The main governing treaty is the 1967 Outer Space Treaty, which has been ratified by all major space-faring nations, including Australia, and is legally binding on 107 countries. The ambiguity is associated with the concept of appropriation related to property rights, which is basically whether or not we can take something for our own and use it from space. This is questioned because the treaty states—

The exploration and use of outer space ... shall be carried out for the benefit and in the interests of all countries ... and shall be for the province of all mankind.

While the Outer Space Treaty does not explicitly forbid the appropriation of space resources by profit actors, it states—

... the Moon and other celestial bodies, is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means.

The USA and Luxembourg provide an interpretation of this law which allows a legal framework within their nations to ensure private property rights in space. It appears these two countries have applied the Lotus principle, which is based on allowing a nation to act in any way they wish, provided they do not contravene an explicit prohibition of international law. As a result, the USA space act was passed in 2015 and Luxembourg's Space Resources Act came into effect in August 2017. These new laws have created a turning point for space resource investment and commercialisation. Both are gaining momentum, and the space mining market is estimated to be worth \$2.84 billion by 2025. Private company iSpace has announced the concept of a moon valley settlement using moon resources to commercialise moon tourism and development. Their space and earth mine planning engineer gained significant mining expertise working at Mount Isa Mines right here in north-west Queensland, acknowledging that we are recognised internationally for our mining know-how.

Given this globally distinctive timing advantage, my purpose today is to focus on the synergies between space, earth exploration and mining along with how Queensland can benefit from a practical application of solving shared problems. After completing the space studies program at the International Space University, I was fortunate enough to be invited onto The Hague International Space Resources Governance Working Group as a technical representative with industry experience. The group was convened by The Hague Institute for Global Justice in 2014 by a round table attended by industry leaders, scientists and diplomats as well as political and legal experts from across the globe. We are currently working on the draft building blocks to develop an international legal framework for the utilisation of space resources.

During this work it became apparent to me how significantly advanced Australia is in the application of resource risk, extraction planning and operation due to our strong governance, which has improved through decades of application of the JORC and Belmont codes and our safety legislation. JORC is the best principles based code in the world which is more transferrable to international law principles than Canada's more prescriptive equivalent. Mining projects governed by these codes of practice are comparable to space projects, as they typically involve significant capital investment and large project time lines. A mining project from discovery to operation, like a moon mission, can often take a decade or more. Space projects are often over time and budget, but we have the skills here to manage these large types of projects.

Deposit discovery rates in Queensland are declining. Each year we do not make a significant discovery we are getting less return for the dollars invested. To address this concern we can either invest more money or find smarter ways to explore. I propose we facilitate the disruption of space technologies into our exploration industry to boost our probability of success of discovering new ore bodies. I believe space related technologies could be the answer to increase the speed at which we turn over prospects and therefore our discovery rate, leading to infrastructure and jobs. Resource activities are Queensland's niche to space, and we know how to explore and discover.

Queensland is advanced in exploration and mining due to our geologically favourable settings and our large land mass, which is second only to Western Australia. In the year ending 2017, Queensland's resource sector contributed \$5.1 billion in wages paid to 38,000 full-time employees, \$16.4 billion in purchases and \$3.8 billion in royalties. The scope is broad for space and earth mining synergies, so being focused is important to ensure impact. Luxembourg recently held a space mining summit. I reached out to one of Australia's leading mining companies for interest. They responded and said that mining in space is on their radar but is not a priority. This indicates to me that there is potential for reinvestment opportunities if we can demonstrate value and return on investment. We can do this by investing in space projects with earth synergies where technology development has reciprocal benefits—essentially aiming for a two-for-one deal.

A few examples of these synergies may be exploration through the moon's regolith. The moon has been impacted by asteroids, leaving it covered in fine dust. One of the biggest challenges in Queensland's exploration is exploring under cover when mineralised rocks have been masked by sediments. Another example is utilising space robotics and instrumentation. The resource prospector Rover, designed by NASA for a Mars mission, is essentially a robotic exploration geologist that has instrumentation which can identify iron associated material that is often an indicator of mineralisation here on earth. Utilising this technology in Queensland could improve Queensland's discovery rate. The final example is that, by developing extraction technologies to utilise in situ materials on the moon in a microgravity environment, we may uncover more effective ways of extracting our low-grade halos to our current ore bodies and extend mine lives in Queensland.

I would like to close with a personal experience. I was fortunate enough to experience the space industry culture during my studies in Europe. The level of collaboration within the space industry is unparalleled. It is demonstrated on the International Space Station, where countries that have been in conflict on earth stand side by side and carry out scientific experiments. It is also demonstrated by the shared excitement when a vehicle launch is successful and shared disappointment and sometimes grief when one fails. The space industry represents a collective international effort to progress humanity beyond earth. Whether motivated by space exploration and mining, hypersonics or remote sensing technologies, international investment, perseverance and collaboration is powerful and truly inspiring. If we dare to be bold enough and commit to being part of a moon exploration mission, the value through STEM promotion across Queensland and throughout Australia would be a substantial value-add. Space investment is still expensive, and by focusing on a combined purpose to the investment the value is increased. I would like to see Queensland use space resources to showcase our expertise to the rest of the world while solving practical problems in our own backyard to promote further investment and sustainability of the space industry.

CHAIR: Thank you very much for your submission. It is quite arresting reading. One of the things I am interested in, and certainly one that you take a different view of, is those priorities listed by the space agency. Can you expand more on what you have written here?

Ms O'Sullivan: I did some high-level research with the dot points that I have there, just trying to see where we place on the list of priorities. The investigation that I did suggests to me that we are probably not cutting edge or leading in the specifics listed. There are openings there in I think the last priority—I cannot remember specifically what it says—but—

CHAIR: 'Specialised space capabilities'.

Ms O'Sullivan: Yes. I think that is our real opening into the niche type markets, yes.

CHAIR: No. 6 is remote asset management. Where do we stand as a nation or a state in perhaps fulfilling that niche?

Ms O'Sullivan: I could not give you an exact ranking. If we are talking with regard to mining, I know that Rio Tinto has significant automation occurring in its Western Australian operations. Some of that is world class, but there are still challenges in transferring that knowledge or application to underground mining due to the difficulties in communication underground. It is typically radio communication underground and some wi-fi but, because mining fronts move around so frequently, it is difficult to have the same application underground. The underground operations are some of our largest operations in the country.

CHAIR: The No. 3 priority is positioning, navigation and timing infrastructure. You note that Australia has access to six high-visibility GNSS but that we can improve our accuracy of what is done. Can you expand on that explain why you have written that?

Ms O'Sullivan: It was just research. I think it was mentioned in the public briefing on Monday as well. I am not an expert in this, so I am a bit hesitant to comment. I am not sure if we specifically need to put more satellites in the air for Australia, unless it is possibly defence related and for confidential type of information. A lot of the really high-tech satellite systems are out there. ESA have just launched their Galileo satellite constellation—I think the first launch was in July—and that is also going to have a lot of benefits for us.

CHAIR: I will stick to questions regarding mining. You talk about the significant number of mid-tier companies that we have in Australia and Queensland and that there is some potential for them to be involved in this aspect of the space industry.

Ms O'Sullivan: Yes, absolutely. If we are looking at it from an exploration perspective, I believe that around three-quarters of the discoveries made in Australia are made by juniors and SMEs. By facilitating their technology and their ability to make discoveries quicker, ultimately that will facilitate jobs, industry and growth in the mining sector.

Mr WEIR: This is about identifying more resources here as well as exploring in space the potential?

Ms O'Sullivan: Yes.

Mr WEIR: What indications are there? What would you be looking for in space? I notice that you have mentioned asteroids.

Ms O'Sullivan: There are two main types of space mining. There is in situ resource utilisation, which basically means living off the land. It is going to be very difficult for us to import a lot of materials from earth. That is probably one that is closer to coming to fruition. My personal opinion of asteroid mining is that it is probably a fair way off. It is going to be very difficult to get an asteroid back to earth and potentially catastrophic with the technology that we have at the moment. I would imagine that asteroid mining is something that would be utilised in space when materials are needed in space.

NASA and the European Space Agency have both proposed missions to the moon. There are a number of moon villages, or moon valleys, that are being proposed both by space agencies and commercial organisations that are working towards that. I think understanding how we can utilise the moon's resources—and mining and extracting and water would be some of the first priorities for the moon, to ensure life sustainability. Also, hydrogen and oxygen can be used as a propellant for vehicles getting on and off the moon. It is a lot cheaper doing it that way, where the moon has a much lower gravity field than the earth, than constantly ferrying people between earth and the moon. Understanding a mine plan around the moon's resources would be fundamental to any of those activities getting off the ground.

Mr MADDEN: Thanks very much for coming in today, Rhonda. In your submission you say—

We are global leaders in mining—why not build on this strength to differentiate ourselves?

Could you enlarge on that?

Ms O'Sullivan: Yes. Essentially, I mentioned that BHP and Rio Tinto are two of the largest mining companies in world. They are ranked Nos 1 and 2 by market capitalisation. BHP originated in Broken Hill and it is now dual listed on the International Stock Exchange, and I believe Rio Tinto is as well. They are both Australian owned. As previously mentioned, Rio Tinto is going leaps and bounds ahead in the automation of the mining industry.

Being in Australia, we have an old geological setting where we have rocks greater than the Paleoproterozoic—greater than 1.6 billion years old. We have a lot of mineral wealth and endowment within our country. We have a number of operations. We have problem solved a lot of extraction processes. We are familiar with many mining methods—block caving, underground, open pit, in situ. We have done in situ leaching of uranium in South Australia. We have such a broad spectrum owing to our large land mass that we have significant expertise in mining.

Mr MADDEN: I wondered whether it might have been more to do with how we can work with the space industry and differentiate ourselves. I was thinking about the aspect of identifying areas that have mining potential. Do you see that we have technology in Australia that is superior to technology in other areas of the world?

Ms O'Sullivan: Yes, specifically with regard to automation. Robotics is something that I think we may be little bit behind on and we could implement into our operations but, yes, the automation side of things, absolutely.

Mr MADDEN: I did not realise that we were leaders in that area. It is good to hear.

Ms O'Sullivan: I think we had our first automated train in the Pilbara carry a large load of iron ore from one of the mines down to Western Australia. That was amazing.

Mr BATT: In relation to the resources that we are looking for, has there been much historical data found from the previous missions to the moon as to the resources that are there, or are we at the stage where we still have to go out and explore and find out what is there in the first place? You mentioned water.

Ms O'Sullivan: Yes.

Mr BATT: Are there any other resources? Is it just the case that we think it is there or do we know what is on there?

Ms O'Sullivan: I think we know on a surficial level what is there. Water has been identified in the poles, and in some of the crater regions that are shadowed from the sun there are some ice reserves there. The Apollo missions took samples and there is significant basaltic coverage in the crust and also basaltic lava caves, which also could be used as shelter from radiation for astronauts. We are not sure what is in those caves, so we are still in the exploration phase there. There are also some silicon rich rock types that can be used for a whole wide variety of 3D-printing applications.

Mr MICKELBERG: You talked about the priorities listed by the Australian Space Agency being too broad and unfocused in the mining space. If you could identify one aspect of that endeavour that would be more worthy of focus than others, what would it be? Would it be facilitating the identification of resources in Australia or would it be about exporting expertise elsewhere, such as the legal framework? You talked about implementing a legal framework that may be a catalyst for an industry. Where would you be focusing your energy?

Ms O'Sullivan: My top two—this is probably outside the scope of Queensland; it is more a national effort—would be potentially following on from the US and Luxembourg and becoming the first nation in the Southern Hemisphere to adopt some similar legal frameworks and also understanding and developing an extraction method for in situ resource utilisation on the moon that could significantly extend the life of the mining of some of our larger deposits, like Mount Isa Mines here in Queensland.

Mr MICKELBERG: Is that about improving efficiencies and decreasing the size and scale? Is that what you are talking about there? When you say 'in situ extraction', presumably that also extends to processing? Is that a fair comment?

Ms O'Sullivan: Yes.

Mr MICKELBERG: You are really talking about making the size and scale sufficient so that we could move it there? What are we talking about?

Ms O'Sullivan: Move what there, sorry?

Mr MICKELBERG: The equipment required to do that. When you say 'using that expertise', what are we talking about? Digging a hole? Are we talking about getting the material there to be able to dig the hole? I am just unsure as to how we physically start that process. That is what I am asking.

Ms O'Sullivan: It is mainly from drilling. Some in situ leaching techniques involve drilling holes and creating a pressure gradient that lets water flow through one hole and into another. During that process, with the lixiviants that are added to the water, it will extract certain types of minerals—whatever you are targeting. It is something that is lightweight that can be launched and can have applications.

Mr MICKELBERG: The impediment at the moment is that the machinery required to drill those holes is too heavy and too big? Is that a summation?

Ms O'Sullivan: Yes, correct.

CHAIR: Rhonda, we have heard about further manned missions to the moon and Mars. The in situ mining for water seems to be the biggest part of it. This is the biggest and first opportunity that we are talking about; is it not?

Ms O'Sullivan: Yes.

CHAIR: You talked about potential ways to extract that water. These missions would be reliant on utilising that water taken in situ; am I correct?

Ms O'Sullivan: For a moon settlement?

CHAIR: Yes, for any future missions to the moon and beyond.

Ms O'Sullivan: Yes.

CHAIR: The Luxembourg legislation is quite interesting. Can you give us some more details about what they have done?

Ms O'Sullivan: Not specific details, other than that I know they have a more open and broad approach than the US and a more inviting and collaborative approach for international private companies to come and participate. Specifically, I have not read the legislation in detail.

CHAIR: In Queensland we have along the coast and out west many small and medium sized companies with very specialised mining engineering expertise. Obviously, we are looking for jobs in the supply chain. Is this a real opportunity for those companies to change what they do so that what they do can be taken into space or used on space missions? I am thinking of companies around Mackay and Gladstone that are very specialised in working in mining engineering. This is a great opportunity for them, is it not?

Ms O'Sullivan: Yes, absolutely. I am not sure that I can expand on that, sorry.

CHAIR: But certainly in your experience you have come across some of those smaller and medium companies throughout Queensland?

Ms O'Sullivan: My area of knowledge is north-west Queensland, around Mount Isa Inlier, Ernest Henry, Cannington areas and base metals.

CHAIR: Can you give an example of some of the people or the companies you have dealt with in north-west Queensland that could perhaps translate their expertise into other fields, like space mining?

Ms O'Sullivan: South32 are the operators of Cannington, previously with BHP. Glencore operates Mount Isa Mines, George Fisher Mine and Ernest Henry mine. Glencore was where the ispace mining engineer gained a lot of his expertise. I believe his skills were around managing large projects on time and on budget and being able to extract resources on schedule.

Scheduling is a complicated part of mining as is making sure the blend of grades getting to the mill and processing is what is expected to be there. Obviously it translates to the bottom dollar of the company. Keeping the variations low in large operations with very complex interactions between underground fleets, mining fleets and processing plants is not something you can get everywhere. It is a unique skill set.

Mr WEIR: You mentioned in your presentation that there had been some discussions with some of the large companies, the Glencores or the BHPs, in this area and that they are just observing at the moment and not investing yet. There is more development to happen before they become involved financially; is that the situation?

Ms O'Sullivan: That is the feeling I get. I feel that if we could demonstrate that there are dual benefits then they would start investing in the technology. It has happened. There was an X-ray diffraction technique that NASA put on a Mars Rover. Olympus is not an Australian company, but it worked with NASA to create a portable XRD unit which is now used as an exploration tool out in the field and underground. It basically tells you what the minerals are inside a rock from a very small sample. It has assisted in minimising variability in processing to the mill.

Mr WEIR: And that was used to see what was under the surface on the moon?

Ms O'Sullivan: Yes, it was a Mars expedition, I believe.

Mr MADDEN: You have mentioned that you work mainly in north-west Queensland. Have you seen any adoption of space technology in that area?

Ms O'Sullivan: The XRD unit I was just referring to I believe was used at Ivanhoe, which is a base metals mine south-east of the Mount Isa area. It is readily available now. The unit has come down in price substantially. I think it costs around \$23,000 for a portable XRD unit. I am sure it is implemented in many operations.

Mr MADDEN: That is great news.

Ms PUGH: Rhonda, you and I were talking earlier about the Lotus principle, which is essentially you can do what you want as long as it is legal and not necessarily ethical. Can you expand on what kinds of challenges that might pose for us if we fail to act and invest further in the industry while we have the opportunity?

Ms O'Sullivan: I am not sure my interpretation is that it is not ethical; it is just if it is not prohibited. The principle is that you are allowed legally, within international law, to take up that activity. With regard to regulation, I noted recently that a Luxembourg based company, Kleos Space, registered on the Australian Stock Exchange. They have been listed. A large number of newspaper articles say they are a space resources company, but when I go to their website I cannot find anything specifically related to space resources. It looks like their technology is communication and satellite based.

If we do have companies reporting space resources on the Australian Stock Exchange there is a risk to investors if they are misreported and not regulated. People could be misled and fraudulent activities could occur. That is basically where the JORC code originated from back in the nickel boom of the 1980s.

Mr MICKELBERG: I think you touched on this in your previous answer, but are there private entities physically operating in this space currently or is it all government led?

Ms O'Sullivan: There are probably around 10 at the moment. Planetary Resources is one. DSI, Deep Space Industries, is another one. The third example is ispace. They are all private companies at the moment.

Mr MICKELBERG: Are they just in an R and D phase or do they have commercialised technology that they are making money off?

Ms O'Sullivan: I could not answer that. I can find out for you.

CHAIR: We might put that on notice. You said earlier that we have expertise in mining, governance and safety regimes that is better than anywhere else in the world. This is something that has obviously been overlooked if we are talking about space mining and the exploitation of resources in space. Is this an area where we are better than anyone else in the world, not being boastful? Am I right in saying that we have better expertise than anywhere else?

Ms O'Sullivan: I believe so. Our competitors would probably be Canada and South America, where they are very mineral endowed.

CHAIR: Canada is more of a prescriptive regime?

Ms O'Sullivan: Their code is, yes. It is more detailed and more prescriptive in terms of exactly what needs to be carried out. Parts of it are not open to as much interpretation. It is not as principle based as ours is.

CHAIR: In your opinion, is the Australian governance infrastructure the best to be translated into a space setting?

Ms O'Sullivan: Yes. With some of the work with the building blocks that we have been working on with The Hague International Space Resources Governance Working Group we have had many conversations around that. There is often a misunderstanding. With those with English as a second language it is sometimes hard to communicate some of those principles based items, what they mean and how they are applicable.

Mr WEIR: On the legal side of it, you said there was a ruling finalised in 2017. You say that the USA and Luxembourg are challenging. Are they challenging that decision?

Ms O'Sullivan: No, just challenging what has been accepted in the past. With the 1967 space treaty I guess it has always been assumed that all of the resources would be used for the good of mankind. It still is that way, but I guess they are just challenging the thinking around exactly what some of the ambiguities in the legislation mean, because the legislation is old and has been around a long time. In the academic literature it is about fifty-fifty on who is right and who is wrong in interpreting the law that is already there.

Mr WEIR: There is a little bit of movement to happen in that space yet?

Ms O'Sullivan: Yes.

CHAIR: There being no further questions, I thank you very much, Rhonda. We really appreciate your time. We have put one question on notice. That one related to which commercial companies are currently operating in space.

Mr MICKELBERG: Not so much operating, but those that have a commercial offering that they are running on a profit or loss basis as opposed to an R and D basis.

CHAIR: Which companies have a commercial offering and are operating in space. If you could provide the answer to that by 10 am on Friday, 26 October, we would appreciate it. Thank you very much.

PHINN, Professor Stuart, Professor of Geography, University of Queensland; and Director, Earth Observation Australia

CHAIR: I now welcome Professor Stuart Phinn from Earth Observation Australia. Would you like to make an opening statement?

Prof. Phinn: Thank you to the honourable members of the committee for the opportunity to present at what is a critical and exciting time for both Queensland and Australia to play a significant part in a new global industry. It is critical, as the time to engage in this industry is short. It is changing extremely rapidly. It is exciting because Queensland has already invested quite heavily in this area in some spaces which we can build on quickly and easily to help build the rest of Queensland's and Australia's space industry capability.

In the briefing session I would like to explain what I mean by 'earth observation', because it means different things to different people, and why we could use Queensland's earth observation activities as a base on which to build the space industry and finish with a proposal for a national earth observation analytics hub or centre to be based in Brisbane which would help drive a lot of those activities, particularly in dual-use technologies across defence, government and out into the private sector.

Earth observation, or remote sensing, is any activity where we collect information about the earth, its atmosphere and oceans from satellite, aircraft and also remotely piloted systems. This activity underpins the collection of geospatial or geographic information, which is essential for pretty much all levels of government, from local to state to Commonwealth, in Australia. I think you heard in the public briefing on Monday from Steven Jacoby about the extensive use of geospatial information in the Queensland government. Satellite based information is a key part of that.

The use of this type of imagery and the information derived from it is rapidly expanding across all sectors of industry and all levels of government. I think some examples you are aware of are that it underpins our daily weather and oceanographic forecasts, disaster management systems, water and power supply, infrastructure, monitoring and operation for defence and mining, agricultural production and environmental monitoring.

The aim of the submission that I presented and what I want to highlight today is a realistic view that we do have a significant industry growth opportunity for Queensland that builds on previous Queensland government investment as well as real predicted market growth, both in Australia and globally, to grow jobs in Queensland and Australia. I will refer again to what I want to highlight as potential dual uses. What we are talking about are jobs in industry but also engaging with government and Defence in that area.

The other point as part of this submission is that I want to highlight a 'Team Australia' approach. Australia has done quite well with earth observation activities because we have collaborated across state agencies with the Commonwealth to engage internationally and with international companies. That is something that we can do more of.

If you look at the reports and market forecasts for space industry growth, the compound annual growth rate for the next couple of years is eight to 10 per cent. The share of that growth in terms of earth observation activities, at least on the Asia-Pacific side of it, is around 30 per cent potentially. That is quite a large potential market increase that we can take advantage of.

In terms of jobs across the geospatial area in Australia, in 2015 we had around 10,000 people in that area. Current market forecasts, looking at around 2020 to 2025, are moving to around 16,000 to 17,000 where earth observation would be a part of it. More detailed modelling is needed of how that might play out in earth observation, but we could be looking at hundreds of jobs in Queensland around that.

I have a few points on why I am presenting in this context. I have been involved over the past 20 years in research to take information collected from satellites and have local, state and Commonwealth governments use it in their legislated activities. That has also involved working with specific industries in agriculture, horticulture and mining to help them work out how to use earth observation and include it in their business processes. As part of that, we have trained a really large number of PhD, postgraduate and undergraduate students in this field. They have gone on to jobs in Australia and also overseas. At the moment we have a challenge of retaining the best of those people, because we have new global space companies trying to get them to work for them all the time.

One of my other roles has been establishing a national coordinating group for the people who collect satellite imagery and use it in industry and government research. That has been in place for the past 4½ years and we have delivered a national plan that everyone contributed to. We are

implementing that plan at the moment. That operation is run out of the University of Queensland. The last point I want to make is that we have had quite extensive engagement with the Queensland state government, particularly through the Department of Environment and Science and the Department of Natural Resources, in helping them build earth observation capacity and helping them become world leaders in that area.

What do I want to achieve in terms of developing Queensland's and Australia's space industry in this submission? I think it is clear in a lot of information that the committee may have read that earth observation is one of three central industries that underpin Australia's current and future space activities. Out of those activities, earth observation may potentially deliver the highest return on investment for Queensland and Australia because of what we have in place in existing infrastructure in government, which industry can also use, and building infrastructure in Defence and research. Queensland is well placed in this area as the Queensland government is recognised Australia-wide and is world leading in its adoption and use of earth observation for legislated monitoring and management activities, and we do have a substantive body of trained people in that area. To take advantage of those opportunities, we have provided a proposal to set up a national earth observation analytics hub in Australia.

I want to highlight a question that was asked in the terms of reference for the committee that relates to the Review of Australia's Space Industry Capability that was used to set up the Space Agency. That review did not fully acknowledge the full extent of earth observation capacity in Australia that can support industry. Possibly by the nature of the review, it was focused on Commonwealth agencies and major companies in south-eastern Australia. It did miss the majority of earth observation activities in state and territory agencies, which, by volume and also by dollars spent, excluding Defence, is the largest in Australia. We support our legislated monitoring and management across states and territories using satellite imagery. Those areas in state and territory governments do already deliver fully operational solutions that have the opportunity to shift sideways and build business and industry around some of those and new areas.

The Australian earth observation community, along with multinational companies and multiple recent global market projections, does show that earth observation is a key niche area where Australia's space capability could be developed to offer the best use of our established investments and expertise. I highlight the Queensland government's investments and expertise in that area. Again, I refer to comments that Steven Jacoby made in the public briefing on Monday. If we build on those, that can maximise returns to the state and also to the nation.

How can we build on those existing investments? The Space Agency's National Civil Space Priorities, the Defence Innovation Hub and the CSIRO's just released Space Roadmap all indicate that there is a willingness for those agencies nationally to work with state governments to build industry capability. Therefore, the analytics hub proposal is in direct response to that. Queensland has a competitive advantage because of its previous investment in government and industry in earth observation and also the investment in positioning navigation and timing. A lot of Queensland activities have helped drive what Geoscience Australia has delivered in its satellite based augmentation system, to deliver precision positioning across the country.

Building earth observation activities will also help drive more upstream applications in terms of developing industry-specific satellites and sensors, such as for agriculture and horticulture. An example of this is in agricultural and horticultural areas, where we are now in a position where we have imagery collected multiple times each day that can be taken by, let us say, Queensland based companies that apply certain algorithms or models to that imagery and they deliver to the grower either a map or information on a website or a direct text report on their phone that tells them the current condition of their crop and how it compared to last month or over the past couple of years. We have a number of companies that are building those capabilities in agriculture and horticulture, and that could potentially be applied to looking at mine site restoration monitoring, infrastructure monitoring and a whole range of activities.

As I mentioned briefly before, our focus on building earth observation analytics can create increased demand for upstream space capabilities. That could include looking at dedicated ground receiving stations here to help receive satellite imagery and process it more quickly and clearly, and developing dedicated satellite systems for specific industries that would then lead on to launch capability.

In closing, the aim of the submission I have provided to the committee and my opening comments here are to present the case that there is a significant industry growth opportunity that can build on previous investment and leapfrog forward in this space. It is an area where there is potential

for dual use in terms of government to industry, and Defence to industry and government as well. It is an area with real actual market growth at the moment that is predicted to continue in the future. Thanks again for the opportunity to address the committee.

CHAIR: Thank you, Professor Phinn. I am glad that you highlighted your national analytics hub proposal. I remind the committee that part of the submission is confidential, pages 11 to 17. The committee will take questions on pages 1 to 10. Professor Phinn, I am also glad that you pointed out that the Review of Australia's Space Industry Capability missed what is happening here in Queensland, which you have highlighted is the consumption of this material by state government agencies, which is a main driver in Queensland; is that correct?

Prof. Phinn: That is correct, yes.

CHAIR: Did you want to expand on what else may have been missed out?

Prof. Phinn: Sure. In that review they looked at who was downloading satellite imagery and changing it into information for different groups to use. If you look at the Queensland government and particularly the Department of Environment and Science and the Department of Natural Resources, both of those supply spatial information to other Queensland government departments for them to make decisions. To take the Department of Environment and Science as an example, to begin with, essentially they are looking at changes in the environment across the entire state. That program has been running since the late 1990s. It has required that department to build a capability to download satellite imagery and produce maps across the whole state on a regular basis. They needed to develop the science and technology to do that and also do the field work to make sure what they were mapping was accurate and understand where it did work and did not work. Based on that, they built a large capability.

At the moment, essentially every night we update that image archive with imagery from both the US and the European Space Agency to give a complete picture of what is across the state. That has taken a team of 10 to 20 people over a number of years to do it. The processing techniques used to develop that are recognised as world leading in terms of the accuracy of the information that is produced, but also we know where the information that is produced does not work. I think this committee has looked at vegetation clearing before. A lot of the science that has gone into where that does and does not work has come through that area. The products that come out of that area are not just used for vegetation management; they are used for a wide range of activities, for example catchment monitoring and water quality monitoring, and they are publicly accessible.

That capability that was built in the Queensland government was in place before the Commonwealth government started to attempt to build a similar system in around late 2010-11. The Queensland government has continued to move forward with that.

The work that is going on in the Department of Natural Resources, Mines and Energy is delivering high spatial resolution imagery to support state and local government applications across the entire state. Basically, they signed a world-leading agreement with Planet, one of the new space companies, to deliver this high spatial resolution imagery on a regular basis across the state. That is where we are now looking at pixel sizes of around three to four metres, with that information being collected four to five times a day and it is potentially accessible and useable. That agency has built capability to collect that information and turn it into decision-ready information.

That was the reason behind the statement there. A lot of that activity has actually been used to help build what is in Canberra at the moment and, through our National Research Infrastructure Program, deliver national scale products where state based information capability is expanded nationally in that sense. A lot of that capability was missed in the review and it is something that is quite significant in terms of supporting Queensland government activities and building national capabilities and is something that could be built on in future.

CHAIR: Thank you. I think that is a good explanation. The state government department downloads that information, processes it in a unique way and has used that expertise, shared it or sold it on to the federal government. There would be great capability for building more value from that, if we pioneered those processing techniques. There is a greater opportunity to further share and commercialise that; am I correct?

Prof. Phinn: That is correct. It is that generation of the intellectual property about turning the images from pictures into a map of, if you are looking at mangoes or avocados, estimated crop yield or tree height—or if you are looking at dams, water quality. As Dr Williams said in his presentation, you do have a very large amount of satellite data sources now available. Where there is opportunity for industry is in building that information delivery, so you are delivering information specifically for St Lucia

certain agriculture applications, horticulture, infrastructure monitoring and mining. It is that expertise that the state government has for some natural resource management, but we are seeing the emergence of smaller companies that are doing that in association with certain, let us say, growers in a certain type of horticulture.

Mr WEIR: As population grows and we require more and more food, would this be a tool to monitor what is being produced, not just in Australia but also across the world? We have a huge drought here in Australia at the moment. I would imagine in 50 years time that would have significant implications. Would you see it getting to the stage where we could see how much wheat is being produced—we are seeing a lot of corn in the US go into ethanol production—to get some grasp of what we are going to produce?

Prof. Phinn: At two levels. The Queensland government already has a land use mapping program that identifies cropped area but it is not updated regularly. If you increased the type of data and the techniques they used, you could conceivably update that and look across the state and the country to begin with, at what is the current area under wheat, cotton or sugarcane. You could then do that globally.

What we are seeing now is start-up companies in the US and also in Western Europe that are starting to provide exactly that service. Companies of three to five people are building the algorithms that do it and then matching it up to on-ground estimates and serving the information out to people on a pay-for-service basis. We do have the capability to build that, and you could build off some government expertise and other companies. There is a Toowoomba company called DataFarming that is doing this at a more local level. If you come down to the farm level, this is where you can start to do things like look at actual condition of crop at the time and include other information to look at predicted yield. If you can do predicted yield, you can do things like essentially plan ahead for how many people you might need to pick things, from a horticulture point of view. You could plan forward and more accurately purchase the number of packing supplies and look at the transport logistics. In doing that, it stops you from overspending or underspending and you can trim things down in that area. They are two areas where there is a lot of potential to do it.

Mr MADDEN: What you are talking about is fascinating, particularly with regard to the horticulture industry. One thing I am thinking about with this wonderful array of information that is available is the ability to get that to the farmer. Do we suffer from a lack of infrastructure with regard to the internet? Is there maybe a logjam or a constriction in getting that information to the farmer?

Prof. Phinn: It currently is a logjam in two ways. The current model is for satellites to send data down to the ground, it is received and then it is processed, let us say, by a small company or the state government and then people can access that off a website. You need bandwidth to have the website and bring that information across to look at the website or to generate a report for your phone. There is bit of a block to begin with, and as we start getting more and more sources of information there is more and more data coming on.

One of the areas we are looking at research-wise at the moment—it has been mentioned previously in some of the submissions—is on-board processing: building satellite systems which are targeted. Let us say you built one specifically for the sugarcane industry or for wheat globally. It collects data in specific colours or wave bands that work, let us say for wheat, and lets you look at wheat yield, applies the algorithm on the satellite and then it sends down. Instead of petabytes and gigabytes you are now talking about hundreds of bytes at a time of information which could go straight to a computer as a simple map, or it could be a text alert. That is an area where there is a lot of research at the moment. If we are able to invest in that, particularly in some of those areas that need regularly updated information—defence intelligence is another one as well for automated processing—we have a number of niche markets that we could build there.

Mr MADDEN: Can we get around that logjam with Telstra 5G or satellite phones? Is there a sneaky way we can get around the wire cable?

Prof. Phinn: That is starting to get outside my area of expertise. Dr Williams commented on the challenge of spectrum availability for transmitting information down. Even if we do create more bandwidth in the wireless context, we are still limited in that space is filling up. If we start moving to light based communication technologies, that might be the next step. One logical option is just to reduce the amount that is coming down so there is not as big a demand on those bandwidths.

Mr BATT: You mentioned the quality of the information. The data is to a much greater standard now—a couple of square metres. In previous committees we have had to deal with that data and the not-so-good quality with it in relation to remnant vegetation. How far back do we have that good data? Is it several years? Is it months?

Prof. Phinn: I have two responses to that. The coarser spatial resolution imagery, with 30-by-30-metre pixels, is back to the mid-1980s. The new satellite imagery with the smaller pixel sizes, if you want it consistent globally, is back to the end of 2016 on a daily basis. That is an area that is changing every couple of months. The business model of the companies that are building these systems now is 'let's get it working and get it up there, figure out what is wrong with it and then build the next one and launch it'. The smaller satellite capability means that, instead of these big hundred million dollar satellites, people are building these smaller ones and they are experimenting with the technology. It is gradually getting better. I think the beginning of this year was probably the first time in history that we had globally consistent very high spatial resolution imagery on a daily basis. That is good, because we can get rid of cloud and so on, but it means that we can start to see what is happening on the ground. We cannot see people or cars and things like that, but you could look at changes in orchards of trees, for example.

The simple answer to your question is: really, the beginning of this year for globally consistent; lesser high quality from the end of 2016. We will see a significant change in the availability of those datasets over the next 18 months, when we have two of the sort of larger global companies launching constellations or groups of higher spatial resolution satellites.

Mr BATT: With the better quality you mentioned, the automation of being able to pick up certain things by whatever you want to put in it will pop it out so you are not looking all the time for something; it will actually show you where that is?

Prof. Phinn: Yes. There are two approaches. One is that you have a big, long archive sitting in your database on the ground, and at the moment that is what works well in the state government because you can look at what are natural changes due to rainfall and other things. The approach in future is that you are able to do some of that up on the satellite, where you actually have an archive up there for doing the processing so that when an image comes in you are comparing what you see there to what is in the archive—is it changing significantly or not?—and then send down basically a smaller data stream.

Ms PUGH: In the final section of your submission you talk about the EO research operations and the PhD program. Could you expand on that?

Prof. Phinn: The primary idea of the analytics hub is connecting business to the science and research and making the link between the two basically easy to overcome. The hub is meant to be in association with groups like CSIRO that we have worked with for over 20 years in that space. The focus is that you have industries that have the specific needs for certain types of information at a certain level of detail and the researchers who are working in a similar space, and then you are matching those two things up to make sure that the solution that is delivered is essentially industry ready. They know they can make decisions from it and go forward.

One of the challenges we have in this area is that there is a skills shortage that is progressing forward. That part of the hub was to actually bring people in and train them in a focused area in that specific space. It is something that we are looking at building at the moment. The hub proposal is one where we are looking for a number of potential sources as well. It is being discussed presently.

Mr MICKELBERG: What is the current percentage split between applications that are legislative monitoring or government type applications versus commercial applications?

Prof. Phinn: In terms of satellite imagery being used?

Mr MICKELBERG: Yes, the applications of satellite imagery.

Prof. Phinn: That is a really good question. In Queensland, off the top of my head, based on my experience as a biased answer, I would say that you are getting close to still probably 50 to 60 per cent government versus 40 per cent industry. That is partly because I think the industry has not had time to develop in this space, because there are a new set of products and services which are available but industries like horticulture, agriculture and infrastructure monitoring do not necessarily trust satellite based services at the moment. There is a process to go forward to show, 'Look, we are able to deliver these things. They meet your needs. They will help you make decisions. There are some problems with them, but they will help in these areas in general.'

Mr MICKELBERG: Can you get full-motion video from satellite feeds currently?

Prof. Phinn: There are two groups doing that. There is a new company called Earth-i, which essentially has what you could call video. It is basically very high frequency images. You can look at car movement, planes and those sorts of things. The challenge with those data streams is that it is not providing you a complete global coverage all the time. It is targeted. Other companies are starting to provide similar things. A company called Planet and their SkySat systems will be providing

something similar as well. The video systems, the really high resolution ones, are really targeted in the sense that they cover small areas and you have to shift them around. That is where you are getting sub 20-centimetre pixels, whereas the imagery that is now three- to five-metre pixels is where we are getting global coverage on a daily basis multiple times.

Mr MICKELBERG: For that high-frequency imagery—effectively video—does the satellite itself have to be launched for a particular geographically bound area? Can it be repositioned when it is up there?

Prof. Phinn: Yes.

Mr MICKELBERG: I can ring them up, if I am in Transport and Main Roads, and say, 'Hey, I want you to survey the Bruce Highway from the Sunshine Coast to Brisbane to watch traffic flows,' for example?

Prof. Phinn: It is actually a constellation of satellites and it is essentially the satellites' task, so as the satellite is flying along they are able to point where it looks. They will not actually move the satellite itself; they will just point the sensor and it basically focuses on that area. Again, the key thing is that it is targeted areas over time. If you have access to that capability, it is a capability to look where you want at specific times.

CHAIR: We have talked about the split between private and public usage. One of the barriers is active partnerships between government and industry. That is one of the reasons behind the hub proposal that you have. Bearing in mind that the proposal is confidential, part of what the hub is about is addressing that lack of partnerships between those two spheres; is that right?

Prof. Phinn: Yes. It is trying to provide a more flexible mechanism in the sense of timing—that is, of addressing problems in a more timely manner—and also in terms of intellectual property in this case as well. For existing funding systems like the Australian Research Council funding, the Linkage program and centres of excellence, there are quite long time delays in applying for these things. It is quite hard to get multiple industries to commit, so it is not flexible enough. This is an area where, particularly with satellite imagery, the changes to the types of images and acquisitions are happening on basically a six-monthly to a yearly basis, so your ability to do things is changing quite quickly. The idea of the hub is that if there is a set funding source for this it has a program which identifies key high-priority areas which will lead to industry useable outcomes so they can come in and partner and essentially build the capability and then move that out to use in industry.

Discussions on the hub development have been in association with CSIRO, so the aim is that we would have complementary hubs in this space to address key areas. In terms of the NovaSAR satellite that Dr Williams mentioned, we have very limited capability for processing radar imagery in Australia. You can probably count on two hands the people in Australia who can turn that into useful information properly. That is one area where you could sit down and look at agricultural or other applications, like ocean surface monitoring, and quite quickly have industry groups say, 'We need this and this,' and then bring people in to help build capability as well. It is a more flexible mechanism for doing it.

We would look at adopting an approach to intellectual property that would be similar to the Defence intelligence centre projects, where the companies would initially retain their IP and license it back to, I guess, the hub if they wanted to use it down the track. That way, small companies can come in and build on their ideas and go out whereas with other models, like in some of the older CRC models, they might potentially lose some control over the IP in that area. It is the timeliness and trying to make sure we can build the small to medium enterprise side of it but also engage with larger companies if they choose to as well.

CHAIR: You mentioned processing that radar data and the fact that, surprisingly, we are not as good as we should be on that and also on-board processing of information. Am I right in saying that these are two big areas of opportunity that we have here in Queensland and they can be done in facilities that we have now and can be done by emerging SMEs?

Prof. Phinn: The on-board processing capability is one where building the algorithms to do it is something that we could definitely do in Queensland. The actual construction of build would mean partnering with groups in other states, particularly New South Wales and the ACT. In one part of it we definitely have potential to do it. The radar processing area is one where we do have some potential, and it would be really good to attract back to Australia the people we have lost to overseas who are trained in that area. As an example, one of our lead scientists in our joint program with the government is currently one of the lead scientists on NASA's GEDI project, which is basically an imaging laser system which is going to produce new height surfaces around the world. It is about to be launched—next month—to sit on the Space Station. The algorithms which have been built and

how they are tested draw on someone who was essentially built and trained here who would be great to attract back here. We have a number of people like that whom it would be good to build those capabilities on.

CHAIR: Once again, it is people we have trained and educated, probably in these very buildings, whom we would love to have come back, and there are great opportunities that we know would exist for them for small and medium enterprises that they might be pioneering as well.

Prof. Phinn: Yes.

Mr MICKELBERG: I am interested in the applications. You talked about some of them, but are things like soil moisture levels something you could observe from imagery to, for example, map drought areas to take it out of a subjective judgement and make it a measurable effect?

Prof. Phinn: The simple answer at the moment is yes, but the methods that are used from satellites at the moment—the ground footprint or pixel size is five kilometres and larger. There is a soil moisture mapping mission that NASA operates that does deliver soil moisture maps, but they are in a research phase. If you did invest more time and on-ground work with them, you could turn that into an operational product which is used. There currently is a group at Monash University that is one of the field based collaborators for that program that checks things in southern Australia, but that is something where Queensland could quite easily become more involved and help build a product. It is actually used already in some state government activities in the Department of Environment and Science to help correct some of the radar imagery and take out soil moisture variations, but it is something where you could build a better capability to extract information at a scale where it is much more useable.

Mr MICKELBERG: We have heard that a lot of the space applications and imagery are Defence led, by virtue of the fact that that is where the investment happened initially. My question is in relation to that skills gap. I know that within your postgraduate programs here you have some existing Defence members. I am interested in your thoughts as to the barriers to those individuals, either in Defence or veterans, who have that skill set getting involved in industry and/or things that are working currently.

Prof. Phinn: Sure. That is a really good question. We have a postgraduate program where we have people who are basically in duty training but then, once they come out of service, get extra skills and then go out as well. That draws across people who are image analysts as well as people who have worked in the field in different areas. At the moment probably the biggest barrier is having a clear path through to industry for them. A number of those people end up in consulting engineering companies doing developments of the sorts of applications we have talked about, but there are generally more people coming out of that program than there are opportunities in industry. Some of them have gone into local government. We have not had any go through to state government, but they do have quite a unique set of skills because of the imagery they have analysed, in terms of how they have had to treat it, and they can take those processes forward into industry and help them as well. The challenge is having enough openings post study for them to move into that are directly related to earth observation analysis and those things. Even though they are all focused, a lot of them have really good on-ground experience which is absolutely essential. If you are going to make decisions from satellite imagery, you have to know what it does see on the ground.

Mr MICKELBERG: I guess your hub proposal would significantly increase the opportunity, given they already have an interface between research bodies like yours?

Prof. Phinn: Yes. Ideally it would build more opportunities for them. Since that initial proposal for the hub was written, there has been increased engagement between the defence community and Earth Observation in terms of whether we can potentially look at more dual-use programs. Currently there is a cooperative research centre round which closes in November. There are six proposals that are short-listed. There is one called CRC SmartSat. There is an earth observation analytics program within that. A part of that will be looking at dual use and I guess developing that as a way forward in Australia so that you have both Defence and civilian use of these potential programs moving forward. If that program did go ahead, it is something which would add a funding stream to the analytics hub and it is identified in the business model as a way of helping it step up.

Mr MICKELBERG: It seems to make sense. I asked the question earlier about duplication of imagery for different applications. We only have so many resources to throw around, so if it can be augmented within an existing funding stream it would make sense.

Prof. Phinn: The interesting thing is that some of these smaller companies around the country which are ex-Defence Force staff who have artificial intelligence experience know that they are helping to refine methods used for land use mapping. There is a range of potential applications, and for these new smaller satellite companies—like Planet, which I mentioned before—a lot of their large potential income is coming from Defence intelligence contracts.

CHAIR: I think that is very useful information to take to that further briefing with the department of communities about their program.

Mr MADDEN: Professor, I see from your introductory letter that you have a number of positions, including director of Earth Observation Australia. There has been considerable discussion today generally about satellites. How many satellites are up there above Queensland? When we talk about satellites up there, are we talking dozens or hundreds?

Prof. Phinn: Just to go back to something Dr Williams mentioned, there are two sorts of orbits of satellites. Low-earth-orbit satellites are typically polar orbiting—that is, they are going around the earth closer to the equator. Those are all 400 to 700 kilometres above the earth's surface. Geostationary satellites are 30,000 to 36,000 kilometres away, so as the earth moves around those satellites stay in the same position. That is why they are used for communications.

In terms of the low-earth-orbit satellites that are used for earth observation, at the moment there are between 2,500 and 3,000. That is earth observation and that is operational, so that is not counting the ones that are inactive and bits and pieces of space junk. I do not know the number of geostationary satellites, but the majority of those—over 90 per cent—are used for communications as opposed to earth observing. Our weather monitoring satellites are geostationary. We have been very fortunate in our relationship with Japan in that for the last 40 years we get all our weather satellite data from Japan. That bilateral relationship is extremely important for supporting the meteorology bureau. The satellite which is up there now is collecting information and the highest repeat frequency is every two minutes, so you get an image every two minutes on the surface of the earth with one-kilometre pixels. That is why the meteorologists love it, because they can look at clouds and how they are moving at different heights and all those things. There is a lot up there. There is a lot of junk up there too.

Mr MADDEN: So we are talking thousands of satellites that we can potentially rely on, even if it is just communication satellites that are just linking?

Prof. Phinn: Yes. The other point about the number of satellites is that one of our civil space priorities, and also a Defence one, is space situational awareness—that is, keeping track of what is up there and where it is going. Australia plays a critical role in that as, I think, Dr Williams alluded to in terms of tracking what is up there and identifying it as well. That is an ongoing challenge and problem.

CHAIR: As there are no further questions, I thank you very much, Professor Phinn. I do not think we have any questions on notice, but thank you very much indeed.

Proceedings suspended from 12.43 pm to 1.16 pm.

GREEN, Mr Nick, General Manager, Defence and Aerospace, Special Projects, Products For Industry

CHAIR: I now welcome Nick Green from Products For Industry. Could you state your name and the position in which you appear today?

Mr Green: My name is Nick Green and I am the General Manager for Defence and Aerospace for Products For Industry. PFI at its core is primarily an automation and robotics upgrade company, but through that we do a lot of different manufacturing and engineering, from the food and beverage industry to mining to agricultural industries to drone technology—pretty much across-the-board.

CHAIR: Would you like to make an opening statement, after which committee members may have some questions for you?

Mr Green: Thanks for having me in today. I have over 20 years of experience in the metal trade industry with roles such as being a qualified fitter and turner specialising in CNC hydraulics and welding, an R and D manager tasked with redevelopment of parts for Australian conditions, a defence base maintenance manager for RAAF Base Amberley and a business development manager in defence and aerospace through PFI. I also sit on the Queensland space industry advisory board to represent SMEs which is currently chaired by Neil Hart.

I have been flying rockets for over 28 years. I have flown hundreds of rockets successfully, from small Glad Wrapped tube type rockets in local parks all the way up to carbon fibre rockets travelling at mach 2. I have also managed to fly hundreds of rockets unsuccessfully, with things coming off and corkscrewing into the air, rockets being turned into confetti from not being strong enough and rockets becoming lawn darts because parachutes did not deploy properly. As it turns out, rocketry is pretty hard. At every other point during that time it has always been a lot of fun.

Personally, I have designed a number of hybrid rocket engines and successfully test fired them through various programs through my career. Next year, starting in February, through Ormeau State School we are planning to do a hybrid rocket program for them, so the kids will be making hybrid rocket motors as part of their school curriculum.

Four years ago I started working on a launch site proposal because I saw a huge link missing in the supply chain for that sort of industry. Part of that is to do with the Gympie proposal that we have talked about a little bit already this morning. However, it soon became pretty evident to me that, even though the industry is very interested in investing in this sort of thing, there was no real economical way for industry to build such a facility—primarily from the lack of private land that can be purchased. Also, the business models around forming such a facility do not really lend themselves well to industry investment. The launch site itself is not really where the money is made in this sort of industry.

Australia has a vibrant aerospace industry, with Queensland leading the way. My question is: why does industry not play a bigger role in the international rocket industry? I simply believe that it is a lack of launch capable sites. If we are going to be doing this sort of thing, I think we need to anchor the supply chain into an area so that we can give it a starter's pistol for industry to start investing largely into this area.

In reference to some of the questions that were brought up before, the Space Agency itself is primarily in charge of collaboration with international bodies to do with giving permissions to launch into space. When a company such as Black Sky Aerospace plans to do launches, it would be seeking advice from the Space Agency then to work collaboratively with those bodies internationally to get the clearances. Through the public arena and laboratories that we have done with CASA, even though we do get clearances through CASA for a lot of our launches we still end up with the public literally flying over the top of our rockets before they are going to be launched. That is just the way the systems are in place. Through the entire program on the planet, no aeroplane has ever accidentally been hit by a rocket from public entities. It is still pretty safe despite that.

One of the questions brought up the Great Barrier Reef and why that is a significant concern. A lot of people think it is primarily to do with the environmental aspects, which are actually manageable. The bigger issue for us is primarily tourism. If we were planning to launch over the Great Barrier Reef, we would have to clear people out of a very large section of the Great Barrier Reef, and that would have a huge impact on tourism. If I try to book out a day when they are not going to be there and then I miss that window and I try to do it the next day, international people trying to book a trip there would then be severely inconvenienced. It becomes something that, as a business model for the state, is not a very good option. Then there are the environmental impacts and problems to do with that. Internationally, people like SpaceX have to book out shipping lanes to make sure that there is no international transfer of shipping going through those areas and things like that. There are a lot of international concerns that affect where your downstream angle is, basically.

Another big one that we were talking about is skills leaving Australia. That is a point of contention, with a number of scientists going overseas. Fleet are in South Australia and they are run by Flavia. Even though their technology is quite interesting—I will talk about that in a minute—they have no ability to manufacture or launch satellites in Australia. Even though they would not mind doing that, it does not really bother them either way. They are more a downstream information source. Even if they had someone in Australia who could make satellites, it is not a great business model because then they have to transfer it overseas to get manufactured. Even though they are an Australian company, they do not do any of the technology work in Australia. All of their funding, which is \$10 million per launch of satellite, is currently going overseas. They are planning to launch upwards of 60 satellites a year. Just that alone would almost fund an industry.

We were talking about the logjam. Their technology has the capacity to put a node at a local farm such that they can connect directly to a satellite, causing a local area network to do with the internet and things like that. When we are talking about farmers getting information, there is technology on the horizon that is the going to help farmers get much greater access to this sort of information going forward.

CHAIR: I like the fact that you specifically connected the launch site as the anchor point in the supply chain. This is obviously one of the issues that we are dealing with—the issue of the launch site. A launch site in Space 2.0 does not have to be a hugely expensive greenfield site. Could you explain for those people like me who are not familiar with the modern needs of a launch site what we would be looking at?

Mr Green: It is never going to be NASA. NASA is a multibillion dollar site built over many, many years. Something more relevant would be Rocket Lab. Without trying to dumb it down too much, they are basically a glorified shed, a concrete strip and some infrastructure to stand the rocket up—and that is it. As far as costs go, the biggest cost is allocation of area. Normally in these situations, as we were talking before about how far away people need to be from rockets of certain sizes, it can be quite large. NASA clears out for SpaceX and things like that upwards of 30, 40 or 50 kilometres, depending on the situation. You will not find anywhere on the coast that has that amount of space. It is not really a thing. The Gympie area, through the Great Sandy National Park, has the potential to have about 30 kilometres clear, full circle, to be able to launch. That is quite unique sitting on the coast of Australia, let alone somewhere close that makes it economically viable for industry to be doing these sorts of things.

With the Gympie site in particular that Michael Smart was talking about, there is a landing strip on Rainbow Beach. The Gympie Regional Council have already talked to me and they are quite happy for us to be doing some things out of there. That is perfect for things like drone technology or landing rockets from hypersonic technology because it is basically a landing strip. Currently it is only being used by some joy flights and people parachuting on to the beach.

Mr WEIR: You said that you have been in and amongst the building of many rockets—some successful and some not. There are a lot of rockets that are successful. Were you experimenting with different materials? What is the success and failure rate?

Mr Green: Being that I started so young, a lot of my rockets were just getting Supa Glue and balsa wood, pressing go and seeing what happens. Things do not always work. As far as an industry's perspective goes, you try to test everything to failure before you put it into that scenario. Obviously failure is always an option. The types of things I was doing were not on that sort of level. That was more just trying to educate myself about this sort of system. I have had some great successes and I have had some decent failures.

Mr WEIR: There is no reason that a facility could not be set up here in Australia to build successful rockets?

Mr Green: You could absolutely build them here. There is no doubt in my mind. Again, they are building across the pond quite successfully. The really interesting thing is that Queensland already has a significant aerospace industry. There is not a technology that is not already being used across-the-board in Queensland that cannot be only mildly adapted to be immediately producing rocket components. It is not a huge outlay at all for industries to start getting involved. A lot of the time the problem is that the company just simply does not know that their technology can do that. There is obviously some education to be had. It is definitely ready to go.

Mr WEIR: I imagine the closer to the facility the better.

Mr Green: Yes. Logistics is a huge problem for all of those sorts of things. Even though NASA is not right on the equator, it is still significantly used and part of the reason for that is that the cost versus return is a problem. You are not going to get quite as much payload on your rocket, which is

basically return for that rocket, but the logistics of trying to do it somewhere on the equator—they do have a launch site in southern America but the cost of that is prohibitive. However, Australia launched their two NBN satellites out of that equatorial launch place right on the equator in southern America, but that was for a few billion dollars. I am not too sure how much but it was a lot.

Mr MADDEN: Continuing the discussion with regard to Gympie as a possible site, I know we are thinking that this would be where we would launch satellites from. I am thinking more from a research facility point of view, with scramjet and other facilities. Would we use that facility a significant amount of time as opposed to at this particular period of time? What need do we have for a facility in Queensland where we can do that sort of research?

Mr Green: Primarily, where we sit today, most Australians do not have the expertise to do rockets. There has to be training—whether that is just with the actual technology or all the way through to how we design the correct safety systems for a launch facility. My very strong belief is that we have to start small and work up to it. We should not be trying to launch to the moon tomorrow. That is just crazy. We should be looking at what is the smallest we can get away with and start working on that, and then aim ourselves in the right direction to be able to invest and, as you were saying, to start doing the research that is required to push in and teach the people doing this how they should be doing it. Then hopefully if we are going to fail we are going to fail on a smaller scale and (a) it will not be expensive and (b) the risk to infrastructure and people will be a lot less.

The Gympie site is unique in that we can launch downrange straight into the ocean. Within 10 kilometres off the coast is Defence airspace. We have the ability to control that a lot easier. Defence has already given me permission to use it. They are very open to this sort of thing. Also, with Amberley being so close, they have the microwave radar-tracking stations at Amberley, which has scope and reach over that particular site, so we would not have to install any rocket-tracking systems or anything like that because it already exists there. If you go further north to Bundaberg and places like that, you would have to install all the tracking systems which we already have here, so it is a significantly cheaper initial start cost. That means we can approach this sort of idea, for example, of launching hypersonic technology. We are just investing in their technology. You could almost get away with what we already have without any real initial outlay.

Mr MADDEN: That is an interesting point that you have raised—the microwave tracking from Amberley, which is in my electorate, fortuitously. What is the range of that tracking? Does it get to Rocky? Does it get to Bundaberg?

Mr Green: That will depend on the altitude you are trying to reach. If something is flying very high up, it will have easier access to it. This is primarily starting to deal with the curvature of the earth. You can get down below the horizon and you are going to start having trouble. In this particular case, you want to start tracking your rocket as soon as possible. Amberley being fairly close, as far as things go, is a huge advantage.

Mr BATT: You mentioned NASA clearing around 30 kilometres. Is there anything set in legislation that says you have to be so far, depending on the size of the rocket, or are we still in the stages of working all of that out through the Space Agency?

Mr Green: Australia does not have any legislation for it that I am aware of. There is nothing in legislation that states that. NASA, being that it is owned by the American public in essence, gives it all out for free. You can look up all of their studies—all of their environmental impact statements, their advisories for areas of clearance for noise levels, along with safety concerns. We do not need to reinvent the wheel on a lot of this. I know the Space Agency has already started signing agreements with other countries. These other countries are quite happy to work with us and teach us this sort of information. Obviously there is work to be done so that we use that sort of information correctly and implement it in the right way, but it should be pretty easily accessible.

Mr BATT: At this point in time, unless something comes along, it would be technically up to the local government of the area you are in to make those approvals of whatever they believe would be the right distances and those sorts of things?

Mr Green: I think it would actually be brought more back to insurance companies, where you would have to do your risk assessment based on what is going on. That is going to push back to how much you are going to get coverage for, based on your risk assessment. The further you can get away from any population centres, obviously the easier and cheaper it is going to be to get insurances based on risk. Failure is always going to be something that you have to be aware of. Obviously life is paramount. You would not want to do anything that could cause those sorts of problems. Going forward for that sort of concept, if we had the ability to launch quite large rockets from barges, like SpaceX is doing off the coast, the kind of infrastructure that that would take is—as I was saying about starting small, that is a big sky concept way down the track, in my opinion.

Mr BATT: You mentioned about being able to clear airspace. I think you talked about booking shipping channels. Again, are there rules and regulations about stopping people from going into those areas or can you advertise that that is happening but if people want to be there you cannot really stop them?

Mr Green: If you are a pilot you can book airspace, which is your flight path. With CASA it is a very similar concept, except we are booking out a column of air that we intend to use in a particular time frame. CASA are very helpful in a lot of regards. They are trying to work within the current legislation. There are some ambiguities and problems to do with that. In essence, anyone can book out the airspace, but they are going to look at it the risk as well. If you are just some random person with no real history, they are going to be a lot more reluctant to give you that clearance than if you were someone with a more reputable background. The only company that currently has airspace booked out on a regular basis is Black Sky Aerospace. Pretty much every company you have heard of in Australia doing rocketry at the moment is launching out of that facility, which is about four hours west of Brisbane.

Ms PUGH: For those who are not aware whom I have not already told, this excellent business is basically one street outside of my electorate and the Premier opened it, so it is very exciting. You are providing some significant jobs in this sector. Would you identify as a small to medium enterprise or would you now be beyond that?

Mr Green: We sit at about 110 people, so we are still an SME at this point.

Ms PUGH: Could you expand on the job creation opportunities that you see this providing for SMEs like yourself in Queensland? I am interested to hear about the job creation opportunities that you can see being involved in the sector.

Mr Green: Defence in general across Queensland is exploding. Everyone would know about the Land 400 phase 2 and 3 potentially coming through the Rheinmetall facility. We are just down the road from that facility. PFi is actually going to be doing some work to build that facility. Plus we are doing work out at Amberley, where PFi is building a lot of the hangars for the new aircraft going in there, plus some of the docking systems.

What PFi is interested in is growth. Space is sort of like an untapped industry in Australia. Because it is such a large market with such a large turnover, the opportunities are just huge. Part of my job is to identify those opportunities and be a part of it. Again, we are in this growth phase of the industry. It does not really exist in Australia. There is a lot of work to be done.

If we are talking jobs, PFi in general—with just trying to manage a launch facility in itself there are probably 10 to 15 jobs. The ability to attract other companies—start-ups and things like that—is huge. We are talking thousands of jobs a year potentially just in what is, in essence, based in regional areas to try to service this kind of industry. Fleet, for example, employs a company overseas which has a hundred-plus people making satellites. You have the New South Wales company that makes satellites. I think there are 10 people in that company. You just have to attract maybe 10 or 12 companies into an area and suddenly you have a huge boom.

Gympie did a jobs growth analysis based on building a launch facility for \$10 million in that Gympie area. Within the first year alone they would have a \$7 million return just in jobs growth, and that was not including tourism plus all of the other things that it could potentially impact. It is pretty significant and pretty fast. Obviously the excitement around it at the moment is generating so much buzz. Tourists want to be a part of it. Just to come and watch the first launch, and things like that, is going to be huge.

CHAIR: Just to clarify, Gympie Regional Council has done an analysis?

Mr Green: Yes, I can supply that to you if you would like to see it.

CHAIR: If you could, that would be wonderful. We will take that as a question on notice. You said that there was a company in New South Wales building satellites.

Mr Green: The University of New South Wales, I think, is building satellites. They just got some funding from the New South Wales government to launch their satellites overseas for \$20 million. Again, that is part of the haemorrhage that we have not just of people. If you want to develop a technology, your money has to leave Australia. If you are trying to get government funding, if you are trying to get private funding, if you are trying to get people, you end up always having to shift that concept overseas, and with the logistics it then becomes cheaper to be overseas.

CHAIR: Did the company that you talked about in New South Wales building satellites get \$20 million from the New South Wales government?

Mr Green: I am pretty sure, yes. I could probably find you a reference.

CHAIR: Let's just say a large amount—but they are going overseas?

Mr Green: They are launching the satellites from overseas because they cannot do it here.

CHAIR: It might be interesting to get some information about that.

Mr MICKELBERG: Just so that I am clear, you have a launch pad and then you would use the existing airstrip to recover the launch vehicle? Would they be together?

Mr Green: That is the initial concept, yes—in the same sort of area. We are not trying clear area or anything like that. We are trying to put them in the same sort of location.

Mr MICKELBERG: You would not be utilising the existing training area for the launch pad?

Mr Green: Existing?

Mr MICKELBERG: Defence training area?

Mr Green: No. That Tin Can Bay area—I am well aware of it, with the explosive munitions and things—is a little bit too far inland. If we talk about the downrange problem, which ends up being a triangle going out, you end up occupying a huge section of Fraser Island. We go back to the tourism problem. If you were going to launch out of that particular area you would have to clear out Fraser Island, which obviously is not going to be something that we are going to achieve anytime soon. You have to be literally as close to a beach as you can get away with to try to make sure that you are not interfering with people in general. Just south of Fraser Island is pretty much the only point on the coast, all the way going north and all the way going south, that you can launch out to the east without going over any islands or any infrastructure.

Mr MICKELBERG: You effectively have an impact trace where it may go—a launch—

Mr Green: Window.

Mr MICKELBERG:—bearing or whatever that you are going to shoot on.

Mr Green: Down range.

Mr MICKELBERG: Then you have a left and right arc that you have to stay within and you overlay that. Is that trace regulated?

Mr Green: Again, it is all based on risk assessment and things like that.

Mr MICKELBERG: It is more an insurance question that you were talking about earlier?

Mr Green: Yes. NASA do have some information about the way they handle it, but it is going to be one of those things where we have to start working on our own systems. That goes back to what I was explaining, that we need to teach ourselves how to do this sort of thing. We can take guidance from what other people have done, but we need to start doing it to learn that sort of idea if we are going to go down that road.

Mr MICKELBERG: Effectively we are trying to shoot between Kingfisher Bay and Noosa? Is that what we are talking about?

CHAIR: Before we go further on that, just remember that there is some confidential work being done.

Mr MICKELBERG: Feel free not to answer if it is confidential information. It is more to contextualise, for example, when we are talking about the subsequent population impacts so that we can consider the concept in a bit more detail.

Mr Green: I am not too scared of the confidentiality as far as the launch facility goes. We will all win if we build something. I am not too worried about where it is. There does need to be research done to make sure that that is where we want to put it, of course. That is my opinion on it. I am one person. We need to have a lot more of an opinion. No matter what site gets chosen, there is always going to be a compromise. It is just a fact. Florida and launching it at NASA has compromises today, even though it is a major industry for them. As I said, they have to stop international shipping going through there. It is not a simple aspect of 'we can just do it and it is all free and easy'. It is never going to be that.

It is always going to be a management process of risk assessment to do with economic benefits versus losses. All of those sorts of things go into it. That is part of why a private entity building a launch facility is just not economically viable. There is too much that goes into something like that to make it a profitable venture. You can make a lot of money out of launching rockets and satellites, but managing the actual launch site is just not a thing. That is part of why NASA still build launch sites—it is not a private entity doing that sort of thing—but they have a lot of private companies launching rockets out of the launch site. It just becomes easier.

CHAIR: We have talked a bit about the launch aspect of it. One of the things I wanted to touch on is space readiness qualification—the process whereby equipment going into space needs to be tested to the most rigorous standards. Obviously this is an opportunity on our supply chain. Could you perhaps expand on the opportunities that space readiness qualification offers Queensland?

Mr Green: Yes. We talked a little bit about it before to do with mining equipment. Even if it is a fairly light piece of mining equipment, most technology that is developed for the planet is not suitable for space. Even if it is light enough, there are still joint systems, engineering concerns, degassing systems, power systems—all of these things that come into play that are not suitable for either low-gravity or zero-atmosphere situations. There is a huge opportunity for Australia, if we have the technology sitting in our backyard that we are currently using, to work out ways that we can get that to become space compliant. Once we go down that road, we can do a lot of other systems, whether that be testing satellites and other systems, for being ready for space.

CHAIR: What infrastructure is needed to test this equipment to be space ready?

Mr Green: Most of it is education. If I am going to be making a piece of equipment, I know the things that do and do not work. Obviously there is testing at some point. You have to test it, and your back interns can do a lot of that sort of thing. In getting to the end of it, at some point you have to put it on a rocket and put it into space and test it. Again, this goes back to the launch facility playing a huge role in that side of things. If I have come up with a new joint that will work a lot better in space than on the planet to use for a piece of mining equipment, the best way to test that is to put it on a rocket.

CHAIR: Are there no special chambers or any other equipment that can get it close enough before it goes into space?

Mr Green: Yes. I am sure there are a couple here at the university where you literally just vacuum all the air out of it. That is a huge step forward. NASA has the biggest one in the world. It is multiple storeys high. It is huge equipment. SpaceX uses it for their top cowling that sits around satellites. We are a long way from that sort of thing but, if you go to that sort of system—plus you can use the same sort of facility for testing rocket motors—these sorts of facilities can be located in regional areas to help stimulate growth and development in regional areas, where the risks associated with doing those sorts of things can be minimised.

CHAIR: Previously today we have talked about the capacity of those mining engineering firms along the eastern seaboard to, with a bit of work, produce products that would be suitable for a space industry. Are we right in saying that?

Mr Green: Absolutely. Mining companies tend to be big, heavy and strong. Obviously, there is a shift to using lighter, more specialised materials. The type of engineering that goes into developing things like that can be shifted very easily to accessing mining equipment, or even things along the lines of remote asset management. We have talked a little bit about that. PFi has made some drones to monitor and deweed farms so that farmers do not have to do as much work with pesticides. That would be hugely beneficial for space systems.

One of my pet interests is being able to manufacture equipment off-planet. That is more important. Rather than trying to get it out of the gravity well that we have on earth, if we can develop systems that are able to 3D-print, manufacture, weld, engineer and maintain off-world, there is a huge area for that. For example, with SpaceX, in trying to launch equipment to Mars, someone has to set up that equipment before humans get there. It is way too risky to send humans with no habitat to arrive at. Having a system that could be developed that can be deployed remotely would be hugely beneficial globally.

We have access to Antarctica, which is quite a good test area for things like Mars, because it is very harsh, very cold and very remote. We have a disaster relief pod that can be deployed remotely and dropped out of a ship and suddenly it self-builds. That sort of technology is far-reaching. Obviously it is very light, because you are designing that sort of thing.

CHAIR: We have hardly touched on the opportunities for 3D printing for that equipment in space. Is that something that has been explored in Queensland? Are you aware of 3D-printing capabilities?

Mr Green: We do not have anything up here as such, but PFi is currently working with a company called Titomic, which works out of Victoria. We touched on it before. They 3D-print titanium. I have been talking to the Queensland government about trying to do a program whereby Northrop Grumman might do some tests on it up here in Queensland. That in itself would not be a huge spin-off as far as jobs are concerned, but it is world-leading technology.

There are direct applications for things like moon missions. A lot of the moon has a high percentage of things like aluminium and titanium. If you could refine that, you can now print structural materials or tools. Then we go back to whether you could manufacture a functional robot off-world—all the way from battery equipment, to manipulation arms, to all sorts of other things—because the more we can do off-world, the cheaper it is to get there.

Ms PUGH: You touched on the tourism opportunities that this could present. My cousin went to St Laurence's and every year he used to do that competition to go to NASA. I think they won twice. Obviously NASA has some really significant tourism opportunities that it has been able to exploit. What would you say are some opportunities that we have to build up our capability in that area? I understand that you are not from the tourism sector but, in working in the sector, what opportunities would you see to attract people to visit these unique sites should we invest in them?

Mr Green: If we step away from the obvious, which is watching a launch—you go away for two minutes and suddenly it has gone—there is also the information with museums about sciences, plus stargazing. A lot of people go to these sorts of remote sites. They get to see the rocket going up, but it ends up being tourism because, with the lack of lights, especially in Gympie, stargazing becomes a big thing. Also, with the launch site being only three hours from Brisbane, we have the capacity where it can be a daytrip and then those tourists who are coming from other areas in Australia can spend time in Brisbane or go to the Gold Coast or other things like that. It becomes a larger spin-off. They come for the rockets and stay for Brisbane.

Mr WEIR: I am curious about the time frame. If you have identified the site, how long would it be until we were in a situation where you could start the countdown?

Mr Green: I could literally launch a rocket out of there tomorrow.

CHAIR: That is very hypothetical.

Mr Green: Suborbital. No, we have a rocket that we could launch there tomorrow.

Mr MICKELBERG: Are we going to do that?

Mr Green: There are still a lot of logistics that go into that. As much as I am saying that, the approvals for the local area and the stress that we are likely to put on locals about something like that quickly, without prior engagement, would be a difficult situation, but it is quite possible, yes.

Mr BATT: In relation to the places that would be able to launch rockets other than the one that you are discussing, you mentioned that the closer it is to the coast the better. Does it necessarily have to be that way? Woomera is in South Australia. If we were looking at places in Queensland, in your opinion is it going to be on the coast?

Mr Green: Yes. They have launched orbital satellites out of Woomera; however, they do not do that anymore, primarily based on the idea that the risk assessment becomes too hard. The downrange involves Brisbane. If they have a problem launching a rocket out of Woomera to orbit, you have Brisbane as a possible fall-out zone. It is just never going to work. The problem is not really that you could not find sites further inland that would be more suitable—in fact, it would be significantly easier if we did something like that; the problem is always downrange. No matter where you end up, Australians love to live on the coast. We have all the coast populated by people.

The preference for the coast makes it a lot easier. You know that there is nothing downrange straightaway. As much as you could get away somewhere else, you would always end up finding a little town or something that you would have to fly over that you now have a problem with.

Mr BATT: Are there many other sites that are on the radar along the Queensland coastline? Historically, there has been talk of Cape York and those sorts of places. Is that still somewhere that could be looked at, or is it the reef and other countries that you have to launch over that put that out of consideration?

Mr Green: Exactly. Equatorial Launch has Indonesia so close to them that they have issues. They have Cape York that they are downrange from. There is always going to be a compromise, but how much do you want to compromise? How viable is that site compared to another site? This has to be assessed. It is not going to be one of those things where you just put a pin on it and go; it is always going to be a consideration of a bunch of different things.

The preference for the Gympie type of area is primarily based on my experience—what I know about the industry and why we would need to choose that. In looking at the entire of Australia, that is pretty much the golden point. It is the location, the location, the location. Being so close to industry, being downrange is perfect. You have a large clear area. It is a bit hard to find anything else like it.

Ms PUGH: You touched on Rheinmetall and Land 400. I am keen to hear how that project could be beneficial to the space industry and how the government and business could leverage off that investment into the space industry.

Mr Green: In general, Queensland's investment into high-tech industries benefits the space industry across-the-board. Immediately, when you are talking high school programs and university programs and you are starting to get companies to invest in high-tech machinery, infrastructure and things like that, they all benefit. Being a CNC machinist myself, it is not very hard to shift a machine from making a tank component to making an aerospace component. It is purely a matter of changing the material that you are cutting on the machine. There are huge synergies across-the-board.

If we also go through to Land 400, a lot of companies are getting clearances to do the security to make these kinds of components because of, obviously, the sensitive nature of them. Now we can go into the sort of aerospace technology through rockets that is ITAR restricted and things. There are quite a number of overlaps through the different industries.

CHAIR: There being no further questions, thank you very much, Mr Green.

HART, Air-Vice Marshal (retired) Neil, Strategic Defence Adviser, Department of State Development, Manufacturing, Infrastructure and Planning; Chair, Queensland Space Industry Reference Group

JOHNSTON, Ms Denise, Executive Director, Defence Industries Queensland, Department of State Development, Manufacturing, Infrastructure and Planning

CHAIR: It is very good to have you here today. I know that the roles you will be playing in this whole process will be crucial and will, in fact, lead the way in many ways for our committee.

Mr Hart: Thank you very much for the opportunity to appear this afternoon before what is a very important inquiry into a very exciting area in the space industry development that we have occurring. I am very pleased to be here, both as the strategic defence adviser as well as the chair of the Space Industry Reference Group that the department has established in the past six months or so.

I also welcome the opportunity to address the committee after a long career in the Air Force and the military with operational exposure to space capabilities as well as concept, strategy and capability development work, including in the most recent Defence white paper, focusing on enhancing a range of the military's key enabling joint capabilities, including its space related capabilities.

I am pleased to have been invited to assist in the development of Queensland's space industry, as I believe there is significant potential for job creation and economic benefit across the nation, not just in Queensland. This is in both the development of a range of local space capabilities, if you like, and the introduction of a range of new customers to the opportunities and benefits from the use of cheaper and more accessible space related capabilities and services. I think that is an important part of this study and this work.

In the time I have been the defence adviser I have been very impressed at how active Queensland has been over the preceding years in developing industry capabilities that provide an excellent foundation and identifying a number of areas of industrial advantage. These, along with a range of Queensland's geographic characteristics, mean that Queensland is not working from ground zero in developing a space industry. Of importance to this development, Queensland has a very robust aerospace sector, which leverages its advanced manufacturing and is underpinned by a very strong research sector. It is apparent that a lot of work has already been done to drive innovation, facilitate cooperation and encourage industry in these and other areas through the priority areas element of the Advance Queensland initiative. This has provided a platform that can be rapidly built on to develop an advanced state based space capability as a part of the aerospace sector outlined in the recent 10-year aerospace road map. One of the main planks of the aerospace road map is to increase Queensland industries' ability to enter new international markets, and the international space economy is a prime target.

While I recognise the size of the space economy and its lure, it is also important to be mindful of the potential for a level of unrealistic expectation surrounding some areas of space capability. Space capability tends to be inherently complex, relying on advanced technologies along with a complex interaction between a range of systems to generate real capability, which makes understanding the benefits quite difficult for the casual observer. I am working with the department to ensure the approach we take to space industry development is methodical, balanced and sensible. This approach is aimed at accessing the broadest range of expertise possible to build an evidence based policy framework for Queensland's space industry—one which is realistic and achievable, broadly considers all aspects of space related capability and ensures we understand the economic benefits to avoid the highs and lows of the historic cycles in Australia's space capability development.

In my role of chairing the Space Industry Reference Group for Queensland—it consists of senior executives from some of our Queensland based aerospace heavyweights, next-generation space related SMEs like Nick, who you just heard from, and prominent academics from some of our leading universities, like Professor Smart behind me—there has been consensus across the group that this methodical, broader approach is the best way to start and proceed. It is not just about developing any space related industry identified; it is about developing a Queensland space industry which is profitable and sustainable and at the same time agile enough to pursue new opportunities as they emerge as part of national endeavours or in response to emerging global demands, including looking at the complete life cycle of space capability. Therefore, this also needs to be done as part of the bigger picture—that is, the national space agenda being guided by the newly formed Australian Space Agency.

I also believe that we need to look beyond the direct job creation opportunities of space industries to the many new customers and economic benefits that will flow from greater and more economic access to space related capabilities and services through the provision of local space capability. This will in turn be further driven by innovation that occurs between and across sectors and through a focus on growing the existing level of pure and applied research in universities and institutes and in turn potentially providing STEM pathways for schools and other educational organisations.

I want to assure the committee that, in support of my role advising the department, I regularly also meet with colleagues from other states at the national level from Defence. All agree on the importance of taking a national approach if we are to become a bigger part of the global space economy. We are all on the same page when we catch up in Canberra. While Queensland has an important role to play, we need to do this as part of the larger Australian framework, which consists of all levels of government across the nation working together with industry, the research sector and Defence collaboratively in the national interest.

Part of the Australian Space Agency's strategy is to develop a dedicated national space industry which leapfrogs us into the forefront of many areas of the space industry supply chain. Queensland, from the foundations of well-developed aerospace, advanced manufacturing and research sectors, has the ability to be part of the leapfrog. Queensland has existing capabilities in many of the national civil space priorities that the Australian Space Agency has already identified. This includes the advanced manufacturing already mentioned, some research in other areas of 3D printing, high-tech materials, earth observation and remote asset management and robotics, a lot of which is driven through both the agriculture and mining sectors. Chair, I will conclude my opening statement. I am open to any particular questions that you have.

CHAIR: Before we get into questions I will ask Denise to launch into her opening address.

Ms Johnston: Good afternoon, chair and members. Thank you for the opportunity again today. As you are aware, I appeared before the committee at the departmental briefing on Monday, 15 October.

As the department's strategic defence adviser for aerospace and chair of the Queensland Space Industry Reference Group, Mr Neil Hart works in a part-time advisory capacity to the department and is here today to share his knowledge and expertise. I am here to assist Mr Hart if there are any questions regarding departmental policy or activities that are outside the scope of his expertise and experience, and that is all I have to say at the moment.

CHAIR: Denise, can we touch on where we are with the work that has been done in recent years in terms of the studies that are underway. Could you touch on that to remind us what work has been done in the last year and what we can look for around the corner?

Ms Johnston: The department has completed a high-level technical study, which was really an early indication for the department about what opportunities there might be in the space sector. We have established a Space Industry Reference Group, which Neil chairs for us, which is another mechanism to ensure that the department is understanding what opportunities are available and what the industry is currently focusing on.

There are currently three pieces of work that we are progressing. The first of those is a capability audit to understand what capability exists within the state, both currently in the space industry and potentially in other industries that could translate to space. The second piece is an economic analysis to understand what we think the opportunities might be for Queensland with regard to the space industry. The third piece is a site investigation for a potential satellite park and space launch facility.

CHAIR: I understand that for the last one there is a confidential feasibility study being conducted now; is that correct?

Ms Johnston: The only piece that is completed at this point is the high-level initial piece. That was recently completed. The site and satellite park are yet to commence. We are finalising the terms of reference.

CHAIR: Mr Hart, one of the things we got from this hearing today is the importance of collaboration across Australia. One of the things you have talked about is a 'Team Queensland' approach meshing in with a 'Team Australia' approach. Can you expand on how important this is?

Mr Hart: There are a couple of capabilities already in Australia that you could establish with the right partnerships. In the last section Nick Green talked about some of the testing that you could do for satellites, vacuum chambers and other things. The Australian National University at Mount St Lucia

Stromlo already has an expensive facility called a Wombat XL, which is a large chamber that can evacuate to vacuum and heat to the very high temperatures that space objects can get to in direct sunlight. It is an expensive capability. It is not used every day. If we were to use some of our advanced aerospace manufacturing industries in Queensland to manufacture satellites or satellite components, there would be some capacity that, with a relationship in these early days, you could go down there and make use of that facility for that final piece of testing. That is one example. There is research and collaboration that others could talk about in more depth that are already in place around Australia where different universities have different levels of expertise.

Obviously there is some great expertise up here in Queensland, particularly around autonomy, artificial intelligence and robotics. A lot of that is tied to the mining industry, for example. The University of New South Wales, which Nick also mentioned, has spun off a company called Skykraft, which has built a couple of very small satellites that were launched for the Air Force. You could create partnerships with these different universities to look at the technology we already have, the research we already have, and get some experience or knowledge about the new applications that we are looking to use. It is that kind of approach that we are looking at.

The other thing is that, downstream from space, it is not just about putting a hunk of metal up in the sky; it is about delivering services, images or something back to industry, to punters out on the street with devices, or to agriculture and mining. Clearly, there are opportunities to deliver those services to a broad range of Australian customers. By the very nature of a satellite you can see a fair bit of Australia. In fact, if you look at Queensland, about halfway up the east coast is somewhere off the Sunshine Coast, so a satellite or coverage that was sitting over the top of that area gives you quite a national reach. Working with other states and industries between universities with testing and evaluation et cetera just makes sense, given the cost of these things up-front.

Mr WEIR: You touched on the subject of profit and economic modelling. What do you base your figures on? Is it stations in other parts of the world? Is it how much private interest there is? Obviously Defence has an interest. I was wondering how that modelling was done.

Mr Hart: If we are going to develop a vibrant, sustainable space industry for Australia then it has to be economically viable for businesses to buy from the Australian manufactured or Australian delivered service rather than from somewhere else. One of the studies Denise mentioned that will go out soon will look at some of those economic viabilities. If you spend any time in America you will notice, for example, that you have satellite radios, satellite on aircraft, and satellite here, there and everywhere because there is that saturation of the service. It is actually quite inexpensive to access a satellite service because of that density. If you look over the top of Australia, we do not have that same density. We do not have that same access, so it makes sense to me that there would be a range of economic benefits that would come from having that greater access. That is what we are hoping to find from these studies. As we go through these studies I think it will also become true that a range of farmers or miners, perhaps, who have not used space historically because it is so much more expensive, or has a time delay associated with it, or other factors, will actually start making use of it because it is more accessible.

To give you an example, one of the companies I have been speaking with talks about getting an image through one of their commercial customers in the sky. Obviously, as the satellite is going around the globe it takes some time for it to move from taking a picture to being within range of a ground station, and that delay time is a delay in you getting your image. Some of our images are downlinked through Alaska, Toulouse in France or various other sites, and it can take 24 to 36 hours for those images to come back to Australia once they are downlinked, processed and then pushed back through the internet. If we were to have some ground facilities and data processing here in Queensland, potentially you could be processing and providing those images within minutes rather than days. Now you have really fresh images that could be used for a number of safety and other applications rather than the time delay that you see.

Mr MADDEN: I have read this report I think from you, Denise. We are talking about the positives and our strengths in geography and infrastructure. What are the areas where we need improvement? Gympie has been mentioned today as a platform for launching rockets and doing technology. Is that an area that we should be focusing on? What are the things we need to improve to get into aerospace?

Mr Hart: I think the approach we are taking is to try to look at everything and work out what is feasible and what is most sensible. If I can put it at its most simple, which I tend to do, there are four big things that we do in space. I have said this to a lot of these folks. They have heard me say it before.

We have spent years looking up at space. Obviously for the space industry, watching where the satellites are, providing a level of control, astronomy and looking for objects and things is one part. We need to investigate what we can do there. We look down from space. Most people put things into space to look back at earth, so there is the earth observation, communications and the other things that support the earth. We look at launch and recovery, then, as obviously the enabler of all those elements. Really, what we are hoping to do is look across that broad range to see where it makes most sense, both for Queensland and also the department, to invest to make sure there is some significant economic benefit.

For the capability audit that Denise mentioned, I think we will find that we have maybe a 80 per cent solution in the aerospace sector with our industry and with our ability to do all sorts of advanced techniques—vacuum raising, vibration testing and all of those things. Aircraft, as most of you know, have pretty demanding standards in terms of how they are built. They have to be light weight.

Space is another step again above that. Doing the research and bringing in those machines is something we want to investigate. What is it? What are those extra few steps we need to take to meet the standards to be able to do the testing that assures us that we can take that next step and really be competitive and up to the standard that we aspire to be and that the global economy demands? What we are hoping to do is, rather than focusing on one or two things—rather than just focusing on launch or whatever—look at all of them and work out where it makes the most sense.

Launch is a very interesting area because of the points that have been made in that last session about the challenges of having to have a nice, clear area so that there is no risk. You recently saw the NASA and Russian astronauts who lost a rocket. Obviously there is a danger zone associated with the initial rocket launch. In that case it was the move from the first to the second stage. There is movement and a new motor ignites, and that is the second period of risk. That is a long way downrange. You end up having to clear a lot of area to make sure that that is not going to come back to earth with explosive contents and all of rest of it.

Exploring the feasibility of that in Queensland is an important part of the launch. Even if it is not possible to do big things out of the locations—as Nick said, moon shots—it might be that we can do something smaller. That is what we are going to try to determine as we go through this process.

Mr BATT: Do we currently have legislation around the launch side of the space industry in Queensland, or is that part of your inquiry?

Mr Hart: I think there are some new things that we have to do. A big part of it will now be led by the Australian Space Agency. I know that they have had a very close look at both the European Space Agency and NASA. Similarly, the Civil Aviation Safety Authority has had a good look at the Federal Aviation Administration in the US and the Europeans to see how they manage the airspace on the way up to space as well. We will pull a lot from that. The new federal legislation that was passed as part of that Space Agency announcement has given us a good head start. A big part of that was a reduction in the liability and insurance costs associated with space and access to space. I think there is more work to be done as we learn.

Ms PUGH: Obviously we are taking a real 'Team Australia' approach here. As part of our role in Team Australia, what vacancies do you see as opportunities for Team Queensland to be able to quickly build capacity and get up to scratch to play our role in Team Australia?

Mr Hart: There are couple of things. First is the geographical advantage of Queensland. If we can find a feasible place to launch and provide that complete supply chain then that is a natural start. The latitude of Brisbane is within about a degree of the latitude of Cape Canaveral. We are 27 degrees from the equator. That is about the same as Cape Canaveral. The geography is good. There is lots of open space and all those things. Obviously there are air traffic, sea lanes, tourism and all sorts of things to consider as we go through.

The approach to manufacturing and research and how that is tied together is a very important piece. In terms of the example that is being led in the mining industry with some of the autonomy and AI, the Japanese currently have a test going on an asteroid out there somewhere, looking to see whether they could recover pieces of an asteroid. I know that asteroid mining is a very interesting element.

Even in terms of what Nick was talking about, if we are going to do moon or Mars missions, some of the expertise that we already have in Queensland for digging and doing things in a remote way could potentially play a role. There are a number of little sectors that you could see potentially playing a role in getting us straight into global efforts or national efforts.

Ms Johnston: There is also the existing aerospace capability within the state. We have a large number of primes who have a base here in Queensland, and some of them are already engaged in space activities or interested in space activities. We also have quite a number of SMEs that already have capability in that. Neil mentioned manufacturing, but I think the aerospace capability that we already have in the state is also a very good basis.

Mr Hart: It is probably worth adding the ground station element, which we are doing as one of the studies. Off the Sunshine Coast somewhere is about halfway between the top of Cape York and the bottom of Tasmania. With a ground station in sight of the satellites you can get that downlink of information that would be able to see a large swathe, almost from New Zealand to New Guinea and out into the Pacific. Queensland has that geographical advantage even in that data delivery, if you like, that we need to have a look at.

Ms PUGH: Are there tandem industries, like mining or defence, that you think we should also be encouraging investment in so that we can leverage off those industries and perhaps try to build our capabilities quicker?

Mr Hart: I think you have three big industries that would immediately stand out. One is mining, obviously, given what you have up here. The second is agriculture. In Queensland there are broadacre farms and other things that really could use assistance or would benefit from satellite imagery and satellite tracking that would then queue into UAVs and other remote technologies. The final one is the environmental management and tourist management of the Barrier Reef and things like that. Again, across large areas from a safety point of view, a connecting point of view and watching weather and other events, you have three large areas that could immediately be looked at for innovation for the benefit of having a more timely and accessible satellite service.

Mr MICKELBERG: The terms of reference of the inquiry overlap significantly with some of the work that you have already commenced. What tangible outcomes would you be looking for from the committee perspective in relation to your work as the head of the reference group?

Mr Hart: We would be hoping that we would come up with a similar analysis that this is feasible and doable. I think the fact that this inquiry is looking at space at the same time is very positive. Apart from many things, we are trying to build a big business case. We are trying to build that momentum that was created when the Space Agency launched.

The technical work that we will find and the economic work that we will find I am hoping then marries with your findings, which then drive from your committee or through your parliament to the policy and legislative responses that then provide that support and enablement, and then the reach from your parliament to the federal parliament, if that is required, really to make sure we have the policy around the industry development that goes ahead.

This is new for Australia, even though we were third into space back in the 1950s. We really have not built a commercial industry around it. Back then it was on Defence land and quite tightly federal government controlled. There is a new policy environment in terms of safety zones, how we manage air traffic and a range of things. That would be the greatest benefit from this inquiry at the same time.

Mr MICKELBERG: Is the committee able to get some clarity as to the anticipated completion dates of those studies that you have commenced or are commencing so that we can establish whether or not that information is going to be available at the point we are coming up with recommendations and/or whether or not we need to change the time frame of the inquiry?

Ms Johnston: Certainly. At this stage I could say it is early next year. We could certainly come back to you with more precise dates. Some of those dates will depend on the contractors who are engaged. We can certainly provide you with that detail.

CHAIR: We will place that question on notice.

Mr MICKELBERG: The committee is due to report at the end of February. If the report was going to be ready in March it might be worthwhile foreshadowing that now so that we could extend the reporting date or vice versa—try to get it completed prior to the committee's report.

CHAIR: I think there is a capacity to work closely together to make sure, as Mr Hart said, it marries together. We talked about the ground stations. I assume that they are the data-processing centres as well?

Mr Hart: There are two elements. One is the big antenna, which needs to be in a radio quiet area if it can. The data-processing centre does not need to be right next door but, as you start looking at some of the modern sensors that are pushing down terabytes of data, you do not then want to be pushing that over the ground over too long a distance. In proximity you would then have some sort of data exploitation and distribution.

CHAIR: It is best, then, if there is a degree of collocation of those centres? Is it possible?

Mr Hart: It is possible, yes. Obviously if you put a data centre in the middle of the outback you do not get too many workers and if you put an antenna in a city you do not get radio quiet. They are probably naturally going to be a little apart.

CHAIR: Is the lack of either of those a potential bottleneck in the supply chain in the space industry?

Mr Hart: I think there has been a limitation on Australia adopting a lot of space capability up until now. I certainly know in my work with Defence that we are very reliant on overseas providers of imagery and other bits and pieces. That does impact on timeliness and the amount of data that you can get. I think it is something that we could do soon and would make a difference in Australia pretty quickly.

The way a satellite works at the moment is that when it is on this side of the earth or over the Antarctic or something it just stores all the data on-board. They do not have unlimited storage. They can be selective as that data starts to get full. As soon as it is within sight of a ground station it squirts as much data as it can down to that ground station and tries to get it off so that it can then start uploading new data.

In terms of the bottleneck over Australia, if we were to provide that ground station it would be a great benefit not just for Australian customers but also for others on the other side of the world who could perhaps get a quicker downlink capability through Australia. It is certainly a bottleneck for Australia in terms of getting data and it would be a great benefit globally.

CHAIR: Looking at the list of the large companies that are here—whether it be Virgin Australia, Boeing, Defence, Airbus, Northrop Grumman and Raycon—is there anywhere in Australia that has such a concentration of potential partners or potential collaborators?

Mr Hart: There is obviously a large concentration in New South Wales. I think the stat I have seen is that 40 per cent of the current space industry is in New South Wales. A lot of them are small and medium enterprises. In terms of raw manufacturing capability, though, I am not sure but I think Queensland is up there. There are not a lot of other states that are building aeroplanes and things like that, so Queensland is certainly near the top of that list.

Ms Johnston: I think Victoria would perhaps argue that they also have a strength in aerospace. There are also some companies in South Australia, but I think Victoria would argue that they have a strength as well.

CHAIR: But it is still worthy to note the advantage that we do have in the location of those companies right here. One of the things that has become apparent today is that having all these opportunities in the supply chain located here will attract business associated with the Rheinmetall contract, but also the naval one for the submarines in South Australia. If we promote or build our industry here, how can we attract work associated with those projects?

Mr Hart: I think one of the really important pieces of Land 400 and of the submarine project—indeed, all Defence projects these days—is that they are much more than the vehicle that you see. All of them require advanced sensors, advanced weapons, networks and communications. As you start to build those industries with very advanced high-technology communications and networks and sensing systems, you are naturally going to start to attract research and development around that, innovation around that, and that starts to then feed, I guess, other industries that spin off or are attracted to work with the very clever people that you have attracted. The reason we are taking a bit of a system of systems approach, if you like, is to identify what we invest in that would help attract all of those other elements to it. To me, it is that innovation and it is about tying together all of those very advanced systems so that we attract the industries that are working in those high-tech areas.

CHAIR: Certainly, as you said, the key element there is very clever people—the critical mass of very highly skilled, very high knowledge-based workers—coming together in one place, which is the crucial element, I do believe, in attracting work from these projects.

Mr Hart: Absolutely.

Mr WEIR: Data has come up a few times. You would be aware of the first stage of the data storage centre that was built out at Toowoomba recently. There will be three stages, so it is going to be quite a large data storage. That would fit into the whole picture?

Mr Hart: Potentially. It really depends on which customer and what they are doing. If, for example, it was a large imagery exploitation that was associated with the downlink then what you would actually want is a whole bunch of terminals with guys and artificial intelligence exploiting and

manipulating those images, for example, or radar images or retasking satellites to get the image because it was not quite right or cloud was in the way or what have you. That is a little different to some of the data centres which tend to just be big air-conditioned rooms full of banks and banks of computers acting as a cloud data store. Clearly, once you start generating more and more of this data, the data centres and the cloud locations around become repositories for this process refined data.

Mr WEIR: So there is certainly an opportunity there?

Mr Hart: Absolutely, and as long as we have that connection—and imagery analysis is a pretty specific skill set—then you can connect it all together, yes.

Mr MICKELBERG: Would you envisage the downlink being led by the private sector or government investment? How do they work? I imagine they are strategically important assets from a national security perspective as well. Presumably it would be a government or a federal government type investment.

Mr Hart: I think they would be commercial. One of the models that we had a look at was the Ningaloo site in Western Australia. What happened in that case was that I think the government assisted with identifying a radio quiet area and then set aside a large chunk of land where they then leased subplots for a number of commercial operators to come in. I have already spoken to the Australian Communications and Media Authority about how we find these radio quiet sites and how we keep them quiet, but if we could do that work then obviously a commercial antenna builder would be much more attracted because it does not have to do all of that work up-front. I think from a government point of view it would be about finding a location that is radio quiet, is close to fibre-optic links, has dry conditions et cetera. It would probably be a case of finding the site and then trying to encourage commercial people to then locate various antennae and other ground stations in that location.

Mr MADDEN: It was interesting, Neil, mentioning the possibility of a ground station at the Sunshine Coast. It made me think about the proposed undersea cable that is going to connect with the eastern seaboard at Maroochydore. That is an issue that has not been raised today with regard to this inquiry. Is there any connection between that source of data and the proposed space industry in Queensland?

Mr Hart: There is certainly an opportunity with the new capacity that will come with that extra undersea cable, particularly if you look at being able to service specific and other customers. Certainly that capacity would be an important part of any commercial operator's business case as they were looking forward to establishing in Queensland.

Mr MADDEN: It adds to our strength in communication, I guess, when we are talking about packets of data being transferred around the place. You were mentioning sending a photograph and that currently it is hours but it could be six minutes. That is what made me think that that undersea cable would be a significant development with regard to communications in Queensland.

Mr Hart: It certainly adds to the business case, I think, for people wanting to come and not being quite so isolated on this side of the earth.

Ms PUGH: In your submission you have outlined the geographic and infrastructure strengths, and you touched on those when you answered my earlier question. Below that you have Queensland's specific strengths in the emerging space industry and you have the sensing services, the support and the design and manufacture. Is that what you meant by the four?

Mr Hart: Yes: look up, look down, communicate and launch and support.

Ms PUGH: Let us assume that we cannot possibly, and it would not necessarily be wise to, give equal attention to all of them. Which of those would you really drill down and say are our opportunities, our key advantages? Would you say that there is one of those four or two of those four where we really stand out, if you had to rank them?

Mr Hart: I think if I had to rank them I would rank them time-wise. I think there are opportunities amongst that that you could do more quickly than others. Even though you could technically launch a rocket tomorrow, it might take a little while to get through the environmental and the other policy changes and the regulatory changes—with CASA and so on—and the feasibilities. There are people with antennae now, so you could point an antenna up and get a partnership with a big company and be doing that very quickly, for example.

There is a timeline to this, I think, that will come out of the studies that we have done, where we can put a road map in place to work through across the broadest range of sectors that we can possibly work at and then as we get further down that road map I am hoping that we can create that

life cycle that we talked about where we can do as much of that life cycle in Queensland as makes sense. Rather than necessarily one being more important than the other—because they are all required, otherwise you do not have a space capability—it will be about working through them in that kind of logical timeline sense and in the time it takes to develop those connections with research or with innovation or to get the machines and collaborations in for manufacturing or what have you. Then I am hoping along the way, if we can build that innovation within the space industry, we can at the same time be slowly bringing along with us on that journey farming, fisheries, tourism, mining and others and making sure that we are innovating across the other sectors as well and building that customer base as we go.

Mr MICKELBERG: Setting aside the legislative, policy and regulatory constraints, what are the tangible limiting factors from a Queensland perspective to getting a space industry up and running and self-sustaining in that life cycle that you talked about?

Mr Hart: The initial big limitation is that we are such a small part of the global space economy that people are going offshore and can do it quickly and relatively cheaply, because that global customer base is predominantly offshore and the industries are offshore. Right now our customer base is small because we have not had good and timely access to satellite imagery, so we kind of have to build this all together. That is why the momentum that has built out of the Space Agency is a really important piece of this, getting people excited about space—not about launching off and putting an astronaut suit on or something like that but about being able to run their business using very good data driven by space. There are a range of those kinds of things that need to come together, if you like, to get us where we want to be.

Mr MICKELBERG: It sounds like there is a fair degree of execution risk in trying to bring multiple factors together at one point in time. Is it a fair contention to say that government is going to have a big role to play in providing the seed funding, for want of a better description, to get this ball rolling?

Mr Hart: I think one of the greatest roles that the government will play is actually connecting different industries. There is a whole bunch of niche research and niche capabilities that are being marketed onshore or offshore right now, but they are not connecting to create a space system. There are people who build the most advanced radars and sensors in the world here in Queensland, or artificial intelligence software and autonomy, but they are not connected to a satellite manufacturer or they are not connected to a rocket builder.

A big part of what we are going to do is a capability audit, not just so that we can see what capabilities we already have and what is missing but so that everyone else can see what capabilities are out there and they can start talking to each other and saying, 'Well, we can build the sensor. You can build the rocket. You can build the—wow! Maybe we have an industry already.' An important part of this is just creating that connection between all of these often fragmented and disparate small pieces which has been driven by the fact that we have not had a national space agenda and policy up until now. We have been a net user of space rather than talking about creating an industry. That is the exciting piece.

A big part of the work we are doing with the Australian Space Agency is to give them access to the data that not just Queensland but all the states already have. They are much better connected to the SMEs and the universities in their local state—what is going on, what they are researching, what they are developing, what they are building, the connections they already have with customers offshore—in America predominantly but with India and Europe and other nations. We are working very closely with the Space Agency, who are only 17 people at the moment and are based in Canberra, to make sure that they do not just see a Canberra view and the people who can afford to go down there and lobby them, but can reach in then to the capabilities that are understood around the nation from each state. They will quickly be able to help us then, not just within the state but across states, to make sure that we potentially have a viable industry somewhere but we just do not know it yet.

Mr MICKELBERG: Does the department see their role as drawing together deal teams, as it were, or existing operators in Queensland so that they can find those relationships and bid for larger deals?

Ms Johnston: Our role within industry development more broadly is about identifying the opportunity, making industry aware of those opportunities and organising network events for those organisations to meet with each other and understand each other. We often do supplier days where we connect primes with SMEs. Actually putting a team together to bid for a project is perhaps a little bit further than we would normally go, but certainly the role of the department is in promoting the opportunity, encouraging it and developing the capability of the businesses so they are better placed to be able to tender or canvass for that work.

Mr Hart: These incubator and innovation events that draw people in can be amazingly successful. I have visited some companies around Brisbane already. One company I visited has a relationship with the Indian Air Force and is building radios for them. It does not work with our own Defence Force department. I asked him how he got that job. At a conference, a friend of a friend introduced him and away he went. Creating those events and those opportunities for people to speak on a platform about what they are doing for others, then to hear that and then connect I think is a pretty powerful start point. Then there are opportunities for particular areas that come out of that for other assistance. However, really that start point is to just understand what elements we have and what elements we do not have and let that industry kind of connect.

Mr MICKELBERG: I am not asking for commercial-in-confidence information in this question. Using the Rheinmetall example, are there primes in this space that have expressed an interest or put forward proposals in relation to driving the space industry through the department at all? The department has had quite a bit to do, as have federal departments, in relation to making those connections with Rheinmetall and mid- and smaller tier operations. Whether or not they pursue them is a broader question. Have any primes, for want of a better description, come to the department and said, 'Hey, we want to operate in this space in Queensland; what do you have?'

Ms Johnston: Neil might want to add to my comment, but I think at this point we are certainly engaging. We have a number of primes on Neil's Space Industry Reference Group. I do not know that we have any specific proposals at this point in time. I suspect the industry is also monitoring what is happening, keen to understand where the Australian Space Agency is heading and what will be the regulatory environment in which the Australian Space Agency will operate. I think they are engaging, but we are certainly not looking at a Land 400 phase 2 proposal at the moment.

Mr Hart: As I see it, the primes are more engaging with the Space Agency at the moment to understand what Australia is doing: are you making this better or different; how does it compare to other places that we might invest in space? However, we are a long way away from a single-digit project with, 'Here is \$1 billion and we want to build an X,' which companies are ready to start bidding for. They are staying aware and they are certainly engaged through the industry reference group. We have some of the big players on that to provide us with—and they have made some very generous offers of—information and connection. Most of their interest at the moment is watching what the Australian Space Agency does in terms of the overall Australian regulation and policy environment.

Mr MICKELBERG: Of course, the Land 400 contract is about building indigenous capacity, for want of a better description, within Australia, because we could have easily bought vehicles that were constructed overseas. We have put a big wedge of money forward because we had a requirement for a capability, but we could have similarly bought them off the shelf from elsewhere, potentially. From a government perspective, is it going to take that degree of investment to get this ball rolling?

Ms Johnston: I think a prime may choose to make an investment of their own accord because they think there is a commercial opportunity. It could come from industry. Certainly government investment may well stimulate further interest.

Mr Hart: I am also watching the defence space because, different to where we are here with commercially driven models, Defence does have big investment programs to invest. They have just turned soil at Kapooka down in Victoria with Northrop Grumman, which is building a large ground station for some of their capability. That is military classified et cetera. The fact that Northrop Grumman are coming into town to do that with Defence potentially provides us with an opportunity to build on their presence in Australia and it lowers their cost to then spin off a commercial venture. We will keep an eye on what they are doing. I will not speak for the Queensland government, but I do not think they are about to put down billions of dollars to buy capability, and that is not the commercial model we are looking for. We can certainly leverage the relationships that get established through Defence and through the Space Agency.

Ms Johnston: Obviously Defence has a very large investment over the next 10 years, and Land 400 was a designated project that was understood and that mechanism for tendering is an understood process within Defence. With space, we are at a much earlier phase. It is understanding what that process will be. Is it a government that is seeking investment or is it industry that is looking to invest? I think it is a little bit different at the moment from, I guess, an established Defence procurement process.

Mr Hart: In fact, the other part of the economic study we will do is to demonstrate to some of these big companies that there is a demand or a potential demand. Obviously that then starts to attract that commercial interest.

Mr MICKELBERG: The implication in my question is that potentially there is not the demand—I do not know. Then we have to either manufacture the demand through government investment or some other mechanism, or accept that it is not doable. That was the cut and thrust of my question.

CHAIR: As there are no further questions, thank you very much, Mr Hart and Ms Johnston. We have one question on notice, which is about the dates of completion of departmental research. Thank you both very much for coming along and being a part of this hearing. We really appreciate it.

Ms Johnston: Can I ask when that response is due?

CHAIR: It is by 10 am on Friday, 26 October.

Proceedings suspended from 2.51 pm to 3.08 pm.

ARMSTRONG, Dr Jason, Senior Manager, Brisbane Technology Centre, Boeing Research and Technology Australia

CHAIR: Thank you very much for coming along, Dr Armstrong. For the record, can you please state the capacity in which you appear today?

Dr Armstrong: I work with Boeing Research and Technology. In that position I look after two research centres in Brisbane—one here on the UQ campus and another one at Brisbane Airport.

CHAIR: Thank you. I invite you to make an opening statement, after which we may have a few questions for you.

Dr Armstrong: I guess to put the context in a little bit deeper for Boeing and the research Boeing is doing in Australia, there is Boeing research in Melbourne which is very focused on the commercial aircraft market. Boeing Research and Technology in Brisbane has the two sites I just mentioned and we spread across five or six different technologies, which I will list in a moment. A number of those technologies are relevant to space flight at the same time.

To give you my background really briefly, I first became involved in the area of space flight in 1991. I did my PhD at a NASA centre in the United States. At that time I was working on biomedical payloads for the space shuttle, so I flew three payloads on a space shuttle. In the nineties I flew on their zero-gravity test aircraft back in that era working with astronauts and also developing payloads at the same time. I then had a career in robotics for a number of years. A lot of that work, even though it was biomedical, was robotic in nature. I returned to Australia in venture capital and then about 5½ years ago began looking after Boeing Research and Technology here in Brisbane.

In terms of Boeing, I will make a few comments on the overarching view. Boeing of course is known by people mostly for its commercial aircraft and that is—it depends on the times and the economic climate—typically around 60 per cent to 70 per cent of revenues. The other 40 per cent or sometimes up to 50 per cent of revenues—it has been as high as that—is Boeing Defense, Space & Security. That includes of course jet fighters, rotorcraft and other planes like that but extends to satellites in orbit, the launch of satellites and many of the spacecraft that have carried humans over the years. Boeing, and its heritage companies it has acquired, has been involved really from day one of the space program, being responsible in part for the Apollo program, the shuttle program and the International Space Station, and currently we are building the Starliner and also working towards the Gateway, which is the lunar orbiting space station, and a mission to Mars. Some of the work we have been doing here in Queensland does contribute to current space programs. I will talk about that in a moment.

I guess it is very public that our CEO has stated that Boeing wants to be the first to get people safely to Mars and back again, so it is a mission of the company to do that by the early 2030s. We are under contract right now with NASA to support the International Space Station, both crew and maintenance. That is a \$1.18 billion contract, if I have that right, and we are building—we are probably halfway through the project—the SLS, which is the next-generation heavy-lift launch contracted by NASA. That rocket is planned to get humans to Mars and of course returning to the moon before that.

The other very active big-picture contract we have going on in space flight is the Starliner. That is the replacement from the US to get astronauts to the Space Station and it is the replacement for the space shuttle, which was retired about 10 years ago. It looks a bit like the old Apollo capsule of the sixties but is very different. It can be re-used 10 times. It is made of modern materials. It is quite a different vehicle. Of course, beyond that, I mentioned that we do a lot of satellite launch and building of satellites as well, so I will not get too much into that.

I will just quickly run through Brisbane in terms of what we do and what may relate to space flight and research. For a number of years here we have done autonomous aircraft—unmanned aircraft—research for the company. Arguably, starting about 10 years ago we were leading the company in unmanned aircraft. The reason for that was that Australia has a very non-congested airspace and a very active regulator in CASA. Those things put together have allowed not only Boeing here locally to use Australia as a test bed but also a number of institutions like CSIRO, QUT, UQ, RMIT and other organisations to become world leading in unmanned aircraft. We continue to do that, but Boeing in the last couple of years has become a lot broader than just our research effort as one of the early entries into unmanned aircraft. The company has publicly stated that things like flying taxis that are automated through to large 777 size freighters will become automated.

We continue to work here on both small and large applications in autonomous systems. I guess as we think about space flight in future years, it has always been highly autonomous. It will be more so in the future, including the Starliner, the new launch vehicle that Boeing is putting forward with

NASA. The astronauts will not actually fly that. They are there in case emergencies arise. It is an autonomous vehicle itself. Not that Boeing is heavily involved in mining, but Australia as a whole has a very rich talent in autonomous systems in large equipment—things related to mining—and I think that has an application to space in terms of mining in space and other areas as well.

The second area I will talk about briefly is software that is used for remote tests or distributed tests. If you think about Skype and then you put it on steroids and imagine a package that lets people chat to people, send videos, send masses of data and have 45 people or so doing that at the same time, that is software we have developed here locally in Queensland, and it has already been used in satellite launches in the US. It enables support crews for launch to not all have to travel to Florida; they can be stationed anywhere in the world and be part of that launch and verification as that is going through. That is a locally developed piece of software that is contributing to part of Boeing's launch capability.

We do modelling and simulation; that is another research team in Brisbane. One of the areas that is applicable to space activities is that we have created a weather server and a whole simulator that will simulate the world in a variety of ways. If we look at the weather server, it looks historically at weather that has happened around the world on any given date; it is all archived—different altitudes, the oceans, the land, cloud cover et cetera. One of the applications potentially for it is for satellite prediction and usage. It can predict and in certain ways work out what cloud cover there may be and what the sampling rates may be for imaging to optimise satellite usage. That is another piece of software that we have developed locally and discussed in terms of its use for space.

The Starliner is the one I will come to now. I have mentioned it a couple of times already. It is this capsule-like spacecraft. It will launch on an Atlas rocket firstly. Launches of the Starliner will commence in 2019. The person who will captain that is Chris Ferguson, who was the last space shuttle commander of the final mission of the space shuttle. Chris Ferguson came to Queensland about a year ago. He gave a lecture on this campus and one at QUT. He is one of our key customers in a piece of virtual reality software we have developed. If you are not familiar with virtual reality, it is where you put the goggles on your head and then you are immersed in another world. One of our research teams—and it is part of our team at the airport facility—is building our virtual reality flight decks. We have completed a first version of the Starliner simulator in virtual reality. You put the goggles on, you are inside the capsule, you can interact with the flight panel and you can perform a procedure like docking with the International Space Station.

That was the first procedure we delivered to Houston. The other procedures we are working on will come in separate iterations. It is great recognition from Houston and something I think we are very proud to have produced locally. That is the first instance of any flight simulator that has ever been created in virtual reality. We are working on 737 and aircraft simulators, but they are actually more complex than a spacecraft and will be in the coming years. The Starliner is the first time the back end of a simulator has been integrated into the visual 3D environment of virtual reality. It is using all of the software that actually runs the vehicle that exists.

There are a couple of things driving that. One is to get away from physical simulators, which are expensive. If you think about 737 flight simulators—and many people here may have seen them—they are on hydraulics; they are massive things. They cost \$20 million apiece. We have six of them out at the airport. If we could rid 80 per cent of those, there is a massive saving in costs. In space there is that saving, but the other business driver and case driver is that if you are sitting in the International Space Station for six or nine months and you have an emergency egress to get back to earth but you have not trained in the procedure for six months, it may not go so well. With the VR goggles people on long-duration space missions could be training to do things they could not do otherwise.

We have other technology programs that probably are not so relevant to space, at least at the moment as we view them. Factory of the Future, the internet of things and developing next-generation production facilities is work we are doing here and another manufacturing area where we are pushing out novel metal shapes in additive manufacturing or on-the-fly manufacturing through the rapid prototyping or addressing legacy aircraft parts. That is something that exists on the floor down there; there is a fairly large robot down there and you can see silver parts all around the floor. That is one of our research programs working with UQ.

Maybe it is worth noting that we are embedded here with the university. It is not the only university we work with. We work locally very heavily with QUT and UQ. Because UQ is the larger university, we had more programs running here and it made sense for us to come on campus to optimise our collaborations with the professors here and use the facilities here in a way that is a

win-win. For example, we have the manufacturing technique of pushing out prototype parts or new parts plus legacy parts in an Advance Queensland program that we managed to secure. It has been very successful for us. The IP terms have been very generous and it is a great example of how we can work with university, government and ourselves as an industry player.

The other thing I will mention is that the next program we are bidding for with NASA is the Gateway. The Gateway is the name for the space station that will orbit the moon. That is part of the program to return to Mars. It is really the next step to get used to being that little bit further away from the earth and have a more complicated scenario before trying Mars. A team locally here is doing all the virtual reality work for that so that the NASA bid enables NASA to get a good look at our design of the outside structure as well as experience the insides of the space station in virtual reality. Again, there are a lot of human factors, psychology, computing, back-end systems integration that go into these sorts of builds for virtual reality. The disciplines we engage with as Boeing are not limited to just software and hardware engineering. Part of the reason we are here on campus is to access psychologists, people in the biomimicry and some of the biology and nanotechnology areas as well as, of course, software and engineering. Perhaps I will stop there. I hope that is okay for an introduction.

CHAIR: Thank you. We really appreciate that. Clearly, as we have seen here, you are a highly collaborative organisation and you have that long relationship with CSIRO as well. You obviously have a fairly substantial workforce throughout Brisbane. How many people do you have working for you throughout Brisbane?

Dr Armstrong: In research and technology we have a number of Boeing subsidiaries in Australia. I will probably have to walk through a number of them on the fly here. In my area, Boeing Research in Brisbane, we have approximately 15 people at the airport facility. There we are embedded with Virgin Airlines and also Boeing Flight Services, which are the guys running the simulators for the day-to-day pilot training. The number of total Boeing staff at that airport facility is probably in the range of 30 to 40. Here at UQ we have about 35 Boeing Research and Technology people and then on the UQ campus we have engaged about 14 PhDs who are doing work directly for us. They are provided with a Boeing scholarship and the intellectual property comes to us. We treat them as much as we can as Boeing badge, so they are part of the team. The facility we have here at UQ is therefore probably supporting about 50 to 55 people coming in and out doing work in different ways.

When we look at Boeing Defence Australia, which is Boeing's largest presence here in Australia, their numbers are approximately 2,300 people. Their hiring rate has been so high; they have really been saturating many of the graduates that come out of software and in particular in engineering locally. Boeing Defence Australia is not active, per se, in space flight technology, but it is assessing different ways as to how it can be involved in the future, both from the military side and the satellite and launch side. It is very early days for that sort of evaluation compared to us as BR&T. We are embedded in delivering products already into that industry and researching future technology.

CHAIR: You have quite a number of people in both those wings of Boeing. Am I right in saying that it helps create that critical mass of highly skilled, highly knowledgeable people within South-East Queensland and the Queensland area to help attract other potential partners or other people looking to get into the supply chains for the space industry? Am I correct in saying that you would see your people in Boeing as being part of that critical mass?

Dr Armstrong: Yes, absolutely. Our goal is not to do everything. We are engaging with SMEs and even trying to aid SMEs locally. We do have our eye on some of the local players looking to get into the space industry as well as how we might marry what we have as a capability with them. Boeing Defence Australia has a number of passionate people with regard to being involved in space flight and space research in the future separate to our team, who are obviously very embedded in delivering there already. There is a growing Queensland presence beyond the existing Boeing businesses locally.

The business I did not mention then was also Insitu Pacific, which is a subsidiary of Boeing, which is in unmanned aircraft. It is probably in a non-military sense focusing very much on oil, mining and gas, but it is an autonomous systems oriented flight company and probably relevant to this whole picture and core capability in Queensland as well.

CHAIR: It is pleasing to hear that in all those parts of Boeing you have that collaborative ethos, as it were, to work with people across industry.

Mr WEIR: That is quite a resume of involvement in space flight and the whole aeronautical industry. One would imagine that you would be playing a fairly active part if a space industry was established here in Queensland?

Dr Armstrong: We would like to if that was the case.

Mr MADDEN: This is a general question. We are here today at the beginning of an inquiry with regard to establishing a space industry in Queensland. Do you have any advice for us about where we should be spending our money?

Dr Armstrong: I will give it a shot.

Mr MADDEN: I know it is a broad question, but give it a shot.

Dr Armstrong: A couple of things come to mind. One is: how does Australia and Australia's mining plus our flight expertise in autonomous systems possibly relate to the future of the space industry? I think that is one area. While we are world leading in Australia, and in Queensland in particular, in autonomous systems in mining and in flight, there is another challenge to get to the space environment, and that is qualifying space hardware and space systems. It is a process that is often long and requires an experience that you have usually done it before and know the system very well to get it there. I think the translation from where we are today to where we need to be is not an easy step. It is having groups like the Australian Space Agency and government where possible accelerating that understanding and possibly working with foreign governments that have done it before or making the approach to that clear, to SMEs in particular, about how you space qualify something, so there is an R and D map for people to get further along the road. I certainly think the autonomous systems space is one worth investing in.

What we have found locally is that we are leading the company here from Queensland in virtual reality—augmented reality maybe not so much. We have a few people in Boeing playing at it, but we are as good as anyone else in Boeing in augmented reality with a lead in virtual reality. I cannot really explain why that is. The US at the moment with its job market and its position, as I am sure you know, is very, very short on tech-savvy people who can deliver these sorts of technology. There may well be an opportunity for that to continue.

There is another Australian group called Opaque Space that has made some headway with NASA as well in Melbourne. I guess that implies this area of IT, virtual reality and augmented reality might be an opportunity and one in which we know there is capability in this region. Some of that stems from the games business. These people are often recruited from the gaming industry for their expertise in creating virtual environments or environments that immerse you in some way. Admittedly, when you get to the aerospace domain you have to put a lot more rigour on it than the gaming industry, and that is where we bring in our software integration engineers, psychologists and other people just to take it up to another level. I think that is another area of opportunity and one we have demonstrated already to be the case.

A final area I will mention off the top of my head is biomedical. A lot of money has been put into Queensland from the Smart State days up to now, and institutions like this university have very strong biomedical institutes and programs. We have engaged the University of Queensland here in a biomedical program that is related to both aviation and space flight. That technology is an antimicrobial. In its first instance the aim is to get it into aircraft. It is to mitigate the possibility of a pandemic or just to generally make aviation something where you will catch a germ or a bug when you get off the aircraft less often—and the same for the flight crews and flight attendants. There are antibacterial surfaces in the world. There are not surfaces that are specific to a virus; you are most likely to catch a cold or flu, not a bacterial infection on an aircraft. The technology that is coming out of here from a collaboration is unique and is something that will specifically target virus and specifically clean itself as a surface when it is done. That is with the Australian Institute of Biotechnology and Nanotechnology.

At the same time I have received some very strong interest from the space community, because a spacecraft is a closed environment. With the International Space Station's missions to Mars, you would be enclosed for a very long period. The growth of biofilms is a real problem up there. It is not so much virus in that case but fungus and bacteria. Astronauts are immunosuppressed, so they are very vulnerable to catching infections. On top of that, microbes actually grow faster in space and mutate more in space, so it is a real deadly cocktail in that regard. The technology for space that we are extracting from this university locally is to address crew health.

Also, there are a lot of liquid based systems for cooling and other reasons on a spacecraft. They actually grow bugs and begin to clog up. Even if it is just in low-earth orbit, it can cost \$10 million to \$100 million to bring that equipment down and put a new one up. If you are on your way to Mars, you cannot even do that. Therefore, making sure those systems stay clean is very important.

When you look at the Mir space station, part of the reason it was allowed to burn up in orbit was that they did not really have the money to prop it up in orbit and keep it there. That was part of it. There were a number of other reasons. Another was that there was a biofilm growing on one of the main windows. They could not replace that and it was degrading the polymer of the window. Again, it shows how that area is particularly important to space flight.

The final interesting category is interplanetary contamination. When we get to Mars we need to have the cleanest possible vehicles and people arrive so that we do not discover our own life form has mutated once it has been put there. That is another application area.

There are a lot of medical challenges in space for astronauts. I am just talking about one niche here of a microbiology challenge and a materials challenge, so I think a lot of the investment in nanotechnology, biomaterials and biomedicine from Queensland could potentially see opportunities.

Boeing has R and D sites in six places around the world outside of the US. Part of the reason for that is to tap into the best technologies around the world. Australia is very good at polymers and it is very good at materials like resin infusion for carbon fibre, which is related to our Melbourne research force as well. I think some of these world-leading niches are where Australia can play.

Mr BATT: Dr Armstrong, you mentioned a lot of the work that you do with NASA such as the Space Station work and the mission work. You mentioned that virtual reality goggles is one of the things your Queensland people did. Does any of the other work that you mentioned come from Queensland or is that from your other offices around the world?

Dr Armstrong: Everything I have mentioned today is coming from Queensland, unless I was talking about the large spacecraft themselves, which are US based. The microbial technology is Queensland. The VR technology and simulator technology is Queensland. The satellite test launch uses software developed here locally that has been put into play there. The weather server is totally Queensland developed here with Boeing people. I have a list. I think that list totals up to seven local projects to date. We are still working on, I think, every one of them at the moment. They are in some stage of delivery or differing stages of development still.

Ms PUGH: I want to touch on the virtual reality technology. In that development you actually call on psychologists. I am curious to hear how that interacts and to hear a bit about the design process. It sounds fascinating.

Dr Armstrong: There are a couple of things there. When you are building a simulator—it does not matter if it is an aircraft simulator or a space flight simulator—we need a psychologist to think about what is the best adult learning scenario for the student to, of course, take the learning in and make it repeatable. That is one component. The other component is using human factors people and psychologists together to work out the ergonomics of the virtual reality environment and the immersive quality of it. What triggers in our brain to think that that virtual reality simulator is a real spacecraft or aircraft? It is using their knowledge as human factors experts and psychologists to work out how we best make those cues happen, to make it as real as possible. We have PhDs in psychology in my team. We have human factors people in Boeing Defence Australia as well. We are collaborating with human factors and psychologists here at the local universities in Queensland to support that side of the research and product development as well.

Mr MICKELBERG: Dr Armstrong, you mentioned briefly the opportunity as it relates to mining and leveraging our strength in that space. By way of background, we heard earlier today on that issue in some detail. Do you have any projects where you are collaborating with entities in that space at the moment?

Dr Armstrong: We do, yes. We are using unmanned aircraft to support monitoring of some of the facilities of oil, gas and mining. Some of those relationships are still in the early stages, but they have been gaining significant traction. That is using our autonomous aircraft technologies and collaborating that way. In this forum I will not go ahead and list names and things, because that is not my unit and I do not want to mention what is still under wraps.

Mr MICKELBERG: You mentioned that you have received funding from Advance Queensland and you briefly mentioned there were favourable IP terms. At the risk of an own goal here, would you have gone ahead with that project had you not had those favourable IP terms?

Dr Armstrong: Probably not. There are two Advance Queensland programs that are running. One is a large one on autonomous systems, locally Queensland driven. That one tends to relate more to the oil, gas and mining infrastructure and how we are collaborating there. The other Advance Queensland one is in rapid prototyping of metal parts and the heritage aircraft being supplied with parts, which we hope may facilitate some local small to medium enterprise activities in the future.

What was crucial in those areas was that we could leverage the IP, so our co-investment there was something we could capitalise on later. Unlike a number of grant programs that one can look at and decide where you are going to put your money, Advance Queensland was very favourable and made a difference, for sure, in that area.

Ms PUGH: Dr Armstrong, you mentioned taking on young people from university and you said that you felt like you were scooping up an awful lot of them. This is a great problem to have. Do you think there are enough graduating in this area for your needs or do you think we need more young people graduating if we are going to grow the space industry?

Dr Armstrong: I would say, no, there are not enough. We need to do everything we can to get more students into STEM. In Australia, as Boeing Research and Technology we have three prongs. One is obviously delivering products and services to fuel the Boeing business. Another is to collaborate locally and leverage with SMEs, universities and government research agencies. Our third prong is engaging in STEM and encouraging future-generation scientists and engineers. For us, as one of three it is a very important activity. It is something that I spend a good deal of my time on, as do a number of my team, on a regular basis with universities, high schools and primary schools.

I think one of the nice things about space as an area is that it is one of the more motivating fields to talk to kids about to get them interested in. They may not end up doing space, but it gets them interested in autonomous systems or computer programming or the engineering skills that we need to be a technology based society in the coming decades. I think space plays an important role in that technology development of our local area.

Mr MADDEN: Dr Armstrong, in your paper you say that one of the projects earmarked for investigation is cabin disease transmission. I presume you are talking about aircraft and not spacecraft?

Dr Armstrong: It is both. A little earlier I mentioned the polymer work with the University of Queensland. That is being applied. Although I did not use the phrase, the other one is cabin disease transmission. It is keeping that minimal in either environment. They are slightly different in terms of how you apply it, but it is the same base technology. It is truly a next-generation technology that UQ has come up with and is working with us on. It is very groundbreaking. We are looking forward to seeing how that pans out in the coming few years.

Mr MADDEN: Certainly it looks like something that is worthy of research.

CHAIR: There being no further questions, we will close this session, bearing in mind that the next part of the program is to go over the road to look at your facilities, Dr Armstrong. That concludes this briefing. Thank you very much to all of the witnesses who have participated today. Thank you very much to the University of Queensland for hosting us today. It really has been an eye-opener and such a blessing to have your hospitality. Thank you to Hansard. Thank you to our secretariat staff as well. It has been a privilege to hold our first public meeting of stakeholders here. I remind people that the transcript of these proceedings will be available on the committee's parliamentary web page in due course. I declare this public hearing closed.

The committee adjourned at 3.39 pm.