LAB-AT-RIG®
CASE STUDY

1

BOX 1 EXECUTIVE SUMMARY

Key findings

The Lab-at-Rig® (LAR) project is well advanced (commercialisation agreement signed in 2015 for LAR '*Version 1*') with the following outputs:

— The project demonstrated that it was possible to efficiently prepare samples from the produced powders at the drill site that could be used in multiple analytical techniques and that samples provided information on a par with that derived from traditional core sampling techniques. This provided the proof of concept needed to secure funding and commitments towards a commercialisation strategy.
— LAR '*version 1*' was successfully deployed and tested. This clearly demonstrated that the technology was 'fit for purpose' and potentially offered advantages to industry and paved the way for commercialising the technology,
— The technology was licenced to Imdex in 2015
— The opportunity to create the next generations of LAR has been demonstrated

The LAR system could be adopted as the industry standard. This would deliver significant royalty revenues back to CSIRO and may also provide new research opportunities through the potential to incorporate other sensing technologies within LAR units.

The cost-benefit analysis is strongly positive – the present value of R&D and commercialisation costs is $32.8 million (2018 dollars, 7 per cent discount rate) while benefits are $578.8 million. The NPV of the project is estimated at $546.0 million giving a benefit-cost ratio of 17.63.

Innovation impact

The technology should enable faster characterisation of Australia's mineral resource base. Anticipated innovation impacts include increased productivity and profitability of the Australian (and global) resources sector as a result of reduced exploration timeframes. There is also a potential flow-through to increased government taxation and royalty revenues.

This case study uses the evaluation framework outlined in the CSIRO Impact Evaluation Guide. The results of applying that framework to the Lab-at-Rig® (LAR) project are summarised in Figure 1.

FIGURE 1.1 LAB-AT-RIG® CASE STUDY – IMPACT FRAMEWORK DIAGRAM

INPUTS	ACTIVITIES	OUTPUTS	OUTCOMES	IMPACTS
– Support from internal and external sources totalling some $14.8 million (CSIRO contribution of $2.67 million) – Background and Pre-existing IP	– Research and assessment of sampling techniques – Design/build LAR '*version 1*' – Testing at Brukunga drill site – Research to facilitate development of LAR '*version 2*' – Research into LAR coiled drilling application	– LAR sampling and analytical protocols – Design/development of LAR instrumentation – LAR systems designed and tested – Successful deployment and testing of LAR '*version 1*' – LAR development advanced – publications; 2 patents; 1 award – Commercialisation agreement/plans	– Trials of the technology in collaboration with Geoscience Australia, Geological Survey of Victoria, Anglo American, GSSA, Kingston, Minotaur, and DET CRC – Partnership with Barrick Gold to trial and further develop LAR – Commercialisation being fast-tracked	– Significant industry wide savings to exploration budgets – Reduced exploration risk and time savings – Acceleration of discovery to development timing – Environmental benefits - reduced exploration footprint and impact – Enhanced exploration firms' social licence to operate

SOURCE: ACIL ALLEN

1.1 Purpose and audience for case study

This case study describes the economic, environmental and social benefits arising from the Lab-at-Rig® (LAR) project.

This evaluation is being undertaken to assess (to a range of stakeholders) the positive impacts arising from the LAR project undertaken by CSIRO. This case study can be read as a standalone report or aggregated with other case studies to substantiate the impact and value of the Mineral Resources Business Unit's activities, as a whole, relative to the funds invested in these activities.

This information in this case study is provided for accountability, communication and continual improvement purposes. Audiences for this report may include Members of Parliament, Government Departments, CSIRO and the general public.

1.2 Background

Mining and exploration companies have not been able to access real time information about the mineralogy and chemistry in the drill-hole using traditional coring and sampling methods. The current core testing process can take as long as six months and involves considerable expenditure. The current approach involves:

— setting up the drill sites
— drilling a series of holes
— extracting cores
— sampling and logging the drill cores
— sending the cores to an offsite laboratory
— analysis of the core and data entry into a database at the lab
— delivering the results of the analysis back to the drilling company.

The Lab-at-Rig® (LAR) project sought to develop technology featuring automated analysis of mineralogy and geochemistry of drill-hole cuttings direct from the drill site (i.e. analysis of the cuttings separated from the drilling fluid as it comes to the surface), while still offering the appropriate sampling methods and quality control processes that are currently provided. With access to real time information about the mineralogy and chemistry in the drill-hole, companies can effectively and efficiently plan what to do next; whether that is to drill deeper, drill further holes, try elsewhere or to stop. LAR will lead to improved decision making and productivity for mineral resource operations, with the potential to deliver massive cost savings in drilling, exploration and overall mining operations.

CSIRO developed the LAR technology in partnership with Imdex Limited and Olympus Australia, under the Deep Exploration Technologies Cooperative Research Centre (DET CRC). The technology enables chemistry and mineralogy of rocks found within a drill hole to be analysed within minutes of drilling - LAR offers a one-hour cycle for the whole process enabling rapid decision making and cost savings.

The LAR system, fitted to a diamond drill rig, and Imdex's AMC™[1] Solids Removal Unit includes:

— a sample preparation unit that collects solids from drill cuttings and dries them
— Olympus X-ray fluorescence and X-ray diffraction sensors to provide chemistry and mineralogy of the sample respectively
— the ability to upload data to REFLEX's™[2] cloud-based platform where it can be analysed and the results provided back to the explorer.

Following the success of the technology development phase, CSIRO partnered with Imdex, Olympus, the University of Adelaide, (UofA), Curtin University and the University of South Australia (UniSA) to work on the $10.8 million collaborative DET CRC LAR Futures Project to deliver research for the '*next generation system*' of LAR, particularly adapting LAR to coiled tubing (CT) drilling platforms. The system will provide: new sensor technologies, improved data analysis and processing for decision making, and be

[1] AMC™ is an Imdex brand providing and seeking to improve on the way drilling fluids, equipment and technology are used – seeking to ensure the execution of drilling programs are to specification, delivered on time, within budget and safely.
[2] REFLEX™ is a leading Imdex brand providing real-time subsurface intelligence solutions for the global minerals industry. The brand's technologies include downhole instrumentation, data management and analytical software for geological modelling.

developed for new applications and drilling platforms. REFLEX™, a business unit in the ASX-listed Imdex Group of Companies, is the commercialisation partner for the technology.

These activities are discussed in more detail in Section 1.3.2.

1.3 Impact Pathway

1.3.1 Project inputs

The total cost for the LAR project was $14.8 million in cash and in-kind contributions (see **Table 1.1** and **Table 1.2**). CSIRO contributed $2.67 million in in-kind and cash contributions, primarily in the form of researcher salaries (approximately 18.0 per cent of the total project cost). Other contributors were DET CRC, Curtin University, Imdex, Olympus, UofA and UniSA. The project was executed in three stages between May 2012 and February 2018, with some partial overlapping in the timing and different partners being engaged at different times. Each stage had its own specific '*Project Agreement*'.

TABLE 1.1 CONTRIBUTIONS TO LAB AT RIG® PROJECT BY STAGE

Phase	Timeframes	Funding contributions ($)	Participants
Stage 1 - Proof of concept	May 2012 – April 2014	$578,810	DET CRC; CSIRO; Curtin
Stage 2 – Technology readiness and commercialisation	July 2013 – Dec 2014	$3,125,500	DET CRC; CSIRO; Imdex; Olympus
Stage 3 – Next generations of LAR	Dec 2013 – Feb 2018	$11,085,083	DET CRC; CSIRO; Curtin; Imdex; Olympus; UofA, UniSA
TOTAL Contributions		**$14,789,393**	

SOURCE: ACIL ALLEN – DETAILS FROM PROJECT AGREEMENT SCHEDULES, CSIRO

CSIRO and the DET CRC were the only two organisations to participate and contribute to all 3 stages of the work. DET CRC provided the bulk of the funding in the form of '*Project Funds*' i.e. cash paid to project partners to carry out tasks specified in the '*Project Agreement*' ($610,500) was internally directed towards DET CRC program leadership and software/proto-type engineering under Stage 3 funding). CSIRO provide primarily in-kind contributions (staff time commitments – full time equivalents [FTE]) with a cash injection of $250,000 during Stage 3 (2015) cash to the DET CRC to be directed towards research activities in the LAR Futures Project. Curtin, the UofA and the UniSA all provided in-kind contributions in the form of FTEs covering researcher, program leader and technical support staff (in effect these FTEs represented matching funding to that provided by DET CRC). Imdex and Olympus came on board as the project moved towards commercialisation (Stage 2) – both companies contributed a combination of staff FTEs and equipment/systems to the project.

TABLE 1.2 SUPPORT FOR THE LAB-AT-RIG® PROJECT

Contributor/type of support/stage	2012 ($)	2013 ($)	2014 ($)	2015 ($)	2016 ($)	2017 ($)	TOTAL($)
Cash							
DET CRC – Stage 1	143,000	145,520					288,520
DET CRC – Stage 2		725,000	275,000				1,000,000
DET CRC – Stage 3 (payments to parties)			650,000	899,000	796,083	503,750	2,848,833
DET CRC – Stage 3 (self-funding)			200,000	260,000	150,500	-	610,500
							$4,747,853
CSIRO – Stage 3 (payment to DET CRC)				250,000			**$250,000**
Total cash	**$143,000**	**$870,520**	**$1,125,000**	**$1,409,000**	**$946,583**	**$503,750**	**$4,997,853**

Contributor/type of support/stage	2012 ($)	2013 ($)	2014 ($)	2015 ($)	2016 ($)	2017 ($)	TOTAL($)
In-kind							
CSIRO – Stage 1	126,000	129,780					255,780
CSIRO – Stage 2		298,000	140,000				438,000
CSIRO – Stage 3			354,000	460,000	552,000	359,000	1,725,000
							$2,418,780
Curtin University – Stage 1	17,000	17,510					34,510
Curtin University – Stage 2		-	-				-
Curtin University – Stage 3			-	22,000	22,000	-	44,000
							$78,510
Imdex – Stage 1	-	-					**-**
Imdex – Stage 2		476,000	238,000				714,000
Imdex – Stage 3			250,000	519,000	616,000	616,000	2,001,000
							$2,715,000
Olympus – Stage 1	-	-					-
Olympus – Stage 2		649,000	324,500				973,500
Olympus – Stage 3			191,000	303,000	303,000	303,000	1,100,000
							$2,073,500
University of Adelaide – Stage 1	-	-					-
University of Adelaide – Stage 2		-	-				-
University of Adelaide – Stage 3			842,000	691,000	308,750	-	1,841,750
							$1,841,750
University of SA – Stage 1	-	-					**-**
University of SA – Stage 2	-	-					-
University of SA – Stage 3			-	-	84,000	580,000	664,000
							664,000
Total In kind support	**143,000**	**$1,570,290**	**$2,339,500**	**$1,995,000**	**$1,885,750**	**$1,858,000**	**$9,791,540**
GRAND TOTAL OF SUPPORT PER YEAR	***$286,000***	***$2,440,810***	***$3,464,500***	***$3,404,000***	***$2,832,333***	***$2,361,750***	***$14,789,393***

SOURCE: ACIL ALLEN – DETAILS FROM PROJECT AGREEMENT SCHEDULES; CSIRO

All parties contributed both Background and Pre-existing intellectual property (IP) to the project. However, neither Background IP nor Pre-existing Project IP was considered to be of intrinsic '*contribution*' value and, therefore, its value is not included in the above contributions (and as such, neither Background IP or Pre-existing Project IP value is taken into account under any revenue sharing arrangements relating to commercialisation of project IP).

1.3.2 Project activities

LAR has been developed in two distinct stages and has been enhanced during the third stage – each with its specific project agreement. Activities undertaken at each stage are outlined below.

Stage 1 - Proof of concept - *Lab-on-the-Rig for Coiled Tubing Greenfields Rig Project Agreement*

The aim of Stage 1 was to characterise physical, chemical and mineralogical properties of rock powders produced by a greenfields rig and determine optimised sample preparation and analytical techniques. A key objective was to test whether these powders were indicative of the rock being drilled through at the time and determine how the sample compared with conventional core samples across a range of analytical techniques.

Work also focused on assessing what techniques could be applied (or needed to be developed) to measure key rock characteristics at the drill site. In particular, it explored whether it was possible to efficiently prepare a standardised sample from the produced powders at the well site that could be used in multiple analytical techniques.

Stage 2 - Technology readiness and commercialisation - *Lab-At-Rig Version 1: Design, Engineering & Build Project Agreement*

Stage 2 was a natural evolution from the outcomes of the Proof of Concept work, aiming to deliver a unit (that could be commercialised) which could:

— dry well head rock powder material and extract a '*fit for purpose*' representative sample
— deliver this sample to an automated loading system
— measure and deliver quantitative mineralogy for ~20 key exploration relevant minerals
— measure and deliver quantitative chemistry with a focus on trace elements and pathfinders
— measurement to be performed within 10 minutes of sample preparation
— deliver QA/QC'ed mineralogy and geochemistry data with downhole depth information (from drill rig) to a database system
— perform simple analytics on the data (i.e. automated-lithogeochemistry) utilising the ioGAS-like data platform
— deliver the data in report format that can aid decision making in real time.

The objective of the project was to build and design a LAR '*version 1*' system as a ruggedized, engineered, turnkey solution. Success would be measured by:

— deployment of the LAR equipment and logging of a drill hole at the DET CRC Brukunga site
— development of a successful commercialisation plan.

The project was a collaboration between Imdex (which had two established brands [Reflex and AMC] in the field of drilling control technologies), Olympus (which manufactures and sells portable x-ray diffraction and x-ray fluorescence sensors) and CSIRO through a mix of DET CRC cash; personnel and hardware, in-kind and contracted operating expenditure. Olympus supplied the sensors used for this stage and Imdex the drilling systems and sampling expertise.

The project consisted of sampling the particles produced when carrying out diamond drilling (ie drilling with diamond tipped drills), drying the samples and then testing them with the portable sensors supplied by Olympus. The project consisted of six key modules needed to deliver the end goal as defined in the proof-of-concept study and the project – i.e. a LAR '*version 1*' system as a prototype for commercialisation:

— **collar capture system to integrate with Imdex's existing Solids Recovery Unit** (Imdex) – to remove sampling bias
— **X-ray Fluorescence (XRF) and X-ray Diffraction(XRD) sensor system for LAR** (Olympus) – a new purpose-built unit
— **Sample Handling System and integration with solids recovery unit** (Imdex, CSIRO and DET CRC) – engineering to seamlessly link the two units
— **automated mineralogy algorithm for XRD analysis** (CSIRO; Olympus) – to address difficulties in processing the XRD spectra which is often manual and time consuming
— **data management and analysis for decision support** (CSIRO; Imdex) – improve LAR functionality through integration of Imdex drilling information capture systems
— **LAR enclosure and control system; integration with drilling platform** (DET CRC) – to be interfaced to the drilling team to receive information from the drill rig while delivering simple start/stop functionality.

The final phase of the Stage 2 project tested deployment of the LAR system to the Brukunga drill testing and training facility to demonstrate real world application. As part of this phase of the project Imdex also ran field tests of the system in case studies were the Imdex Solids Recovery Unit was currently deployed. This allowed evaluation of the sampling, analytical and sampling precision estimates in several different application areas (i.e. copper, gold, nickel). LAR was offered for commercialisation at the end of this Stage and was licenced to Imdex in 2015. Since then, the company has been developing the prototype into a commercial product.

Stage 3 – Next generations of LAR - *Lab-at-Rig® Futures Project Agreement*

The Lab-at-Rig® Futures project sought to enhance the equipment/systems (developed during Stage 2) and develop the next generations of LAR to a technology readiness level that would support commercialisation and uptake by drilling companies. Stage 3 had two key focus areas:

— a pipeline of research informed by a roadmap that will develop future LAR versions with new sensors, algorithms and data support; including a prototype LAR Laser Induced Breakdown Spectroscopy (LIBS) enhanced version
— the adaptation of the LAR to work with coiled tubing (CT) drilling and possibly other drilling platforms (in addition to diamond drilling technology – addressed at Stage 2) to deliver a technical prototype LAR for Coiled Tubing drilling.

The LAR Futures project was conducted over four years using a staged approach to align with parallel activities and timeframes within the DET CRC (CT drilling development, rig monitoring, downhole tools) and the development, build and commercialisation of LAR '*version 1*'. The project identified seven modules where the technology required additional research, namely:

— **Future Sensors: Roadmap, Development and Deployment -** focused on other sensor systems and their potential use in powder characterisation for geological applications. This research was supported by the preparation of a 10-year roadmap completed within the first 12 months of the project that maps out sensor technology development with respect to application in the geosciences. The research fed into a phase of testing, development and deployment appropriate to the LAR project.
— **Assessing, Testing and Deploying LIBS for light elements -** a priority next generation sensor in the LAR system. This was a priority given the potential to deliver light element analyses currently difficult or impossible with air-based XRF systems. The aim was to add LIBS as a module into a prototype LAR '*version 2*'.
— **Advanced Level '0' Algorithms for LAR Sensors** – to build on pre-existing expertise to improve the application of the modelling of XRF and XRD sensor signals for improved automated outputs.
— **Data to Knowledge -** to deliver the underpinning geological outputs defined in Stage 1 (and more broadly) as automated processes within the data-rich LAR system.
— **Towards LAR-Fluids -** to provide real time analysis of drilling fluids and provide feedback information about drilling muds, cover/rock geochemistry and drilling optimisation information.
— **Adaption of the LAR to the CT Drilling platform** – applying the methodology developed and refine at Stage 1 to the study of the material produced during CT drilling including the full characterisation of the material to show that it is a representative sample of the rock mass.
— **Proof-Of-Concept & Engineering the LAR-CT** – including technical planning for the engineering modification and underpinning science for LAR to work with the next generation drilling platform.

1.3.3 Project outputs

Project outputs for each stage are summarised below.

Stage 1 - Proof of concept

The final report from the Stage 1 research made recommendations for sampling and analytical protocols and design of lab on the rig instrumentation with specific application for rock powder samples produced at the well-head. The project clearly demonstrated that it was possible to efficiently prepare samples from the produced powders at the well site that could be used in multiple analytical techniques and that samples provided information on a par with that derived from traditional core sampling techniques.

The results of this work by CSIRO and Curtin University provided the proof of concept needed to secure funding for the next stage of the program and commitments towards a commercialisation strategy.

Stage 2 – Technology readiness and commercialisation

Stage 2 outputs included the design, delivery and testing of a prototype sample handling system and a sensor system – both of which were essential to enabling LAR to perform to industry expectations. An automated mineralogical algorithm was developed and demonstrated on DET CRC Brukunga data and LAR '*version 1*' decision support algorithms were defined with consultation with industry partners. Successful operation of both data handling and management systems and the decision support algorithm were demonstrated using DET CRC Brukunga data.

A patent for the LAR technology was developed and submitted.

Deployment and testing of the LAR '*version 1*' at Brukunga was successfully demonstrated. The results from Stage 2 were very positive – best summed up by James Cleverley (Imdex) who referred to LAR as "*Probably be the most disruptive technology for the* *mining industry for the next five years.*" LAR '*version 1*' paved the way towards commercialisation, clearly demonstrating that the technology was 'fit for purpose' and potentially offered advantages to industry.

The technology was offered for commercialisation and licenced to Imdex in 2015.

Stage 3 – Next generations of LAR

The research conducted in relation to each of the seven modules sought to pre-empt issues that would prevent the technology's further commercialisation and provide an early indication on what additional investments are needed to enhance the LAR technology and take to market. A technology development plan for LAR-Fluids with clear commercialisation pathways has been prepared. The research has also expanded the application of the LAR's technology to CT drilling with the delivery of proof-of-concept and development of a LAR-CT technical prototype (i.e. engineering design) to enable commercialisation with Imdex as an appropriate partner having the full licence to LAR.

Publications

There are three publications associated with the LAR project in peer reviewed journals:

— Uvarova, Y., Gazley, M., Cleverley, J., Baensch, A., Lawie, D., and leGras, M. (2016*): Representative, high-spatial resolution geochemistry from diamond drill fines (powders): An example from Brukunga, Adelaide, South Australia*. Journal of Geochemical Exploration. 170, 1-9.

— Hillis R.R., Giles D., van der Wielen S.E., Baensch A, Cleverley J.S., Fabris A., Halley S.W., Harris B.D., Hill S.M., Kanck P.A., Kepic A., Soe S.P., Stewart G., and Uvarova Y. (2014): *Coiled tubing drilling and real-time sensing – enabling prospecting drilling in the 21st century?* Economic Geology, Special Publication 18, 243-259.

— Uvarova Y.A., Cleverley J.C., Baensch A. and Verrall M. (2014): *Coupled XRF and XRD analyses for rapid and low-cost characterization of geological materials in the mineral exploration and mining industry*. EXPLORE Newsletter for the Association of Applied Geochemists, 162, 1-14.

The project has also produced a large number of technical reports. However these will remain commercial-in-confidence until June 2018.

Patents

There are two patents associated with the LAR project:

— Autonomous Sampling and Analysis System and Method for use in Exploration Drilling

— Drying Apparatus and Related Method.

Awards

The Sample Handling Sensor System developed within the Lab-at-Rig® project, won the Best Technology Prize at the DET CRC Annual Conference in 2014.

Innovation/commercialisation

A commercialisation agreement between CSIRO, Olympus, Imdex and DET CRC was signed in 2015. The agreement is set out in **Table 1.3**.

TABLE 1.3 COMMERCIALISATION AGREEMENT

Party	Share of royalties
CSIRO	20 per cent
DET CRC	20 per cent
Imdex	30 per cent
Olympus	30 per cent
Assay While Drilling (REFLEX business unit)	1.25% of profit

SOURCE: ACIL ALLEN

Imdex is seeking to move the LAR project forward over the next year. Imdex has a good understanding of what the market wants and has developed a five-year business plan to meet that need. A decision has been taken to commercialise the technology early to ensure that it was not left on the shelf.

1.3.4 Project Outcomes

Imdex is currently working in partnership with Barrick Gold[3] in Nevada to trial and further develop the technology. Barrick Gold has contributed $1 million to help accelerate the commercialisation (this will be recouped through lower costs when the technology is at commercial readiness level and is offered as a service - with no loss of IP). Barrick is using the technology at its Windfall Lake site for six months (Feb – July 2018).

To move to full commercial production, Imdex estimates:

— additional expenditure of $2.5 million on non-recurring engineering work leading to LAR launch and (investment) recovery would be needed for the first year
— there might be a need to spend a further $15 million over the next 2 to 3 years to develop a fully automated commercial product and bring the technology to market.

The project has delivered impressive results including:

— the rapid availability of data that can inform decision making to stop or reduce drilling (the ability to '*fail fast*') thus saving time and money
— being able to spend drilling funds more efficiently through earlier and faster decision making allowing for more strategically focused drilling programs
— the delivery of more drill holes/wells for the same amount of money - Imdex estimates that LAR could save around $1 million from a $5 million four-hole drilling program.

The initial target market is early adopter (innovative) mid cap mining companies. This will be followed by larger companies. Imdex believes that junior explorers are unlikely to use the LAR technology.

The commercial partners foresee considerable benefit in getting LAR to market through the lease of LAR units to drilling companies.

1.3.5 Adoption

There are no other comparable technologies on the market. There are other competitors including existing laboratories, on-site core scanning laboratories (although the cost to set up an onsite laboratory is considerably higher and turn-around times slower than LAR offers) and other screening technologies.

While LAR is unique, it will not fully replace laboratory testing of all samples - there will always be a need for off-site commercial laboratories to undertake more detailed examination of samples. However, Imdex believes that virtually all decisions can be taken utilising just the data available from XRF and XRD testing.

There is opportunity for LAR to evolve and grow with the potential to incorporate other sensing technologies (should they emerge in the future) - Imdex would look to CSIRO to carry out any R&D required for this purpose.

1.3.6 Impacts

The availability of a fully automated commercial LAR system is still some years off, and so the benefits are yet to be realised. However, the impact on and benefits to the broader exploration industry which uses diamond drilling techniques are relatively clear (and are highly likely to also apply to coil drilling techniques).

Industry impacts/benefits

— **Drill hole savings** – LAR allows an exploration company to '*fail faster*'. For example, a typical number of drill holes on a tenement is five. LAR provides real time feedback on the sample and its potential which enables the exploration company to decide early whether to drill the fourth or fifth well. This allows the company to either move on more quickly to explore a new tenement or rapidly move to mining the tenement in question. Given most exploration companies have fixed exploration budgets, the LAR technology facilitates the more effective and efficient use of their fixed exploration budget. It will effectively reduce exploration risk.

[3] Barrick Gold Corporation is a major global gold mining company – its Nevada operation is a world class integrated gold mining operation, with 3,000 employees and 800 contractors, utilising both open pit and underground mining methods, and hosts a range of processing facilities.

  - This benefit could in principle allow mining companies to increase their discovery rates without increasing their exploration budgets. While this is potentially a very significant benefit, it is difficult to accurately quantify and attribute to CSIRO or the LAR research program – at least until it can be tested as part of more widespread deployment of the technology.
- **Time savings -** Most sample testing results take 3-6 months to be returned from an off-site laboratory. There is evidence (from Canada) that this is a major concern and that the time delays are slowing the exploration and development of key mining areas. Time delays also add to the cost burden – using off site laboratory analysis may result in the exploration company dismantling/mothballing the rig while waiting for samples to be analysed and then having to reassemble it once positive results become available.

Environmental impacts/benefits

- Widespread deployment of the LAR technology will deliver environmental benefits including a reduction in:
  - the number of drill holes – leading to a reduced exploration footprint
  - transport emissions associated with taking samples to and from laboratories or having to return to a drill site/re-enter a well months after the initial core was taken
  - the volume of chemicals used to test samples.
- These environmental benefits are expected to help drilling companies obtain and maintain their social licence to operate.

1.4 Clarifying the Impacts

1.4.1 Counterfactual

There are no other research groups in Australia or elsewhere undertaking research/technology development of this kind. The LAR technology would not exist without the research and development efforts of CSIRO and the other project partners.

1.4.2 Attribution

CSIRO and Imdex believe that the benefits from the research should be examined/valued at a whole-of-program level and not from an individual project level – as the benefits from one project accrue to the next project. The project partners consider the commercialisation agreement to be a good proxy for allocating benefits from the research to CSIRO and other partners. Based on this, ACIL Allen has used the commercialisation agreement as the basis for attributing 20 per cent of the benefits to CSIRO.

1.5 Evaluating the Impacts

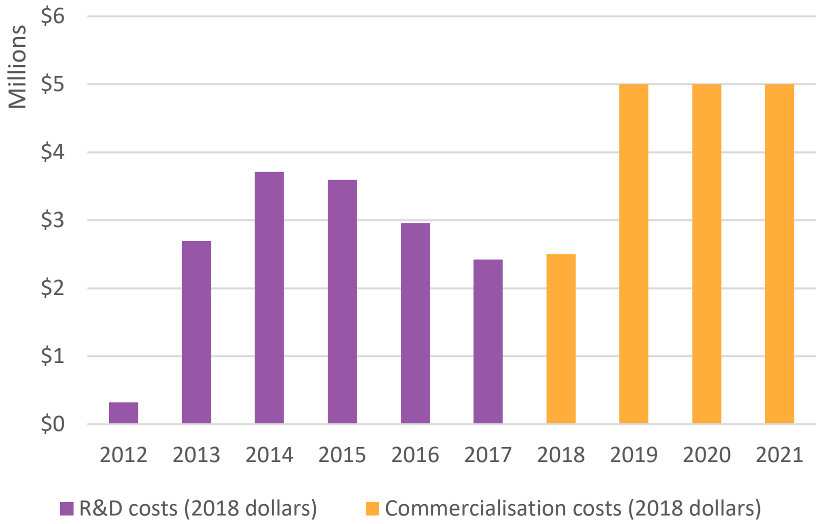
1.5.1 Cost-Benefit Analysis

Costs

As shown previously in **Table 1.2**, the total R&D costs of the LAR project (incurred from between and 2017) are $14,789,393 (in nominal terms, equivalent to $15.38 million in 2018 dollars). Commercialisation costs (in 2018 dollars) are projected to be $2.5 million in 2018, $5.0 million in 2019, $5.0 million in 2020 and $5.0 million in 2021.

The R&D and commercialisation costs from 2012 to 2021 in 2018 dollars are shown in **Figure 1.2**.

Figure 1.2 - R&D and commercialisation costs of the Lab-at-Rig® project, 2012 to 2021 (2018 dollars)



SOURCE: CSIRO

Manufacturing costs are assumed to be $250,000 per unit in 2018 dollars.

Benefits

Direct benefits to the commercialisation partners are difficult to calculate given that the commercialisation period extends to 2021 before formal sales are expected to begin in 2022 (see Section 1.3.4). ACIL Allen has estimated the benefits of the LAR project based on the projected revenues that it will generate from 2022 onwards. This is a conservative estimate of benefits as the lessees of the equipment will likely receive benefits in excess of the leasing price (otherwise they would not lease the equipment).

ACIL Allen has applied the following assumptions to develop an estimate of the benefits:

— first sales/lease of units by Imdex occur in 2022 with lease payments of $2,000 per day in 2018 dollars while the units are on-site

— rig utilisation rates of approximately 50 per cent (thus lease payments are expected to be made for 50 per cent of the year)

— there are some 5,000 to 6,000 diamond drill rigs operating worldwide - approximately 75 per cent of these are above ground rigs which could potentially use the technology

— an uptake rate of 220 units in year one (2022) with annual growth of an additional 5 per cent of market share (implying *new* leases of 220 units in 2022 and 206 units in each year thereafter)

— that the useful life of the equipment is conservatively assumed to be 3 years

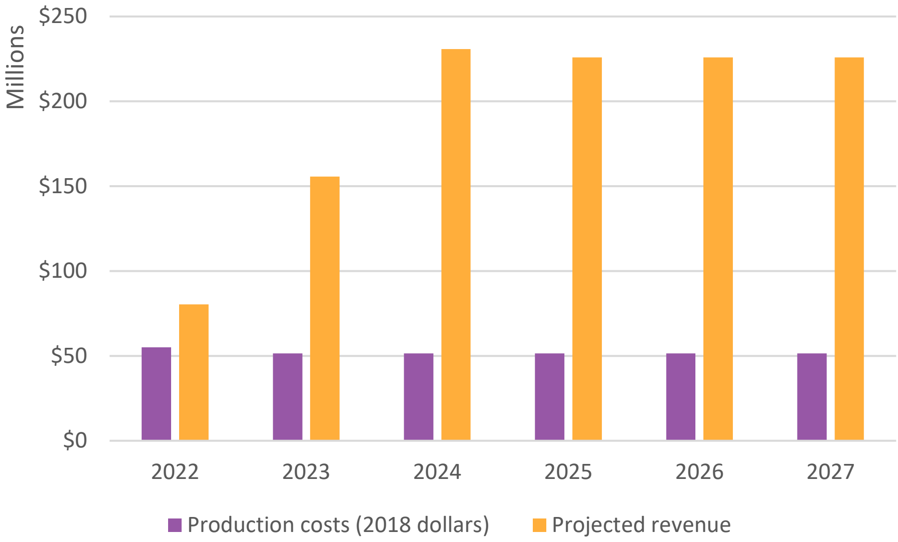
— that the benefits end in 2027 as we assume that a similar product would have been developed at that time if CSIRO had not participated in the Lab-at-Rig project

— that royalties are 3 per cent of revenues (of which 30 per cent are paid to a non-Australian company, Olympus)

— in addition to the royalties paid to Olympus, it is conservatively assumed that a portion of revenues equal to 50 per cent of manufacturing costs '*leak out*' of the Australian economy as a result of payments for foreign-sourced inputs used in the manufacturing of the equipment.

Based on the above assumptions, the projected production costs and revenues earned from lessees between 2022 and 2027 are shown in **Figure 1.3**.

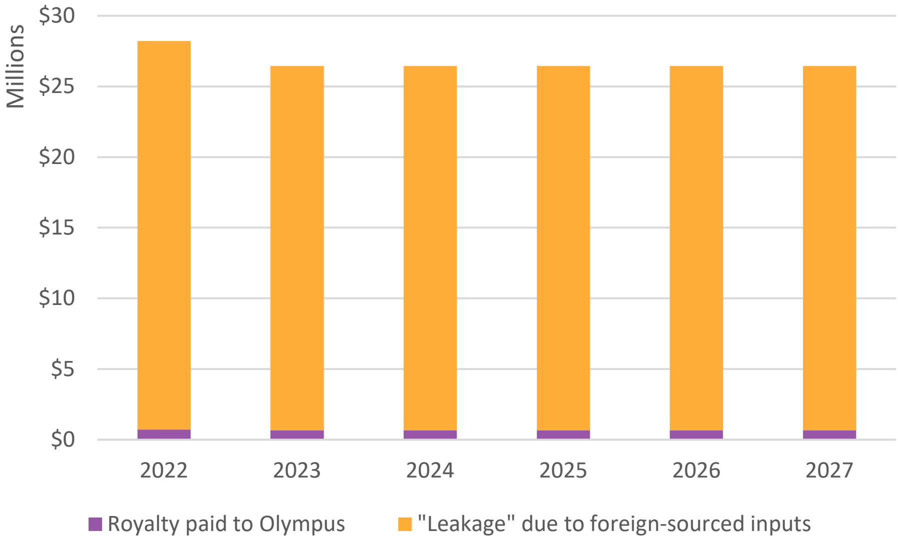
Figure 1.3 - Projected production costs and revenues, 2022 to 2027 (2018 dollars)



Source: ACIL Allen calculations

The “leakage” of revenues from the Australian economy due to the royalties paid to Olympus and the cost of foreign-sourced manufacturing inputs, between 2022 and 2027, are shown in **Figure 1.4**.

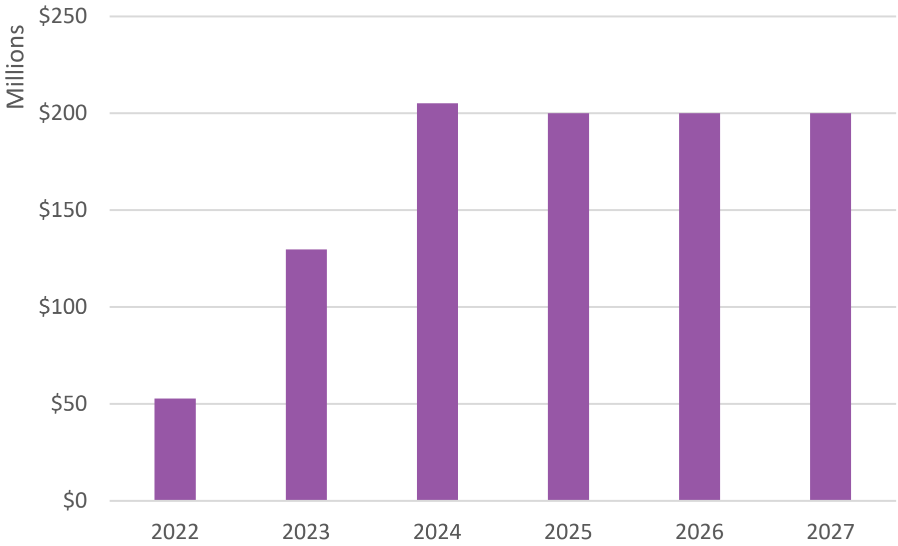
Figure 1.4 – “Leakage” out of the Australian economy due to royalties paid to Olympus and cost of foreign-sourced inputs, 2022 to 2027 (2018 dollars)



Source: ACIL Allen calculations

The resulting annual benefits to the Australian economy from the LAR project between 2022 and 2027 are shown in **Figure 1.5**. These benefits (value added to the Australian economy through the entire supply chain) encompass returns to capital (profits) and labour (wages and salaries) at Imdex as well as payments made by Imdex to Australian suppliers for Australian-sourced inputs.

Figure 1.5 – Projected annual benefits of the Lab-at-Rig® project to the Australian economy, 2022 to 2027 (2018 dollars)



Source: ACIL Allen calculations

Assessment of benefits against costs

The present value (PV) of R&D costs and commercialisation costs of the LAR project are $32.8 million in 2018 dollars under a 7 per cent real discount rate. The PV of benefits are estimated at $578.8 million in 2018 dollars under the same discount rate.

The net present value (NPV) of the project, obtained by subtracting the present value of benefits from the present value of costs, is therefore estimated at $546.0 million in 2018 dollars under a 7 per cent real discount rate. The benefit-cost ratio, obtained by dividing the present value of benefits by the present value of costs, is estimated at 17.63.

Sensitivity analysis

ACIL Allen has tested the impact of varying a number of the assumptions made to calculate the BCR for the LAR project. The results of doing so are discussed below.

In the central case of the cost-benefit analysis, it is assumed that the lease payment per day for Imdex's LAR equipment is $2,000 per day. If the lease payment is $2,500 per day, the BCR rises from 17.63 to 22.76. If the lease payment is $1,500 per day, the BCR falls to 12.50.

In the central case of the CBA, it is assumed that the production cost of the equipment is $250,000 per unit. If the production cost is $150,000 per unit, the BCR rises from 17.63 to 18.78 If the production cost is $350,000 per unit, the BCR falls to 16.47.

In the central case of the CBA, it is assumed that the gain in market share each year post-2022 is 5 per cent. If the gain is 8 per cent each year, the BCR rises from 17.63 to 25.62. If the gain is 2 per cent each year, the BCR falls to 9.63.

In the central case of the CBA, it is assumed that a portion of revenues equal to 50 per cent of manufacturing costs is "leaked out" of the Australian economy due to payment for foreign-sourced inputs. If the leakage rate is 30 per cent of manufacturing costs, the BCR rises from 17.63 to 18.78. If the leakage rate is 70 per cent of manufacturing costs, the BCR falls to 16.47.

In the central case of the CBA, it is conservatively assumed that the useful life of the equipment is 3 years. If the useful life is 5 years, the BCR increases from 17.63 to 23.96.

In the central case of the CBA, a 7 per cent real discount rate has been applied. Under a 4 per cent real discount rate, the BCR rises from 17.63 to 22.03. Under a 10 per cent real discount rate, the BCR falls to 14.13.

1.5.2 Potential future impacts

With commercialisation still some years away, LAR is far from realising its full impact. If the fully commercialised LAR system lives up to expectations and deliver results on a par with traditional laboratory core analysis it is highly likely that it will be adopted as the industry standard. This will deliver significant royalty revenues back to CSIRO and may also provide new research opportunities through the potential to incorporate other sensing technologies within LAR units.

Anticipated economic benefits relate to increasing the productivity and profitability of the Australian (and global) resources sector and more fully realising the economic value of its resources through reduced exploration timeframes – with potential flow-through to increased government taxation and royalty revenues. It should enable faster characterisation of Australia's mineral resource base.

Imdex aims to bring the LAR technology to market within three years. The cost-benefit analysis anticipates that approximately 840 units will be deployed by the end of 2025.

1.5.3 Distribution effects on users

Industry users of the LAR technology will realise significant gains in productivity (and in some cases their profitability). LAR will facilitate the more effective and efficient use of fixed exploration budgets and allow companies to stretch their budgets further - it will reduce exploration risk. It will enable mining companies to increase their discovery rates for the same expenditure and significantly close the gap between discovery and production start-up.

1.5.4 Externalities or other flow-on effects on non-users

Positive externalities will accrue to the broader community in the form of environmental benefits derived from a reduction in the exploration footprint, a reduction in greenhouse gas emissions and a reduction in the volume of chemicals used in exploration processes and sample analysis.