The Nuclear Fuel Cycle Royal Commission
Response to Tentative Findings.

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On Behalf of

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Steele Environment Solutions makes the following response to the Nuclear Fuel Cycle Royal Commission's Tentative Findings. Steele Environment Solutions is an Australian company which through its GeoRoc® brand is developing wasteforms, processes and technologies to treat radioactive and toxic waste streams. It is also developing a new range of Vulloy® advanced materials for aerospace, defence, nuclear and chemical industry applications. The company also produces bespoke equipment for high temperature applications including the supply of prototype equipment for radioactive waste treatment applications.

Steele Environment Solutions and its subsidiaries have team members, who hold collectively more than 75 years of experience in the development of wasteforms and processes to treat challenging nuclear wastes. Team members have led projects funded by the US Department of Energy[1,2,3] and the Nuclear Decommissioning Authority[4,5,6], as well as working collaboratively with private nuclear engineering companies. Steele Environment Solutions' UK subsidiary, GeoRoc Ltd., has successfully completed contracts in the UK with Sellafield Ltd. and Innovate UK to demonstrate waste treatment technology.

In our submission to the review we stated that the key points needing assessment are the economics of and viability of the supply chain for the Nuclear Fuel Cycle in South Australia. The establishment of a Fuel Cycle industry within South Australia will necessitate the contracting of Tier 1 and Tier 2 international nuclear engineering companies, as they hold the expertise necessary to undertake such large projects. However, for South Australian to reap the full benefits of the process it will need to build the involvement of Australian based companies and industries. Otherwise, most of the high technology, high value, engineering design and equipment manufacture will be undertaken off-shore.

General Comments on the Findings

We agree with broad thrust of the commission's findings. The involvement of South Australia in the nuclear fuel cycle, beyond mining for uranium, offers opportunities for high-value, high technology job creation and economic growth.

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[1] M.W.A. Stewart, E.R. Vance, A. Jostsons, and B.B. Ebbinghaus, "Near-Equilibrium Processing of Ceramics for Actinide Disposition", J. Aust. Ceram. Soc., **39** [2] 130-148, (2003).

[2] M.W.A Stewart, E.R Vance, A. Jostsons, K. Finnie, A.R. Day, B.B. Ebbinghaus, "Atmosphere Processing Effects on Titanate Ceramics Designed for Plutonium Disposition", pp. 381-388 in *Scientific Basis for Nuclear Waste Management XXV*, ed. B.P. McGrail and G.A. Cragnolino, Mater. Res. Soc. Symp. Proc., Vol. 713, Materials Research Society, Warrendale, PA, USA, 2002.

[3] M.W.A. Stewart, B.D. Begg, R.A. Day, S. Moricca, E.R. Vance and P.A. Walls, "Low-risk alternative waste forms for actinide immobilization", paper 5212, *Waste Management 05*, CD-ROM, Feb. 27 - Mar. 3, 2005, Tucson, AZ, USA.

[4] M.W.A. Stewart, S.A. Moricca, E.R. Vance, R.A. Day, E.R. Maddrell, C.R. Scales and J. Hobbs, "Hot-Isostatic Pressing Of Chlorine-Containing Plutonium Residues And Wastes" *Materials Science of Nuclear Waste Management Symposium, TMS2013*, San Antonio, TX, USA, March 2-7, 2013.

[5] M. Stewart, S. Moricca, E. Vance, Y. Zhang, C. Scales, E. Maddrell and J. Hobbs "Glass-Ceramic Waste Forms for Uranium and Plutonium Residues Wastes" paper 13164, *Waste Management 2013*, Feb 24-28, 2013, Phoenix AZ, USA.

[6] J.W. Hobbs, C.R. Scales, E.R. Maddrell, M.W.A. Stewart and S.A. Moricca, "A programme to immobilise plutonium residues at Sellafield", paper 0084, *INMM 53rd Annual Meeting*, July 15-19, 2012, Orlando, Florida, USA.

Value adding to the uranium mined in South Australia should be a long-term goal. We agree that currently there is an over-capacity of enrichment facilities, however, the option of enrichment should be kept open as these facilities age and need to be replaced. One can then consider building a fuel fabrication and fuel leasing business. However, we understand that this is long-term and may occur over 50 years.

The fastest way to enter the Nuclear Fuel Cycle market; 11 years after a decision is made according to the Jacobs Reports. There already exists a large quantity of nuclear waste that requires a long-term disposition path and the details of this have been given in *Paper 2 - Potential international inventories and revenues* of the Jacob Report.

The design of the facility will be dependant upon whether its mission is to:

i. Store used fuel for future reprocessing, either in a purpose built near surface store or underground facility. In this case the design will need to allow retrieval of the fuel.
ii. Permanently dispose of used fuel of in a Geological Disposal Facility. Note that given some of the waste may not be fuel some form of Geological Facility will be required.

The choice will affect the type of facility and the economics.

The following are some general comments on information in the commission reports related to waste management. From the report *Nuclear Fuel cycle Commission – Tentative Findings:*

- Pg.15 No 62 – while there are differences between current Australian origin radioactive wastes and spent nuclear fuel, the principles around managing them are the same.
- Pg.15 No 63 – Technical/Engineering issues associated with radioactive waste management and a facility are readily manageable. The biggest challenge will be the in gaining political and social agreement on any nuclear waste management project. The example of several failed attempts to establish a site for Australia's small volume of radioactive waste are an example of the challenges faced. In any case both State and Federal agreement will be required for the project to proceed and succeed.
- Pg.15 No 69 a. Not all wasteforms[7] are insoluble. For example, cement waste forms are permeable to water and isotopes such as caesium-137 can leach out of the matrix. Hence, we believe that cement, while it has its applications, is not a good waste form for higher activity wastes. Whereas, ceramic wasteforms have very, very low solubilities in groundwater and hence are more suitable for long-lived wastes.
- Pg. 15 No 69 b – Soluble isotopes could be leached by groundwater from spent (used) fuel, if the cladding is breached. Hence, spent fuel is typically contained within a specially designed canister. The Swedish concept of encasing the used fuel in copper is a means of overcoming this, however, it is expensive and uses a precious resource. Hence, reprocessing to recover the unused uranium and plutonium and then placing the high level waste generated into a more durable wasteform with a smaller volume has some attractions.
- Pg. 15 No 69 c – One could argue that steel and concrete serve more as a radiation barrier around the waste container and while barriers necessary for transport, they would be unnecessary if the container is placed in a shielded vault or deep underground.

[7] By wasteform we mean the form in which the radioactive waste is incorporated or encapsulated. This could be glass, synroc, glass-ceramics, other ceramics, metal, cement, etc.

- Pg. 15 No 69d – The first factors in preventing the release of radioisotopes from the repository site is to choose the right geology, i.e., low groundwater flows, and have a wasteform with very low solubility. Secondary barriers such as clay layers, metal cans, etc. also assist. Hence, the multi-barrier concept – to reduce the risk.
- Pg. 16 No 70 – We agree that the biggest challenge is community acceptance. However, compensation should not be limited to those immediately next to the facility. Those further afield must have buy-in and rewards, otherwise you get the doughnut effect, which was one thing that halted the UK's first move toward a Geological Disposal Facility in West Cumbria. The local councils that benefited from the employment provided by the Facility, and by the Sellafield Site nearby were for the proposal, however, those further afield in Cumbria (the Lake District) saw no benefit to themselves and hence the County Council voted against the facility.
- Pg. 16 No 77a - The waste is not all retained in the spent fuel ceramic, some of it , including soluble caesium iodide resides at the interface between the ceramic fuel and the fuel cladding. In addition, not all fuel is ceramic, some are metal, such as UK Magnox fuels. However, South Australia has the authority to restrict the fuel imports to certain categories.
- Pg. 17 No 83 – We would not see proliferation as a major challenge for the waste facility. Safeguards systems have been in place and working for many years. One of the biggest challenge facing Safeguards and Regulators will be having sufficient staff with experience, including technical and engineering experience, to make informed and correct decisions. This gets back to the long lead times and competition for talented people that we raised in our original submission.
- Pg 19 No 92 – One challenge in actually realising the economic benefits will be the loss of high level engineering skills between now and the repository opening. The car industry is closing now, and this will flow on to the industries that service it. Mining Industry is in a slowdown. How will South Australia retain and retrain its skill base? Are there interim measures that can be undertaken to build up a nuclear industry in South Australia?
- Pg. 28 Nos. 152-154 – The skill base required will include specialist nuclear engineering, but will also require specialist nuclear science and nuclear regulatory skills. While some such skills exist in Australia within ANSTO, ARPANSA, ASNO, state bodies and private industry, there is nowhere near enough to fill the vacancies for the workforce and there are large gaps in fuel cycle expertise[8]. Hence the importation of skills and the use of international nuclear engineering companies will become a necessity. With global nuclear new build and on-going decommissioning of nuclear facilities, there is going to be intense international competition for scarce resources. Some of the skills such as geologists, trades, etc. are transferable from other fields, but having worked in the nuclear business for 30 years we understand that there is unique experience and knowledge that can only be fully understood from actual hands-on working within the nuclear industry.

[8] This was not always the case in Australia. The Australian Atomic Energy Commission (AAEC), the predecessor of ANSTO, operated projects across the fuel cycle, with programs in fuel fabrication, fuel testing, uranium purification, enrichment (centrifuge and later laser (Silex)), nuclear materials, reactor types, etc. ANSTO's Act specifically excluded it from fuel cycle work and as a consequence Australia progressively lost that expertise as e AAEC as programs stopped and staff moved on or retired. ANSTO focused on neutron beam work and radioisotope production.

From the *Jacobs MCM (2016), Radioactive waste storage and disposal facilities in South Australia — quantitative cost analysis and business case* document:

1. The document gives examples of used nuclear fuel and intermediate level waste (ILW), but there is no mention of high level waste (HLW) wasteforms, such as the glass produced by AREVA (an ILW version of which was repatriated to Australia). The term "high level waste" has negative connotations, but it is merely used to distinguish this type of waste, which generates significant decay heat early in its lifecycle, from ILW. The radioactive waste is in effect concentrated into a smaller volume, compared to the used fuel from which it was extracted. The vitrified waste is in a suitable form for disposal in a Geological Facility and it is considered to be more durable than spent fuel. It terms of their long-term radiotoxicity HLW wasteforms may be considered to be less radiotoxic than spent fuel as the long-lived plutonium and uranium isotopes have been removed for reuse.
2. We do not recommend accepting the bitumised forms of ILW, as we believe they pose fire risks. Cemented and other forms of ILW would be manageable. Appropriate waste acceptance criteria (WAC) can be used to manage the risk[9].
3. "*The ISF would receive UF and ILW in project year 11 after the decision proceed, siting, licensing and construction were completed*." This of course is conditional on having a site licensed and ready to go. Given international and local experience in establishing nuclear waste stores or repositories, the actual timeframe from saying "yes, we want to enter the nuclear waste management market" may be twice, or more that. The social and political factors in getting such a project up are very challenging. However, the nuclear industry, like the many mining industry projects is used to long-term projects.
4. We agree that a State body would need to own the waste once delivered. The commercial risk posed by delays to such projects and the non-proliferation issues would negate private enterprise ownership. However, the delivery of the project should be carried out by private enterprise such that a supply chain can be established in South Australia.

Comments on - *Jacobs, Radioactive Waste Storage and Disposal Facilities in South Australia – Quantitative Cost Analysis and Business Case, 9th Feb. 2016*

1. Those mentioned above also apply to this document.
2. Pg. 17 "**'multi-barrier system'**, while multi-barriers are the norm for Geological Repositories, it is advantageous to have a low "source term", i.e., choosing wasteforms and packages that are resistant to leaching.
3. Pg. 18 Table 2.1 –While UO_2 (uranium dioxide) fuel can be a good wasteform under the correct pH and redox conditions, it does not retain all the fission products. The leach rates from spent fuel are incongruent, different isotopes reside within different parts of the fuel rod. Caesium and iodine are enriched at the fuel cladding – fuel pellet interface. Hence, the wasteform for fuel rods is the fuel bundles containing the rods plus the

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[9] Controlling Risk – Waste Acceptance Criteria - There is much in the literature about the risk of such facilities. E.g., the Organisation for Economic Co-operation and Development (OECD), Nuclear Energy Agency (NEA) has an ongoing program on geological disposal in repositories. A means of controlling risk is to develop waste acceptance criteria (WAC) that will ensure that the wasteform and waste packages meet safety criteria. This is something in which Steele Environment Solutions/GeoRoc staff has experience in, and we put an overview for the commission in an Appendix of our original submission.

overpack. This is why the Swedish model is using copper encapsulation and alternatively the US Yucca Mountain project specified stainless steel canisters. For a South Australian Facility this may not be necessary as "drier" geological conditions may be feasible and alternative barrier systems are available. What it will be necessary is a test program to verify the suitability of the sites as is mentioned later in the report.

Challenges for the Supply Chain

Challenges exist for Australian companies, in particular small to medium enterprises, wishing to be involved in the project:

1. Long-term project that is decades away from being delivered.
2. A small current market in Australia.
3. Finding employees with the nuclear skill base and retaining them.
4. Uncertainty of continuity – overhangs all of the above.

If the aim of the South Australian Government is to create a new, high technology industry with the accompanying jobs and increase in economic activity it brings then the private sector must be involved. Given the lack of a private nuclear sector in Australia this would of necessity involve the partnering of local companies with international nuclear engineering companies. This is the model Steele Environment Solutions is taking with the projects it is considering.

This competition is not only a competition for individuals, but also a competition to attract companies with experience and expertise to a project.

Competition for Resources

The **competition for resources** poses a challenge for establishing a nuclear industry in South Australia. Is the market sufficiently large and the profitability such that companies will be interested in investing? As an example, the UK nuclear clean-up program is typically between $3-5 billion per year and dominated by a Government market under the Nuclear Decommissioning Authority. Even at this level, several speakers at the 2011 Nuclear Decommissioning Conference said that the market was too small, and too regulated to attract and support a large competitive industry base compared to other fields[10]. A similar warning, largely driven by the higher commercial risk in the nuclear cleanup industry compared to other investment options, was given by industry heads about the US Department Energy Clean-up program, at the recent Waste Management 2015 conference. Thus there is internal competition within companies. Furthermore, being Government funded the market is prone to budget and this can threaten the continuity in the supply chain[11]. The key to getting the right skills into the marketplaces will be projects with a consistency of funding over a long period. This will require a change in thinking about Government contracting methodology.

A collaborative approach to project delivery involving consortia or alliance type structures will likely be necessary for success and mechanisms to allow this need to be in place. One of the

[10]H. Lal, "Current and Future Funding - the effect on the UK Nuclear Decommissioning Industry", *Nuclear Decommissioning Conference,* April 5-6, 2011, Manchester, UK.
[11] . Wheeler and T. Jones, "Ensure Continuity in the Supply Chain", *Nuclear Decommissioning Conference*, April 5-6, 2011, Manchester, UK.

key changes to the relationships in the supply chain that is starting to occur in international radioactive waste management and legacy clean-up projects, is the change in the delivery models from transactional basis to a partnership basis. Much of this is driven by the length of the projects (many years to decades) and uncertainty/unknowns in such projects that makes it difficult to define the scope and specifications to a level that is suitable for a purely transactional model. Similar challenges will be faced in South Australia. Public-private partnerships and partnerships between prime contractors and sub-contractors are critical in bringing the resources and skills to a project and meeting the challenges that occur in nuclear projects. This is particularly so when delivering complex or first-of-a-kind projects. A model we think shows this shift to strategic partnership from a transactional model changes relationships was given by White[12] (Figure 1). It has been our experience that the most successful projects have been those in which the customer and supplier act as partners to deliver the desired outcome.

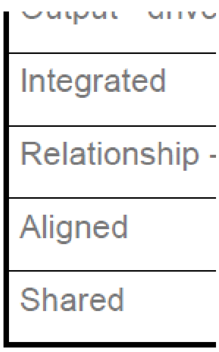

Figure 1: The difference between the new strategic partnership based model (left) and the traditional transactional model (right) taken from White.

Steele Environment Solutions has invested a considerable amount of time, effort and money in attempting to undertake collaborative nuclear projects in Australia. Unfortunately, no projects have been obtained from the efforts. As a consequence we have shifted our emphasis to international opportunities and opportunities outside the nuclear area. However, we would still like to invest in nuclear opportunities within South Australia should the conditions and opportunities arise.

Starting Point for a Supply Chain

If a nuclear industry is to be established in South Australia then it requires the development of a commercial supply chain. The model of establishing a purely government owned body to

[12] S, White, "Partnering in the Decommissioning Market", *Nuclear Decommissioning Conference*, April 5-6, 2011, Manchester, UK.

undertake the work would limit opportunities for private investment, stifle innovation and place an unnecessary burden on the taxpayer. Currently opportunities in the radioactive waste treatment market are limited and largely closed to commercial investment. However, there are current activities undertaken by government bodies that could be transferred to private operations. This would assist in starting the building of a private nuclear market in South Australia beyond the uranium mining area.

One way to achieve this would be to restructure the operations of Australian Government nuclear bodies by contracting-out secondary, non-research, activities that private industry readily undertakes. For example, ANSTO is a national scientific laboratory, but currently undertakes in-house waste management, nuclear engineering and other activities that could more effectively and efficiently be undertaken by private industry, with its much lower overhead costs than ANSTO, as is the case in many international jurisdictions.

Currently ANSTO is proposing to spend $70-100 million to build a facility to treat only one of the wastes arising from Mo-99 production, where the other wastes will need additional process lines to treat them. This line was supposed to be completed by 2015[13], but is now likely to be delayed by a further 3-4 years. A potentially better option for the Nation would be to establish a multi-mission waste treatment plant close to the store/repository that is capable of handling a wider variety of wastes, including those emanating from activities at ANSTO. Such a plant would be of interest to international and local investors and would provide a firm basis for establishing a local supply chain.

As detailed in previous reviews[14,15] there are also medical, industrial and mining wastes that such a waste facility could accommodate.

Note: that the hazards from nuclear/radioactive wastes include not only radioisotopes, but also include chemotoxic elements, with some waste containing elements such as mercury, cadmium and heavy metals. These wastes are typically referred to as mixed wastes. The technology developed to treat radioactive wastes may also be applicable to toxic wastes, thus broadening the scope for private investment.

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[13] C. K. W. Cheung, E. R. Vance, M. W. A. Stewart, D. R. M. Brew, W. Bermudez, T. Eddowes and S. Moricca, "The Intermediate Level Liquid Molybdenum-99 Waste Treatment Process at the Australian Nuclear Science and Technology Organisation", ATALANTE 2012 – Nuclear Chemistry For Sustainable Fuel Cycles, Procedia Chem., **7,** 548 (2012).

[14] Parliament of the Commonwealth of Australia, *No Time to Waste – Report to the Senate on the dangers of radioactive Waste*, April 1996.

[15] Dept. of Industry and Science, "Radioactive Waste in Australia", http://www.radioactivewaste.gov.au/radioactive-waste-australia/australias-radioactive-waste