TRACTUUM

# ULTRAFINE+® IMPACT ASSESSMENT

Source: CSIRO

May 2023

| Date | Role | Name |
|---|---|---|
| May 2023 | Author | Harmeet Kaur, Tractuum |
| | Final Approval | Sandra Occhipinti, CSIRO |
| | Reviewers | George Rivers, Rivers Economic Consulting |
| | | Anna Petts, SA Govt |
| | | Brad Whisson, LabWest |
| | | Darren Holden, GeoSpy |
| | | Dean Tuck, Dreadnought |
| | | Anicia Henne, CSIRO |
| | | Ryan Noble, CSIRO |
| | | Fang Huang, CSIRO |

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# Glossary

| | |
|---|---|
| **AC** | Air Core |
| **AGES** | Annual Geoscience Exploration Seminar |
| **BD** | Business Development |
| **BAU** | Business as usual |
| **BU** | Business Unit |
| **CBA** | Cost Benefit Analysis |
| **CPI** | Consumer Price Index |
| **CRCs** | Cooperative research centres |
| **CSIRO** | Commonwealth Scientific and Industrial Research Organisation |
| **DEM** | Department for Energy and Mining |
| **FTIR** | Fourier transform infrared |
| **FTE** | Full Time Employee |
| **ICP-OES** | Inductively coupled plasma-optical emission spectroscopy |
| **ICP-MS** | Inductively coupled plasma mass spectrometry |
| **IP** | Intellectual Property |
| **IRL** | Investment Readiness Level |
| **ML** | Machine Learning |
| **NIRS** | Near-infrared spectroscopy |
| **PV** | Present Value |
| **R&D** | Research and Development |
| **RC** | Reverse Circulation |
| **SLO** | Social Licence to Operate |
| **SME** | Small and medium sized |
| **TBL** | Triple Bottom Line |
| **TRL** | Technology Readiness Level |
| **WA** | Western Australia |

# Definitions

**Adoption:** The 'outcome' phase wherein the research outputs start to be used by the initial users and translated into measurable outcomes and impacts. Uptake and adoption may begin in the form of trials undertaken by CSIRO (i.e., internal use only) or by selected 'next users' (such as industry partners or government bodies, i.e.,external use).

**Impact:** Any benefit to the economy, environment, and society beyond contributions to academic knowledge resulting from development and adoption of research (in focus).

**Nugget effect:** The inability to take a representative subsample from a portion of pulverised, gold-bearing geological material. A phenomenon wherein subsamples will tend to bias low compared with the 'true' overall gold grade, with occasional very high bias.[1]

**Notes:**
Unless specified otherwise, all dollar values are in AUD.
All profits mean profits before taxes.

[1] https://www.labwest.net/technical-articles/nugget-effect-in-the-laboratory/#:~:text=This%20leads%20to%20what%20is,with%20occasional%20very%20high%20bias.

# UltraFine+: Unlocking new mineral exploration targets

## Research Outputs

UltraFine+

## Adoption Vehicle

LABWEST

*exclusive licence*

## Key Stakeholders

Mineral Exploration companies

## Key Impacts

Economic

Economic Performance

Improved risk management

Social

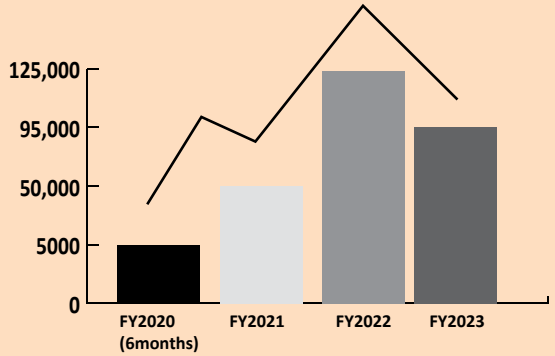
Improved health and safety

Innovation and human capital

Environmental

Lower drilling footprint

## Adoption




## CBA: Investment and Benefits

| | |
|---|---|
| Investment (in PV | 1.4 million |
| Investment (in PV | BCR: 36<br>NPV: 49 million |

## Qualitative Benefits

- Jobs
- **UltraFine+® Next Gen Analytics tool**
- Collaborations
- Export income

## Impact Determinants

- Customer expectation and awareness
- Discovery of commercially successful deposits
- Team support

## Ongoing/Future research

**UltraFine+® Next Gen Analytics tool**

# 1 Executive summary

Australia is the second largest gold producer in the world; however, new gold discoveries are declining. The financial risk associated with gold exploration is a critical challenge for the industry and threatens medium to long-term gold production.

## Challenge

Greenfields mineral exploration in a transported cover is often hindered by a failure to detect, understand, and evaluate near-surface geochemical anomalies in the regolith, which covers ~ 80% of the continent.[2]

Surface exploration involves collecting and analysing soil samples. The traditional techniques have remained unchanged in the last 30 years and typically limited to analysing <250 µm fraction of soil. The nugget effect is a frequent challenge faced by the industry.

## Response

CSIRO, in collaboration with LabWest, developed the UltraFine+® technique for soil analysis designed for 0-30 m of transported cover. The technique focuses on separating and analysing only the ultrafine fraction (< 2 µm) of a given sample, as most metals in transported cover tend to adsorb preferentially to clay particles and other fine 'scavenging' phases with large surface areas. Removing the bulk of the 'barren' portion increases the signal-to-background ratio, and nugget effects (for gold) are removed. The <2 µm fraction has been found to represent the most effective and cost-efficient sample medium to use.

## Adoption vehicle

UltraFine+®, now an established approach to surface exploration, is commercially available exclusively through LabWest. The technique was commercialised in FY2020 (second half).

## Impacts

UltraFine+® has seen a surge in demand since its roll-out and has been mentioned in many ASX releases . It has been used by 163 mineral exploration companies within Australia and making its way into global markets. The adoption of technique has delivered a range of incremental economic, social, and environmental impacts compared to traditional soil sampling methods, including (but not limited to):

- reduced risks, and costs, and improved productivity for the mineral exploration sector. Quicker ability to determine the commercial viability of deposits
- greater demand and new revenue streams for LabWest (an SME). Growth in revenue of upto 80% and creation of new jobs.
- relatively lower drilling footprint (vs traditional technique)
- new CSIRO sources of revenue and collaborations (internal and external)

Cost Benefit Analysis conducted from Australia's perspective for period between FY2020-FY2033 estimates:

- BCR of 36 and NPV of ~49 mil AUD (in present value) without deadweight loss
- BCR of 30 and NPV of ~48 mil AUD (in present value) with deadweight loss

## Other prospective outcomes

LabWest is working towards driving the adoption of UltraFine+® in overseas markets and has already entered six countries (Finland, Japan, Tanzania, Burkina Faso, New Zealand, and Namibia). There are future prospects for export income and the adoption of technique for the detection of critical metals and high-value rare earth elements in emerging markets.

UltraFine+® Next Gen Analytics prototype workflow development is underway (not yet commercialised) and a product of collaboration between CSIRO Minerals and Data61 BUs, post the success of foundational UltraFine+® R&D . This prototype integrates Machine Learning (ML) with decades of regolith expertise to deliver results that can be viewed via a HTML-based dashboard to fast-track

[2] https://www.csiro.au/en/work-with-us/industries/mining-resources/resourceful-magazine/issue-28/ultrafines-labwest

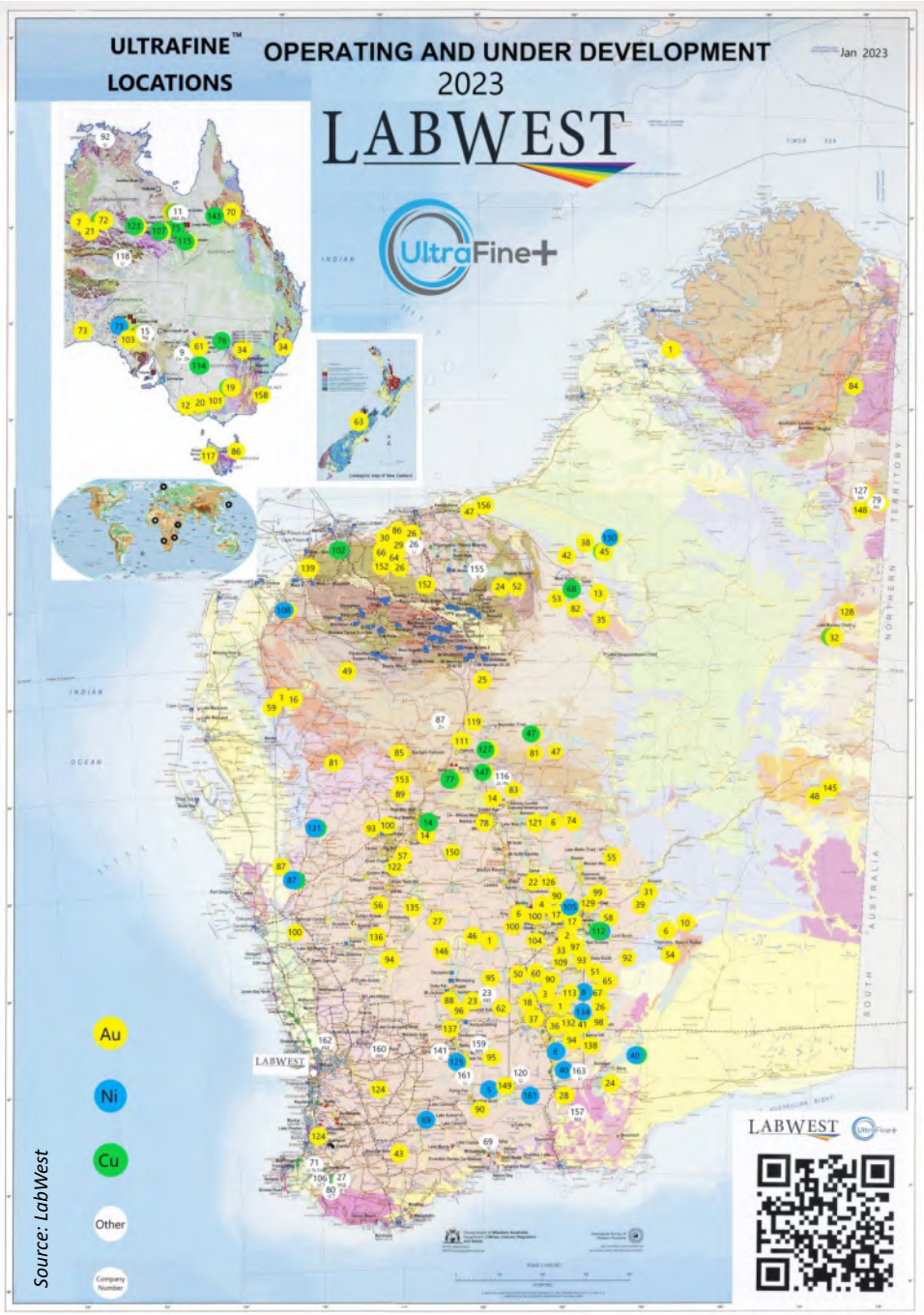
analysis. There is significant enthusiasm within the industry to test and try the capabilities of this new platform to prioritise target areas for exploration, simplify and accelerate the exploration workflows.

## Conclusion

The current assessment is largely ex-ante, with a small ex-post component. Data that underpins the CBA is based on the CSIRO's internal information, LabWest data, advice from external stakeholders, literature review, and calculated assumptions. In all instances, lower-bound estimates and conservative assumptions have been used.

Due to inherent ambiguity associated with how the future might unfold, and the longer-term time frames, the confidence rating in the benefits assessment for this study is rated as medium-low by Tractuum.

This impact assessment provides a significant blueprint to conduct impact management for UltraFine+® in the future. Future monitoring and measurement of the adoption of the technique and tracking the ultimate benefits to initial/end-users would help generate the necessary evidence to support a more robust impact assessment in the coming years while addressing data constraints and bottlenecks in the impact delivery process.



# 2 Introduction

## Investment rationale

### Global Challenge

Australia is the second largest gold producer in the world; however new gold discoveries are declining. The financial risks associated with gold exploration is a key challenge for the industry and threatens medium to long-term gold production. Mineral exploration in greenfields settings in particular is expensive.Australia spent ~$1750 million on gold exploration and ~$2800 million on overall mineral exploration in 2020, out of which $956 million was spent on greenfields exploration.[3] Western Australia (WA) remains the hub for minerals exploration in the country, with an overall share of 61% of total expenditure.

### Science Challenge

Greenfields mineral exploration in transported cover is often hindered by a failure to detect, understand, and evaluate near-surface geochemical anomalies in the regolith, which covers ~ 80% of the continent.[4]

For decades, the presence of mineral commodities during surface exploration has been established by collecting soil samples and analysing them. The traditional techniques have remained unchanged in the last 30 years and typically limited to analysing <250 µm. In particular, 'nugget effect' - i.e. the inability to take a representative sub-sample from a gold-bearing geological material - is a common challenge faced by the industry.[5] Subsamples frequently bias to extremes (low or high) compared with the actual gold concentration; this variation can cause a loss of confidence in the analytical technique. Also, the traditional soil analysis provides limited elemental analysis of the sample, which restricts understanding of the overall system.

### CSIRO's Response

### UltraFine+® Method

In order to address the challenges of minerals exploration in transported cover, CSIRO in collaboration with LabWest, developed the UltraFine+® technique for soil analysis designed for 0-30 m of transported cover, hereto referred to in this document as UltraFine+®. This method is based on separating and analysing only the ultrafine fraction (<2 µm) of a given sample, as most metals in transported cover tend to adsorb preferentially to clay particles and other fine 'scavenging' phases with large surface areas. These 'ultra-fine' particles have more surface area which can bind gold and other metals that move through the environment and so form geochemical signatures of orebodies lying many metres below soil or sand. By removing the bulk of the coarse-grained, i.e. 'barren' portion of the sample, the signal-to-background ratio is increased, and nugget effects (for gold) are removed. The <2 µm fraction has been found to represent the most effective and cost-efficient sample medium to use.

The technique enhances the detection sensitivity with up to 100 – 300 % increased concentrations of Au, Cu and Zn. The testing method requires smaller sample amounts and hence creates a lower environmental impact from drilling compared to traditional methods.

[3] https://globalroadtechnology.com/mining-exploration-and-geology-in-australia/
[4] https://www.csiro.au/en/work-with-us/industries/mining-resources/resourceful-magazine/issue-28/ultrafines-labwest
[5] https://www.labwest.net/technical-articles/nugget-effect-in-the-laboratory/

## Collaboration

UltraFine+® resulted from a partnership between CSIRO, LabWest, the Minerals Research Institute of Western Australia, the Geological Survey of Western Australia, and several exploration companies. **Image 1** compares soil analysis results between traditional and UltraFine+® methods.

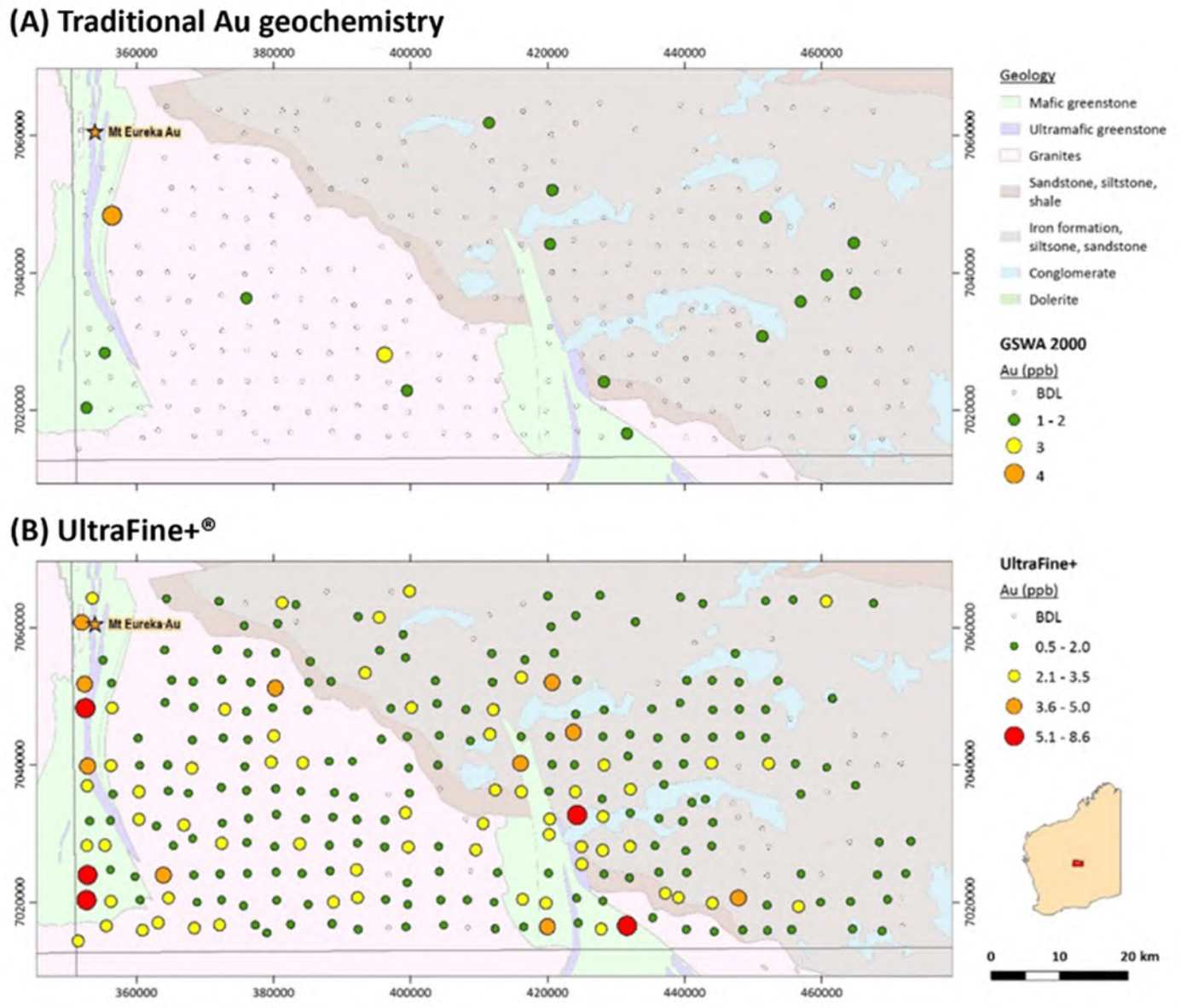


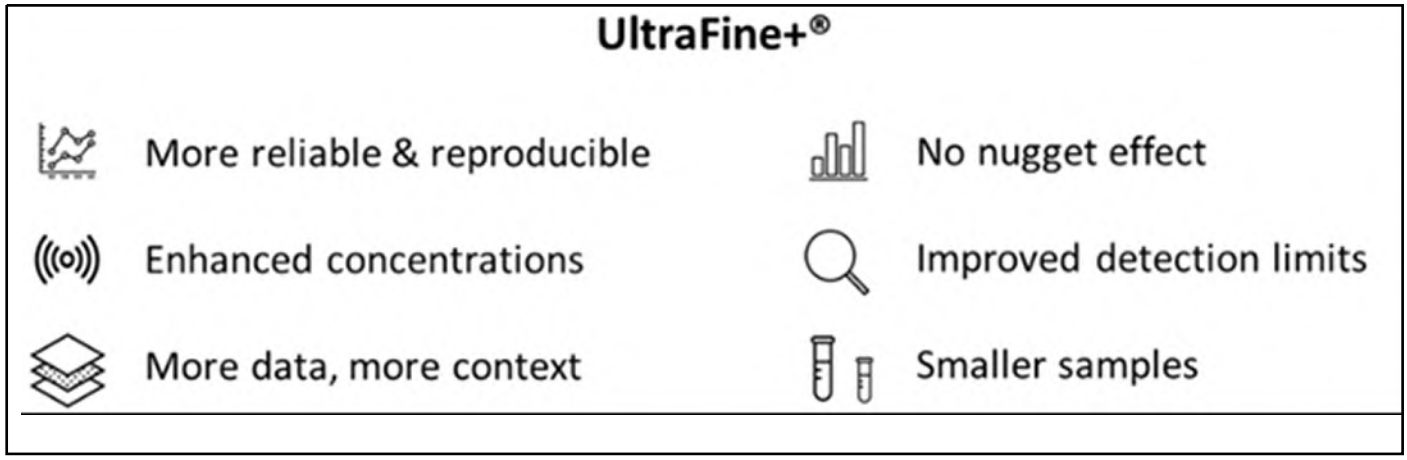

**Image 1: Comparison of soil analyses via traditional and UltraFine+® methods.**

# Current Scenario

## Commercialised product

UltraFine+® is now an established approach to surface exploration analysis using proven geochemical methods with increased sensitivity to detect signals at the surface. The analysis process - commercially available exclusively through LabWest - involves a physical step to retain the fine microparticles and a chemical step to test for the presence of gold and other elements.[6]

[6] https://www.csiro.au/en/work-with-us/industries/mining-resources/exploration/sampling-methods/ultrafine-gold




UltraFine+® is a data acquisition technique that gives more and better data. Under this research, CSIRO has also worked on lowering detection limits for the 50+ elements and developed other important soil property analyses (including spectral mineralogy, Electrical Conductivity (EC), pH and particle size analysis). The technique has proven to be useful for geologists and geochemists to help "see through" shallow to moderate cover. UltraFine+® has also been used to re-analyse historical soil samples. The new data has been used to update geochemistry of the region and is helping mining companies identify new target areas for exploration.

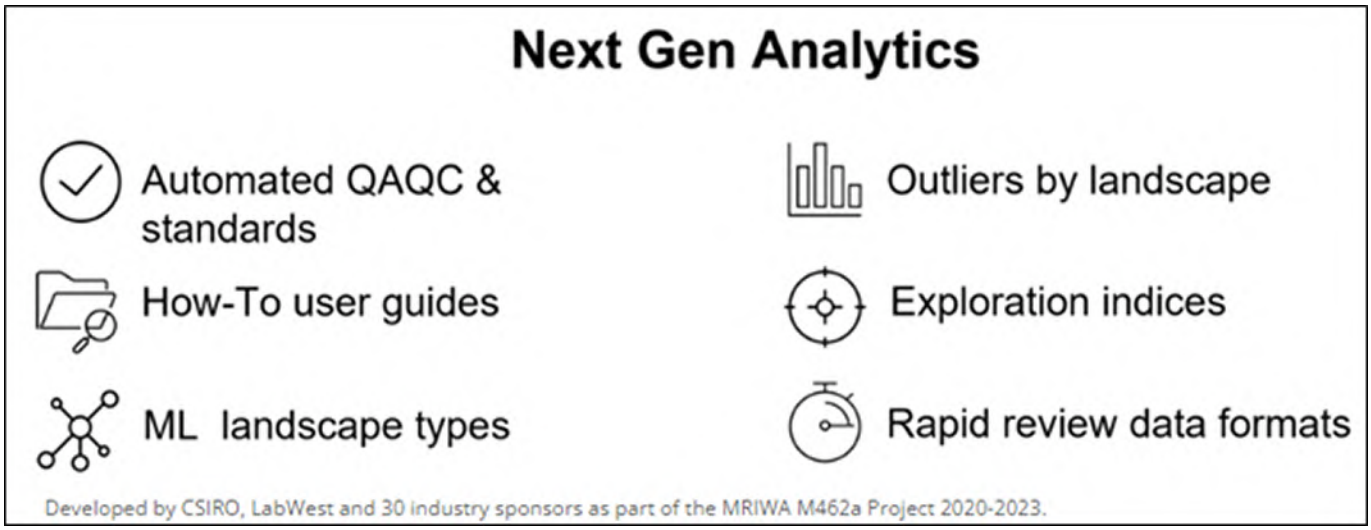
## Ongoing research

### UltraFine+® Next Gen Analytics prototype

This initiative is an outcome of initial industry traction in UltraFine+®. Next Gen Analytics research has developed a prototype workflow (not yet commercialised) and integrates Machine Learning (ML) with decades of regolith expertise to deliver results that can be viewed via a HTML-based dashboard to fast-track analysis. The prototype provides tools for the interpretation of data from UltraFine+® analysis in landscape context, as well as just simplifying all the processing steps (e.g. QAQC) that a geochemist needs to go through to assess their data. It combines the UltraFine+® soil analysis method with high-quality spatial data, creating ML-derived, first-pass data products with a vision to make a step change for the industry and creating an automated QA/QC 'traffic light' system for all analyses. The additional first-pass interpretations and results add value to the standard commercial output provided by LabWest, by providing rapid first-pass interpretation and an ability to view information easily.

At this early testing stage of the Next Gen Analytics prototype planned to be eventually commercialised by CSIRO, key outputs include proxy regolith landscape clusters; maps and boxplots of elemental outliers by landscape type; Principal Component Analysis and exploration ratios; soil texture diagrams, source and dispersion directions; and regolith geochemical indices. Outputs are expected to be made available in a number of easy-to-use files from a web viewer platform, GeoTIFFs, PNGs and CSVs to shapefiles to make it easy to fast-track user interpretation of results.

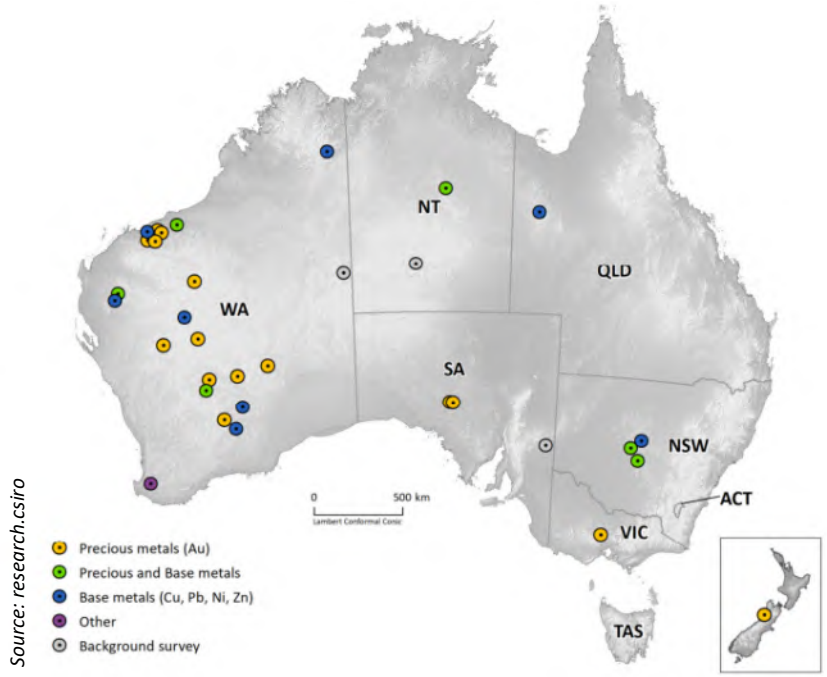
As mentioned, the development of Next Gen Analytics initiative is under progress. The prospective research outputs and benefits from this research are highlighted in Section 7. **Due to early-stage nature of this work, the focus of the current impact evaluation is on assessment of benefits from development and adoption of UltraFine+® technique ONLY**. Any future benefits enabled by commercialisation of Next Gen Analytics will be evaluated in next versions of impact assessments.




## Purpose of Impact Assessment

For CSIRO to fulfil its purpose, it must provide its stakeholders (and itself) with robust evidence that its activities are delivering impact. **The purpose of this impact assessment is to estimate the potential triple bottom line (TBL) impacts from investment into the development and adoption of CSIRO's UltraFine+® technique for surface exploration analysis for gold and other high-value elements.** This assessment is expected to help key stakeholders understand the impact of this initiative; support impact management to strengthen impact performance; and efficiently and effectively communicate results to all stakeholders to raise awareness and interest in the technology. In addition, the evaluation is also expected to underpin future funding requests for the ongoing research under this initiative.

The study outlines the impact logic model (Impact Pathway) and evaluates the industry-recognised five dimensions of impact. The assessment covers the direct and indirect impacts from adoption of research. As per information shared by CSIRO's R&D team, the development of the technology commenced in FY2015, and was rolled out for commercial uptake by LabWest in FY2020. The study compares the proportion of estimated benefits attributable to CSIRO's investment with the project costs directly contributed by CSIRO. Figure 1 provides key objectives for the measurement of impacts during an investment cycle. UltraFine+® sits under phase 3 of this cycle.




*Source: research.csiro*

[7] https://impactfrontiers.org/norms/five-dimensions-of-impact/

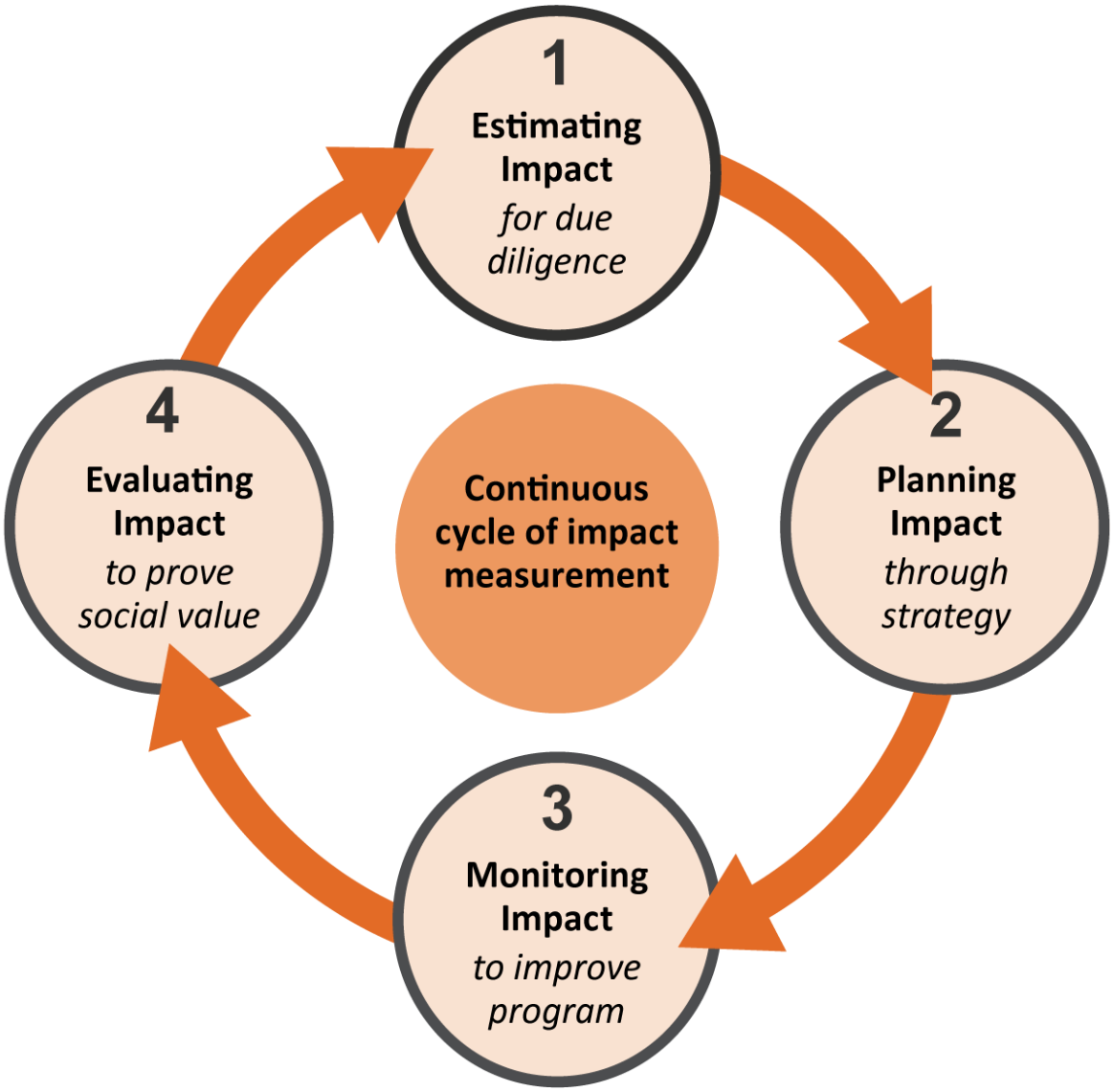



**Figure 1: Continuous cycle of Impact measurement objectives[8]**

This report can be read as a stand-alone item, or in conjunction with other CSIRO Minerals business unit (BU) evaluations. The information is provided for the purposes of accountability, internal funding (APaIRS) communication, engagement, continuous improvement, and future impact management. Some of the other ways in which this impact data may be used during the investment process by both investors and investees are highlighted in Figure 2 below. The audiences include (but are not limited to) CSIRO Minerals and Data61 BUs (especially program and leadership teams); Business Development (BD) managers and researchers; LabWest; Mineral exploration companies; Environmental management companies; Commonwealth, state, and local governments; digital solution providers; and interested members of the public.

[8] www.hbs.edu/socialenterprise/Documents/MeasuringImpact.pdf

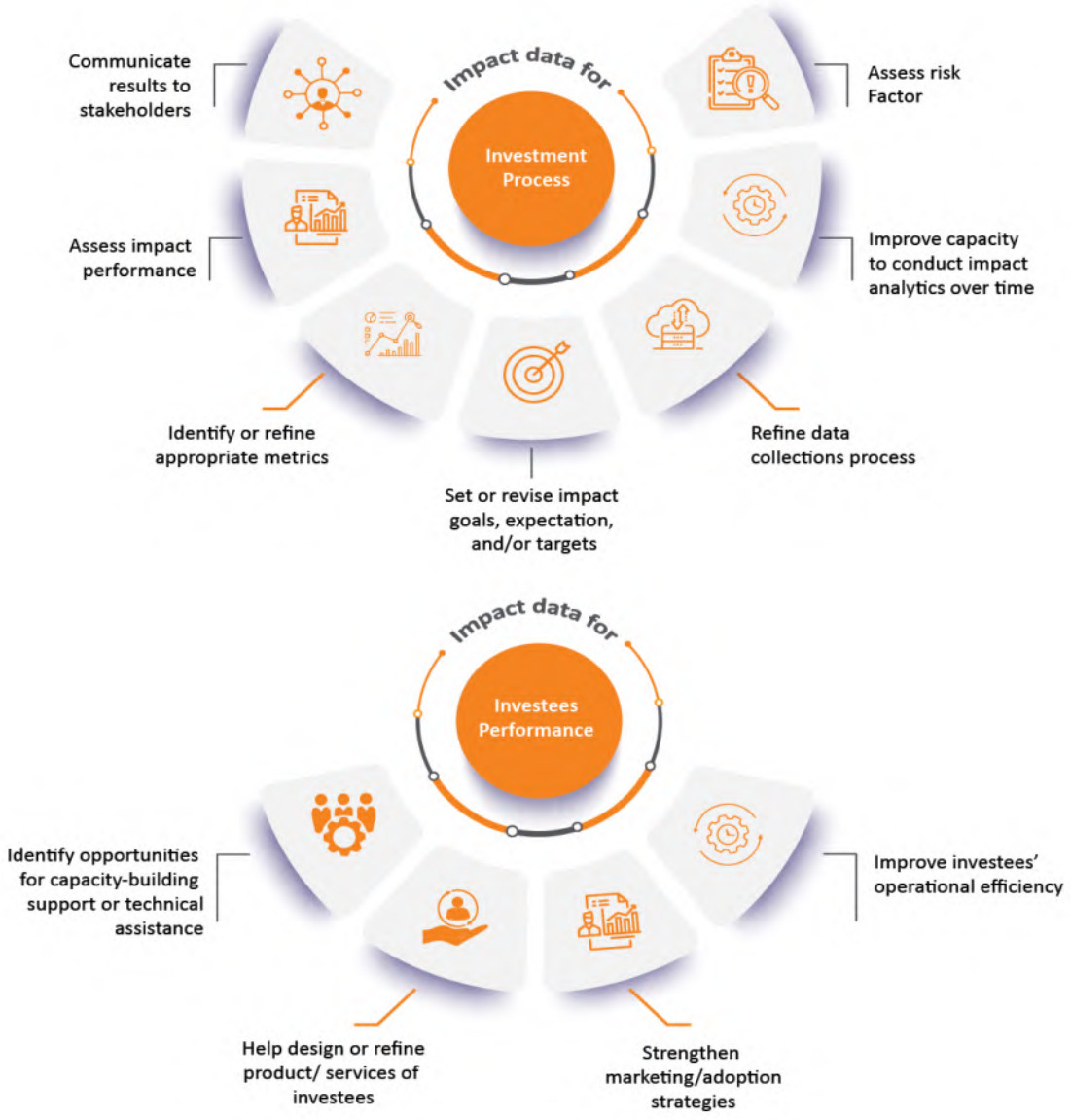



**Figure 2: Ways in which this impact data is used by the investors and investees during the investment process**

**Box 1 Ex-ante Assessment**

As will be clear from subsequent sections of the assessment, with UltraFine+® being in its early years of uptake, the benefits estimation is largely ex-ante (before realisation) at this stage. An ex-ante evaluation is considered a significant step for impact management of a project throughout its lifecycle as it:

i. provides an opportunity to identify the causal links underlying the investment's path to impact, and allows the investors and others to assess the strengths of these linkages;

ii. helps establish a baseline to effectively determine the changes delivered through the project;

iii. promotes due diligence for sound decision-making;

iv. assists with improved implementation, as well as evaluation planning and monitoring;

v. allows evidence-based evaluation and reporting later on in the journey of the work.

vi. benefits future programs (such as Next Gen Analytics) that emerge out of the foundational work.

Hence, projects guided by an ex-ante assessment will have better opportunities to maximise their outcomes and impacts performance. However, a lack of adequate real-world evidence-based data at this stage makes these assessments highly uncertain.

# 3 Impact assessment approach and report structure

### Step 1: Impact Pathway

The impact analysis presented in this report starts with the Impact Pathway, given in Section 4 below. The Impact Pathway gives a snapshot of the anticipated causal relationship from the original research project, through the creation of the research outputs, uptake, and adoption of outcomes, to the prospective impacts for the assessment of benefits. Being an early-stage, strategic research, Figure 3 denotes a complex chain of events with a range of variables affecting each link in the chain. Each phase of the impact pathway, causal linkages and benefits to key stakeholders are discussed in greater detail in Section 4.

### Step 2: Assessment of benefits - Methodology

The methodology for the assessment of benefits is outlined in Section 5. It considers the important elements of Cost Benefit Analysis (CBA) and details the data sources used in the evaluation and the review process.

### Step 3: Quantitative Assessment of Impacts

Prospective quantitative benefits from this program of work are estimated in Section 6. The section covers the modelling approach and identifies different benefits streams in the first part. The assessment includes the economic model with its associated assumptions and limitations. Tractuum employs multiple complementary approaches in its analysis to capture different facets of potential benefits. The assessment hypothesises several scenarios of adoption and impact for the estimation of benefits. The unit of evaluation, the data that is collected for it, and the methodology used to interrogate that data, are all functions of the evaluation's purpose and audience (see Section 2 above). The CBA results, as well as a sensitivity analysis, are covered in the last part.

### Step 4: Qualitative Assessment of Impacts

UltraFine+® is an early-stage initiative and has recently been commercialised. Due to the necessarily limited availability of data, quantitative assessment of many quantifiable benefit streams is not possible at this stage. In addition, some benefits are not quantifiable by nature. Section 7 provides a qualitative assessment of such benefits from the development and adoption of UltraFine+®.

### Step 5: Conclusions and confidence rating in the assessment

Concluding remarks with a confidence rating of this impact assessment are set out in Section 8.

*Source: CSIRO*

# 4 Impact pathway and discussion

## Impact Pathway

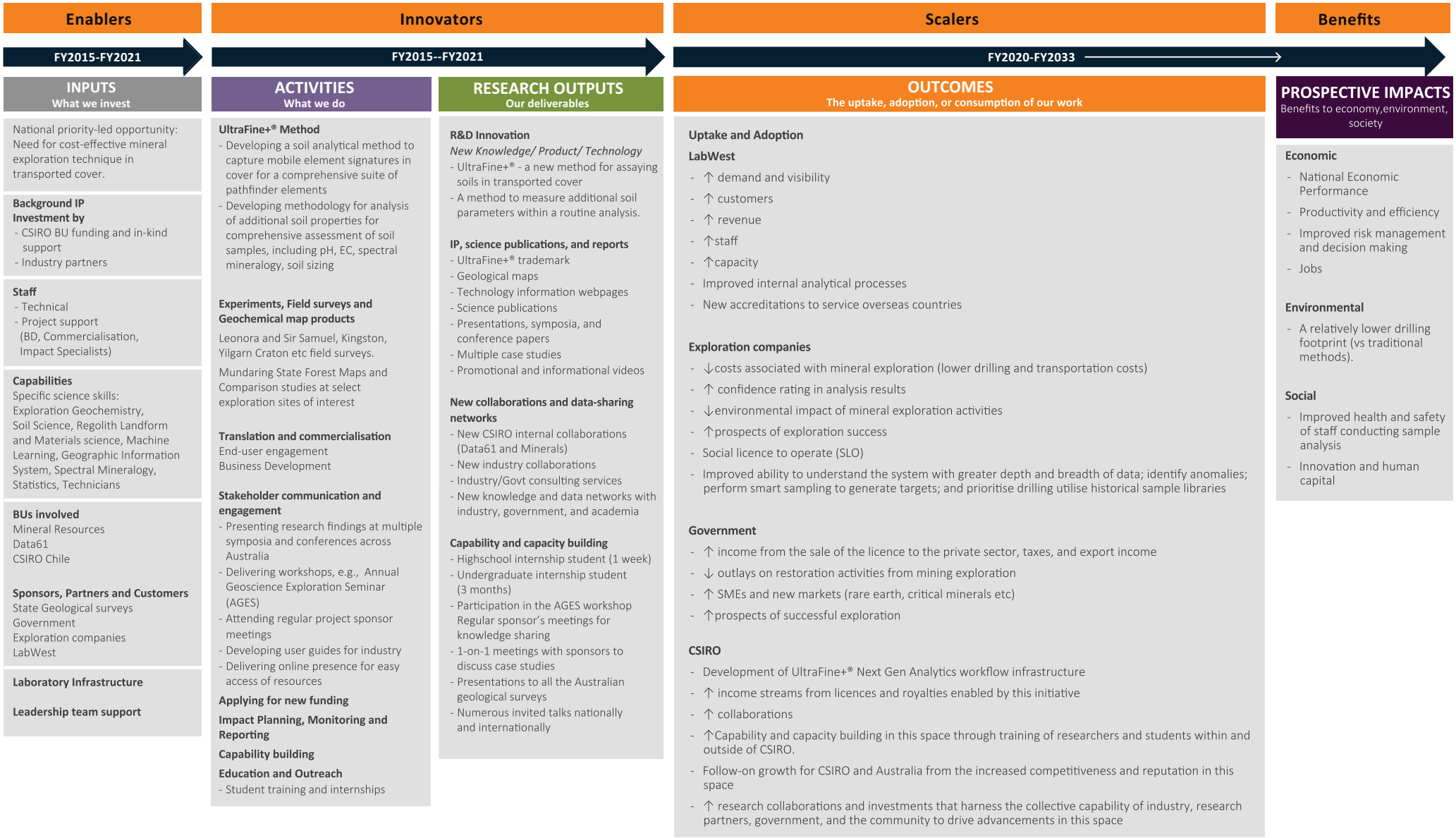



**Figure 3: UltraFine+® - Impact Pathway**

## Impact Pathway Discussion

### A. Developmental Phase: Outputs

**Information source:** CSIRO UltraFine+® R&D team

#### Outputs

*This section covers the research solutions, services, and/or capacities that result from the completion of activities performed within the UltraFine+® initiative, defined as Outputs or Research Outputs.*

#### R&D Innovation – UltraFine+® technique (delivered)

Phase 1 of this work carried out in collaboration with LabWest began in 2016 and delivered UltraFine+®, a new method for assaying soils in transported cover in 2018. This cost-effective surveying technique was initially targeted for gold exploration. However, its application has been expanded for the exploration of other elements such as copper and zinc. There are ongoing efforts to include rare earth metals and critical elements such as lithium, cobalt, tin, etc. It delivers greater breadth and depth of information such as the routine measurement of additional soil parameters to aid decision-making in exploration activities.

*UltraFine+® Next Gen Analytics research (in progress)*

*UltraFine+®*R&D led to another significant collaboration between CSIRO Minerals and Data61 BUs to develop the *UltraFine+®* Next Gen Analytics research workflow. See Section 7 for further details.

#### Intellectual Property, science publications, and technical reports

The R&D has delivered several technical resources that provide new knowledge about the UltraFine+® and the upcoming UltraFine+® Next Gen Analytics research workflow. These include:

i. CSIRO owns the trademark – registered IP. CSIRO's Intellectual Property (IP) position is around workflow and integration of future algorithms.

ii. UltraFine+® information web pages

iii. Journal articles

- Noble, R.R. et al. (2019) "Application of ultrafine fraction soil extraction and analysis for mineral exploration," Geochemistry: Exploration, Environment, Analysis, 20(1), pp. 129–154. Available at: https://doi.org/10.1144/geochem2019-009
- Noble, R.R. et al. (2019) "Refining fine fraction soil extraction methods and analysis for mineral exploration," Geochemistry: Exploration, Environment, Analysis, 20(1), pp. 113–128. Available at: https://doi.org/10.1144/geochem2019-008
- Determination of micro and nanoparticulate fraction gold in regolith

There are more publications in pipeline expected to be released in the next 6 months – 1 year.

iv. Presentations and conference papers through participation in different conferences and symposia

v. Technical/project reports

UltraFine+® Next Gen Analytics Northern Territory Geological Survey – MacDonnell Ranges

UltraFine+® Next Gen Analytics Geological Survey of New South Wales – Cobar Projects

UltraFine+® Next Gen Analytics Geological Survey of Queensland – Jericho

MRIWA Report no. 462 Multi-scaled near surface exploration using Ultrafine soil

vi. Multiple case studies (~50) that highlight results from adoption (available upon request)

vii. Promotional and informational videos

- UltraFine+® intro video
- GSSA TECHNICAL UPDATE: CSIRO Mineral UltraFine+® Fraction Collaboration
- Discovery Day 2020: CSIRO: UltraFine+® surface geochemistry of the Gawler Craton
- Using Ultrafine (and Other) Soil Fractions To Improve Exploration - Ryan Noble CSIRO
- Exploring through cover with interfaces and indicator minerals 2020061
- Ryan Noble, CSIRO - UltraFine+® The transformative change to near-surface exploration
- Using Ultrafine (and Other) Soil Fractions To Improve Exploration - Ryan Noble CSIRO
- Extracting more from exploration soil samples. UltraFine+® and Next Gen Analytics

#### New collaborations and data-sharing networks

- Under this initiative, CSIRO is collaborating with other CSIRO BUs (Data61) and >30 external organisations to advance the R&D.
- CSIRO is occasionally providing consulting

– services of varying degrees to different companies.

### Skill Development Outputs

Capability and capacity-building activities that include:

– Highschool internship student program of 1 week duration

– Undergraduate internship student program of 3 months duration

– Participation in the Annual Geoscience Exploration Seminar (AGES) workshop

– Regular sponsor's meetings for knowledge sharing

– 1-on-1 meetings with sponsors to discuss case studies

– Presentations to all the Australian geological surveys

– Numerous invited talks nationally and internationally

## B. Developmental Phase (Pre-Outputs): Inputs and Activities

**Information source:** CSIRO UltraFine+® R&D team

### Inputs

*This section covers the key resources applied to deliver activities under this initiative.*

The key input requirements to accomplish science deliverables are identified in Figures 3 and 4. Relevant details of the main inputs are discussed below.

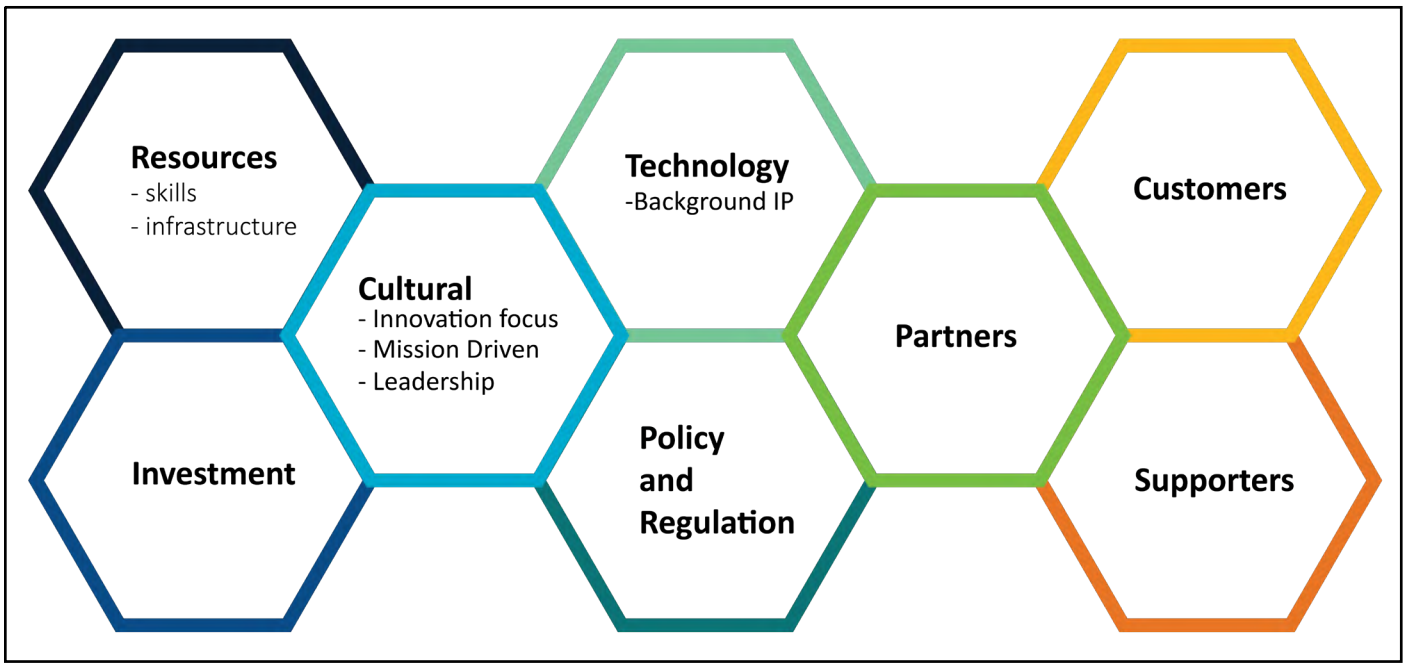



**Figure 4: Key inputs to deliver against objectives of UltraFine+® Initiative**

### A. Costs

Table 1 depicts the investment made by CSIRO and partners to undertake activities for this initiative. All costs have been expressed in real dollars (i.e., adjusted for inflation) and then discounted using this real social discount rate. The dollar year for inflation adjustment and the base year for discounting are FY2023 (same).

**Table 1: Financial and in-kind support for the UltraFine+® initiative**

| Cost Category | FY2015 | FY2016 | FY2017 | FY2018 | FY2019 | FY2020 | FY2021 |
|---|---|---|---|---|---|---|---|
| **1. MRIWA M462 -Ultrafine Au for exploration**<br>Duration: 3 years<br>CSIRO WBS: MRIWA M462 | | | | | | | |
| **Cash** | | | | | | | |
| CSIRO | | | | | | | |
| External | $137,168 | $137,166 | $137,166 | | | | |
| **In-Kind Contributions** | | | | | | | |
| CSIRO | $92,000 | $92,000 | $92,000 | | | | |
| External | | | | | | | |
| **2. De Grey UltraFine+®Surface Geochemistry**<br>Duration: 6 – 18 Months<br>CSIRO WBS: R-15090-01 | | | | | | | |
| **Cash** | | | | | | | |
| CSIRO | | | | | | | |
| External | | | | | | $26,914 | $26,914 |
| **In-Kind Contributions** | | | | | | | |
| CSIRO | | | | | | $19,793 | $19,793 |
| External | | | | | | | |
| **Total Expenditure (Real, CPI adjusted)** | $266,041 | $262,685 | $257,664 | $0 | $0 | $50,287 | $48,887 |
| **Total Expenditure (PV, FY2023$) @7% DR** $266,041 | **$1,383,180** | | | | | | |
| **Overall CSIRO Expenditure (Real, CPI adjusted)** | $106,803 | $105,456 | $103,441 | $0 | $0 | $21,310 | $20,717 |
| **Overall CSIRO Expenditure (PV, FY2023$) @7% DR** | **$557,907** | | | | | | |

To the extent that CSIRO research was funded by the government out of increased taxation, the project would have had an adverse effect on economic activity in Australia. This deadweight loss would be a cost attributable to this UltraFine+® R&D and will be included in the CBA calculations in Section 6.

**B. Staff : Technical and project support**

- CSIRO experts: Exploration geochemistry, Soil science, Regolith landform and materials science, Machine Learning, Geographic Information System, Spectral Mineralogy, Statistics, Technicians[9]
- LabWest expertise with a wide range of sensitive regolith geochemical techniques
- Project support experts: Business Development (BD), Commercialisation and Impact Specialists
- CSIRO BUs involved: Mineral Resources, Data61 and CSIRO Chile

**C. Laboratory infrastructure** for performing necessary soil testing

**D. Networks**

- **Technical partners:** LabWest
- **Sponsors:** See the list of sponsors in Appendix D.
- **Funders:** Minerals Research Institute of Western Australia, Geological Survey of Western Australia
- **Beneficiaries:** Exploration companies in the mining sector. See the list of companies that have used the product in Appendix D; geological surveys; Research organisations.

**E. BU leadership support** has played a critical role to drive this research.

## Activities

*This section covers the actions taken or work performed through which inputs (see above) are mobilised to achieve specific outputs.*

The main activities performed by the team under this initiative are covered in Figure 3 above.

### Research and Development

CSIRO team began the development of UltraFine+® technique in 2015. The work began as a student project followed by development of technique in collaboration with LabWest.

### Experiments, Field surveys and Geochemical map products

Under this effort the team conducted a number of experiments, orientation field surveys and developed new regional geochemical map products for Western Australia.

### Translation and commercialisation

The R&D team actively engaged with a number of mineral exploration companies to try, test, and validate the UltraFine+® technique. LabWest has been working actively to market and promote the technique in Australia (especially WA) and now globally as well.

### Stakeholder (technical partners and initial/end-user) engagement and communication

Participating in:

- symposia and conferences
- AGES workshop
- sponsor meetings

### Impact planning, monitoring, and reporting

### New funding applications

The R&D team has been working actively to engage with industry to get sponsors and funders to support this work as well as ongoing research. The team has also been successful in getting other grants such as Innovations Connections.

### Education and outreach

UltraFine+® R&D has been supporting a high school internship of a student for a period of 1 week and an undergraduate student internship for a period of 3-months annually.

## C. Adoption Phase (Post-Outputs): Outcomes and Impacts

## Outcomes

*The intended or desired medium-term effects/change expected to be realised from the successful uptake of research outputs from UltraFine+® research by users. This would require the collective effort of partners (commercialisation partner/initial user/end-user etc).*

**Information source:** CSIRO UltraFine+® R&D team, LabWest, Dreadnought, GeoSpy, DEM

[9] CSIRO UltraFine+® team – UltraFine+

As the value of UltraFine+® research lies with those who adopt the outputs, the uptake and adoption of research outputs is an essential precursor to realise any benefits. The current and expected outcomes for the key stakeholders are given in the Impact Pathway in Figure 3 and discussed below.

### i. LabWest

LabWest plays a critical role as the main vehicle for the adoption of UltraFine+® and rolled out the technology for commercial adoption in the second half of FY2020. Since then, exploration companies submit the on-site soil samples to LabWest for UltraFine+® analysis. LabWest may also be involved directly or indirectly in the roll-out of the Next Gen Analytics prototype, expected to be directly commercialised by CSIRO in FY2025.

Brad Whisson, MD, LabWest shared that the adoption of UltraFine+® has been instrumental in putting LabWest on the map and opening new opportunities for the small and medium sized enterprise (**SME**). Although LabWest has been in operation since 2008, it has only seen a spike in demand for its services in the last 3-4 years. With an increase in client base by 400-500%, the adoption of UltraFine+® has been critical in attracting new customers from across Australia and driving business growth by more than 80%. The SME has grown their staff from 15 to 25 FTEs during this period to address new demand; added new infrastructure to increase capacity by 3X; and acquired new accreditations to be able to receive samples for testing from overseas markets such as Canada, Africa and South America. LabWest has dedicated a section of the lab exclusively for UltraFine+® work and 80% of the company's current activities are centred around these operations to support new uptake in greenfields exploration space.

The growth in demand for LabWest services has also provided the SME with an impetus to streamline their internal workflows, address bottlenecks and adopt the latest digital solutions. These measures have enhanced employee engagement, productivity, and efficiency to improve performance and better position them for future growth.

In addition, the traditional process of soil sampling requires drying, crushing, and pulverising, etc., which is eliminated by UltraFine+®. This reduces the chances of contamination of samples and simplifies the analysis process for chemists/ analysts, while improving their health and safety.

**LabWest Testimonial**

*"LabWest Minerals Analysis (LabWest) has been part of the UltraFine+ development project both as a technical contributor and commercial partner with CSIRO for over 7 years. The project, and its resulting product, the UltraFine+ technique, enabled LabWest to assist in development of, then bring to the market, a novel approach to surface exploration for minerals, that fitted very well in our niche and was well received by industry.*
*The CSIRO project team, led by Dr Ryan Noble, was easy to work with and very cooperative during the development phase, and supportive of our commercialisation efforts.*
*LabWest has enjoyed attention from the market as awareness of the technique has grown, and it has become a significant proportion of our sales revenue. It has been particularly pleasing offering an innovative product that is genuinely beneficial to our clients in offering a cost-competitive, technically superior alternative to traditional surface geochemical sampling and analysis techniques.*
*We look forward to assisting CSIRO in bringing the next stage of development, NextGen Analytics, to fruition."*

**Brad Whisson, MD, LabWest**

### ii. Gold (and Mineral) exploration companies

Tractuum interviewed Dean Tuck - Dreadnought, Darren Holden - GeoSpy and Anna Petts - DEM to obtain insights about industry benefits from the adoption of technology. There was a consistent agreement that in comparison to traditional methods, UltraFine+® added unique and critical benefits in the following ways:

- eliminating nugget effects in gold exploration.
- reducing the cost (time and effort) associated with exploration during the preliminary soil sample acquisition process.
- providing more accurate data with a higher-confidence rating and wider field of view to decrease the risks associated with exploration.
- developing solutions for smart sampling and producing faster sampling results to inform timely decision making.
- generating new and useful information through more detailed analysis to help practitioners better understand what is happening within a system and identify anomalies.
- lowering the relative drilling footprint of soil analysis step during the exploration process.
- improving the utilisation of historical sample libraries by re-assaying to find new targets and information.

All the above factors are expected to improve the overall prospects for exploration success for the Australian mining industry. Based on a conversation with industry experts, the standardised and simple nature of the technique and its conventional assay makes it fathomable and attractive for adoption.

The adoption of the technology does not require any additional training for on-site samplers/technicians or new tools compared withtraditional methods. The sampling needs for UltraFine+® help reduce the need for air core (AC) drilling (required for traditional geochemistry) in some cases where there is a strict regolith terrain in the absence of a deep weathering profile. In other words, it does not need a deeper regolith/interface sample on shallow covered areas as the surface geochemistry results with UltraFine+® are sufficient to go straight to the deeper drilling methods. This allows the samplers to go directly from soils to Reverse Circulation (RC) drilling. The elimination of AC drilling delivers significant cost, effort and environmental impact savings from the sampling process compared with traditional methods, without compromising the survey results.

The particle refinement process associated with UltraFine+® renders higher confidence in the data and improved ability to "see through" cover. Since the focus is on the fine fraction, the higher sensitivity and therefore effectively lower detection limits reduce bias and generate more accuracy and confidence. This can play a critical role in generating targets and prioritising drilling. Currently, there are no comparable solutions that can deliver these benefits.

Some of the new information such as hyperspectral data is a lot cheaper to obtain from satellites and do not improve resolution to the existing sites. However, this information from UltraFine+® analysis has been reported to be particularly useful for greenfields sites, as creating a regolith map for the first pass provides greater confidence in the interpretation of satellite data.


**Image 2: Comparison of Traditional and UltraFine+® sample sizes**

**Customer Testimonial**

*"I am extremely pleased to furnish this testimonial for UltraFine+® geochemistry technology. I have been involved with several organizations that have rolled out the technology across multiple terrain types and target commodities in Western Australia. There is beauty in the simplicity of this technique and I firmly believe that it produces reliable results that can see mineral systems through thin transported cover, as well as smoothing out localized concentration effects in residual regolith environments. Working with Ryan Noble and the team at the CSIRO has been an absolute pleasure.*

*I believe that further research is required to really understand what (i) UltraFine+® is telling us in complex weathering and transported cover environments. For a technique developed initially for gold, I also encourage the CSIRO to continue research on multi-element for other commodity types. Pathfinders, for example, for LCT pegmatite or rare earth element exploration through transported cover do not have fully developed indices yet, but I believe further research will enhance the knowledge required to add these to the toolbox.*

*Furthermore, the CSIRO team made great strides forward with the NextGen analytics using machine learning technologies for outlier analysis, yet the decision to discontinue this as an (R&D) service in the short-term is a little disappointing. Having said that, UltraFine+® is an excellent breakthrough in low-level detection geochemistry and I look forward to LabWest continuing to supply the service for the benefit of the mineral exploration industry."*

**Darren Holden, Geologist**

### iii. Government

The mining sector has been one of the largest contributors to Australia's economy in the past decade as the largest source of GDP growth, export revenue and a significant source of government revenue.[10] Although a big discovery that attributes its success to UltraFine+® is yet to occur, industry experts underline the significance of technology to simplify and de-risk the exploration process while improving the likelihood of success. Hence the adoption of technology does lay the prospects to increase the revenue for the government from new explorations within Australia.

The new revenue streams (producer surplus) for LabWest from planned domestic and potential overseas operations as well as costs saved by the mining industry are expected to generate more income in the form of taxes and export income for the government.

Due to the critical importance of the Minerals sector in driving the economy, the success of UltraFine+® is expected to enhance the reputation of Australia globally.

If the technique is deemed viable for exploration of critical metals including Li or other high-value rare earth elements, it could reduce reliance on overseas nations while supporting new and emerging markets and the growth of SMEs within Australia.

### iv. CSIRO

Given the significance of minerals exploration in Australia, UltraFine+® R&D continues to deliver reputational gains for CSIRO. The R&D has generated new income in the form of licence fees and royalties from LabWest. New income streams have also emerged from new projects and collaborations as a result of this work. UltraFine+® work started in 2015 as a student initiative; CSIRO currently collaborates with >31 organisations under this initiative.

The new networks as a result of this R&D will be leveraged by CSIRO to harness the collective capability of industry, research partners, government, and community to advance the Technology Readiness Level (TRL) of this initiative.

[10] https://www.minerals.org.au/news/boosting-mineral-exploration-unlock-future-prosperity#:~:text=Mining%20has%20been%20the%20largest,in%20company%20taxes%20and%20royalties.

Longer-term commitment from networks also has the potential to drive a more coordinated focus to attract key stakeholders and new investments to progress Investment Readiness Level (IRL) for this initiative and for future research.

The development of the Next Gen Analytics prototype brought together Minerals BU with Data61, the digital arm of CSIRO, to provide deep regolith expertise through digital solutions, with a vision to open new opportunities to drive minerals exploration within Australia. Although bigger companies have reported using ML methods for parts of soil analysis workflows, an end-to-end solution such as the proposed prototype is expected to be a first of its kind solution.

CSIRO's Strategic Objectives being addressed[11]

The initiative supports two of the four CSIRO's strategic objectives, namely:

Objective 1: Deliver Impact through innovation

Objective 2: Purpose-driven science and technology

CSIRO's key challenges being addressed[12]

The initiative addresses one of the six CSIRO Challenges, deemed as areas of great significance to Australia in the current environment:

**Sustainable Energy and Resources:** Build regional energy and resource security and our competitiveness while lowering emissions

## Prospective Impacts

**Box 2: Overall impact = Direct impact + sector level impact**

**Direct impact:** Σ (benefits generated through directly working with customers and partners)

**Sector-level/Broader impact:** Σ (benefits generated through raising industry's benchmark understanding and awareness, and sparking new innovations)

As highlighted in Box 2 above, the adoption of research outputs externally to CSIRO is expected to have direct and sector-level impacts. It is only when outputs are being used externally that work has a practical application to which a realised value can be attached. It is also important to note that for an impact to be claimed as a 'CSIRO impact,' there must be a clear pathway leading from the impact back to CSIRO. The prospective direct triple bottom line (TBL) impacts from the uptake of research outputs from the UltraFine+® initiative are summarised in Table 2 below.

[11] https://www.csiro.au/en/about/strategy
[12] https://www.csiro.au/en/about/challenges-missions/challenges

**Table 2: Prospective TBL impacts from the development and adoption of UltraFine+® technology.**

| | |
|---|---|
| **Economic** | *National Economic Performance*<br>– *growth of a SME like LabWest*<br>– *on-site costs saved from factors such as the soil sample acquisition process and reduced the need for AC drilling*<br>– *improved prospects for exploration success*<br>– *improved methods for the detection of Au and base metals, that works effectively for exploration of many critical metals including Li and potentially high-value rare earth elements, allowing explorers to look at many potential resource targets in their tenement areas*<br>– *prospective export income* |
| | Productivity, and efficiency<br>– *the shorter pathway to establish the commercial viability of sites during the mineral exploration process* |
| | Improved risk management and decision making |
| | New Jobs |
| **Environmental** | A relatively lower drilling footprint (vs traditional methods). |
| **Social** | Improved health and safety of staff conducting sample analysis |
| | Innovation and human capital (creativity and innovation) |

# 5 Assessment of benefits - Methodology

## Methodology

As mentioned earlier in the report, the assessment of prospective benefits from this program of work is conducted using a mixed-methods approach, i.e., a quantitative (CBA) and qualitative analyses. The evaluation mainly focuses on the direct impacts of the adoption of technology; however, some sector-level impacts are considered in the qualitative assessment.

### CBA

CSIRO uses CBA as its primary methodology for research impact evaluation. The evaluation follows guidelines from the latest CSIRO *Impact Evaluation Guide.* Costs and benefits have been recalculated in order to be expressed in a dollar value at a common point in time, namely in FY2023 $AUD, using the Consumer Price Index (CPI). Benefit-Cost Ratio (BCR) and Net Present Value (NPV) are used to express the results of analysis.

Given that information on recurrent incremental adoption costs is commercial in confidence (CIC) and not available for analysis, the impact assessment uses a BCR formula expressed in its most common and simplest form as the present value of economic benefits divided by the present value of adaptive, development and extension costs.

*Benefit Cost Ratio=PV($B_t$)/ PV($C_t$)*

*Where*

*PV($B_t$) is the present value of the benefits at time t*

*PV($C_t$) is the present value of the costs at time t*

A BCR that is greater than '1' means that a $1 of cost provides for more than a $1 of benefit and that, therefore, UltraFine+® provides a net positive impact in the quantitative sense.

The NPV is calculated as difference between the present value of the incremental benefits and the present value of the incremental costs. This can be expressed using the following equation:

$$\mathrm{NPV} = \sum \mathrm{PV}(\mathrm{B}_t) - \sum \mathrm{PV}(\mathrm{C}_t)$$

Costs are assumed to be incurred at the beginning of a period, and benefits accrued at the end of a period. Present value calculations of costs and benefits have also been harmonised so that they have a common base year of FY2023 across the program. A real discount rate of 7 per cent has been assumed in these present value recalculations.[13] This subsequent section provides an estimate of the realised and potential future impacts through an incremental *gain in revenue for LabWest and incremental soil sample surveying costs saved by gold exploration companies to assess* the first-round effects from the adoption of UltraFine+®.

## Data Sources

Due to the early-stage nature of this work, Tractuum used complementary data sources to estimate potential impacts. CSIRO's UltraFine+® R&D team was interviewed early on and provided background information and documents for this review. A number of industry research publications and technical reports were reviewed. These sources have been referenced in Appendix B. Stakeholders from LabWest (initial user), and Dreadnought, GeoSpy Capricorn Metals, Iceni Gold, Lodestar Minerals and DEM (end users of research outputs) were interviewed to obtain insights about prospective real-world benefits from the adoption of the technology. They also provided inputs on potential risks and roadblocks in the pathway of technology adoption, based on their industry knowledge.

## Expert Panel Review

Industry experts consulted for this review were requested to validate the quantified and qualitative descriptions of the outcomes and impacts they expect to be realised from the development and adoption of UltraFine+®, before finalising the impact evaluation.

## Perspective and stakeholders

CSIRO is a national institution that is funded by the national government; its work affects Australian society as a whole. A CBA, therefore, needs to be conducted from a national perspective. The analysis

[13] *As per CSIRO (2020) Impact Evaluation Guide p. 13*

captures the impact in the direct primary market. Any benefits realised by other nations from the adoption of the technology are beyond the scope of this study. Also, since the technology is in its early years, the analysis is restricted to adoption in the domestic market only, i.e., CBA does not quantify any potential export income for Australia as a consequence of this work. Notwithstanding these are highlighted in the qualitative analysis in Section 7.

The assessment captures additional economic costs and benefits arising from the uptake of the UltraFine+® technology for key stakeholders involved in this initiative, which include (but are not limited to):

i. LabWest
ii. Private and public sector mineral exploration companies
iii. CSIRO (Minerals and Data61 BUs)
iv. Government (federal, state, and local)
v. Customers and the broader community

However, there currently is insufficient information available to allow a distributional analysis of the welfare gains to the different stakeholders from the R&D and adoption of UltraFine+®.

## Project and Counterfactual Scenarios

### Project Scenario

The use of UltraFine+® technology for soil analysis over 0-30 m of transported cover.

### Counterfactual Scenario

The continuation of the use of the traditional methods for soil analysis of transported cover in the absence of a comparable domestic or overseas solution.

The assessment hypothesises several scenarios of adoption and impact for the estimation of benefits.

**Box 3 Key differentiators of UltraFine+® vs Traditional soil analysis methods**

i. Elimination of nugget effect in gold exploration. Particularly valuable on-sites that are difficult to explore.
ii. Enhanced detection sensitivity (100 – 300 %) i.e., the UltraFine+® samples are more likely to see gold and other minerals. This is particularly of huge value in low detection areas.
iii. Improved accuracy. Particle refinement process improves the ability to see through cover, eliminate anomalies, and gives more confidence in the data for minerals exploration companies to generate targets.
iv. Reduced need for conducting AC programs in some cases.
v. Imparts the ability to reach the finish line sooner, i.e., establish the commercial viability of a deposit.
vi. Standardised and simplified nature of technique with integrated workflow. Most of the processing occurs at the lab, so any differences induced by samplers are remedied at the lab without compromising the analysis results.
vii. Provides more information in one pass and significantly reduces the need for resampling. Additional information helps practitioners better understand what is happening within the system and decrease the risk to some extent in exploration activities.
viii. Better suited for emerging needs of the industry such as interest in critical and high-value rare earth elements.
ix. Comparable solutions do not exist in Australia or overseas. Even clay fraction analysis is not comparable to UltraFine+® analysis. In most cases, the black-boxed nature of solutions and their cost intensive nature affects the trust in techniques and their uptake by industry. UltraFine+® is cost-effective and based on simple conventional assay. This has helped drive interest in technique and its adoption.

## Timelines for costs and benefits

**Costs:** The costs considered in the cost-benefit analyses include the costs incurred by CSIRO and the research partners to produce the UltraFine+® research outputs since FY2015. Additional in-kind contribution by industry was not captured due to data limitations. Any new investment in the original UltraFine+® research (under investigation in this review) has seemingly stopped around FY2021, based on information provided by the R&D team.

**Benefits:** The net benefits from the program are estimated as the difference between the 'with program' (project case) and 'without program' (counterfactual case) scenarios. Where data is available, usage and adoption costs borne by end-users should have been included in the analysis and deducted from benefits. For any R&D work, there are lags between the delivery of the technology and the realisation of benefits post-adoption.

The analysis involves a small component of ex-post analysis (relating to the benefits in the period FY2020 to FY2023), and a component of ex-ante analysis forecasting the benefits flowing from the research activities over the period FY2024 to FY2033. A conservative approach is adopted wherein the future benefits are assessed for 10 years. This period is arbitrarily chosen to keep the CBA consistent with other CSIRO impact evaluations. In fact, the benefits are expected to flow much beyond this period. However, the benefit and cost projections beyond 10 years help reduce the inherent uncertainty inherent in estimating future benefits and costs.

**Table 3: UltraFine+® technology development and adoption timeline**

| | |
|---|---|
| R&D inception (CSIRO) | FY2015 |
| Commercialisation (LabWest) | FY2020 |
| Costs assessment period | FY2015-FY2021 |
| Benefits assessment period | FY2020-FY2033 |
| | Ex-post: FY2020-FY2023 |
| | Ex-ante: FY2024-FY2033 |

## Adoption

*How much of the anticipated impact is still to occur?*

The adoption level of technology is expected to increase once threshold confidence is achieved through early adopters. As indicated by point A in Figure 5 below, the UltraFine+® method is currently in its early phase of adoption, and most of the anticipated impact is yet to occur. It must be noted that Figure 5 is for indicative purposes only. For the monitoring and evaluation of impact, mapping the adoptionpathway and indicators of progress towards targetedadoption levels would be useful for the purpose ofimpact management.

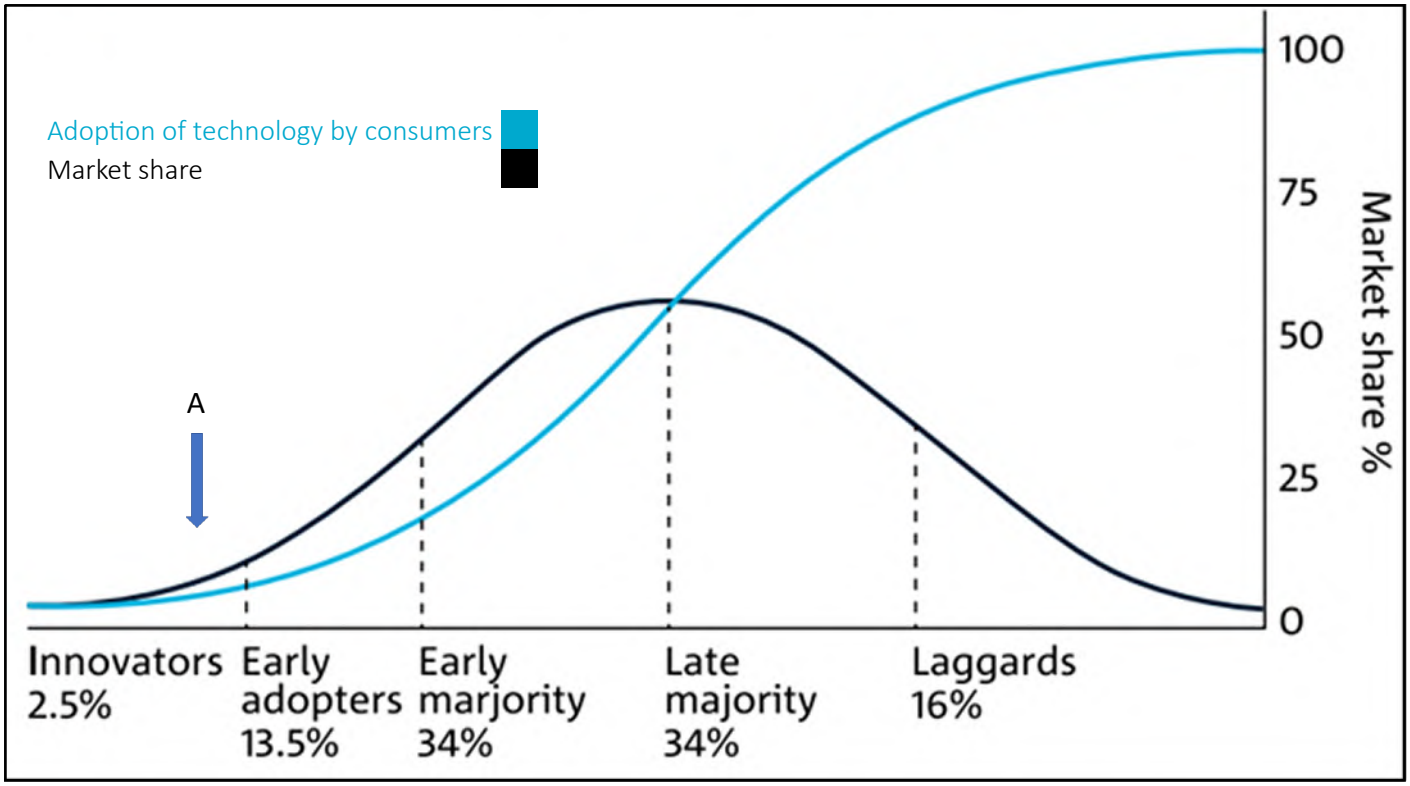



**Figure 5: Indicative impact adoption profile.[14] 'A' indicates the current adoption level of UltraFine+®**

*[14]Source: Rogers, 1995, p.247 (provided in CSIRO Impact Evaluation Guide Feb 2020). The gentle bell-shaped curve represents the groups of consumers adopting a new technology and the S-curve represents the market share which reaches 100% following complete adoption.*

# 6 Quantitative assessment of impacts

## A. Modelling approach

**Information source:** CSIRO UltraFine+® R&D team, LabWest, Dreadnought, GeoSpy, DEM, Capricorn Metals, Iceni Gold, Lodestar Minerals

**Box 4: Impact = ƒ (Proprietary product, Adoption at scale)**

Impact will be delivered when a robust technology is adopted. The quantum of impact is directly dependent upon the depth (incremental benefits), duration (period of benefits) and scale of adoption.

This section discusses the key benefits streams under focus for the quantitative evaluation of impacts from the adoption of UltraFine+® technology. Due to the early-stage nature of this work, a narrow lens has been applied to quantify the benefits. The net benefit to Australian society of UltraFine+® is assessed as the **additional social costs and additional social benefits** over and above the traditional soil sampling procedures, i.e., the difference between "With (Project Case)" and "Without R&D (Counterfactual Case)" scenarios.

### 1. LabWest Benefits (B1)

#### UltraFine+® sampling - costs and margins

UltraFine+® analysis is offered by LabWest as two popular packages:

- UltraFine+®Full-suite: Average price - $61.60/ sample
- UltraFine geochemical-only: Average price - $45.80/ sample
- Traditional sampling: Average price - $45/sample

As briefly mentioned earlier, UltraFine+® utilises a much simpler preparation procedure, one that does not require the manual and energy-intensive processing (drying, crushing, and grinding) as the the traditional soil sampling process. This is expected to positively benefit the health and safety of the workforce involved in the sample preparation process and free up their time to focus on more stimulating and higher value-added analysis tasks. However, UltraFine+® does require more back-end data handling by qualified chemists than usual 'off-the-shelf' techniques. Overall UltraFine+® is reported to have lower analysis costs and higher profit margins and **hence gross profit for LabWest on either option averages about $10/sample more than equivalent traditional analysis packages.** Increase in consumers' willingness to pay is reflected by upto 35% premiums paid for the UltraFine+® Full-suite sampling, and an increase in demand for LabWest's services.

**The benefits for LabWest from UltraFine+® services are measured as lower upstream analysis costs, new revenue and demand enabled by UltraFine+® vs 'Traditional technique' sample processing.**

It is important to note that the results from the two kinds of analyses – Traditional and UltraFine+® are viewed as two different products. The industry experts noted that the UltraFine+® technique cannot be seen as more expensive than traditional techniques, because these are not comparable. The quality and quantity of outputs from UltraFine+® are significantly higher and provide a wider field of view compared to a traditional technique. To clarify further, a comparable 'traditional technique' does not exist. In cases where Australian Laboratory Service's AuME-ST43 (analytical suite) option is added to traditional methods to make them comparable with analysis, detection limits and sample preparation, the sampling costs are $70/sample (i.e., higher than the cost of the UltraFine+® Full-suite), without including the additional information offered by UltraFine+® suite.

Since various techniques that are used to provide the full UltraFine+® data package are bundled by LabWest, including clay separation; sample digestion and analysis by Inductively coupled plasma-optical emission spectroscopy (ICP-OES) and Inductively coupled plasma mass spectrometry (ICP-MS); Near-infrared spectroscopy (NIRS) for clay minerals; Fourier transform infrared (FTIR) Spectroscopy for organic carbon content; laser sizing of head sample; and pH and EC analysis the UltraFine+® package is cost-competitive with traditional techniques (which only offer preparation plus the digestion and ICP analysis). If all these techniques utilised for UltraFine+® were charged at usual commercial rates, the package costs would be well over $100 per sample, as opposed to the current price of $61.50/sample. Market review also suggests highly competitive price of UltraFine+® sampling compared to competitor pricing of comparable solutions.[15]

| Stakeholder | Estimated additional benefits (vs traditional methods of soil sampling) |
|---|---|
| | **Initial Impacts** |
| **LabWest**<br>**Outcomes (in-focus):** Revenue Growth (and Customer Growth) | ↑ revenue (from higher gross profits, price premium and increased demand induced by UltraFine+®)<br>↑health and safety of the workforce<br>Improvement in baseline traditional analysis |

### Benefits to other analysis offerings at LabWest

Continued development of the UltraFine+® technique has delivered incremental benefits to the baseline traditional analysis as well. These include lowering of ICP-MS detection limits, improving ability in controlling digestion parameters, and removing inter-batch variations. It is difficult to estimate how much of this would have been undertaken regardless, but LabWest claims UltraFine+® development certainly helped drive these improvements for the traditional technique.

## 2. Mineral exploration companies benefits

### i. Incremental on-site sample collection cost savings (B2)

Sample collection for UltraFine+® (~200g/sample) offers cost savings compared with traditional sampling (~2kg soil/sample) methods as the required sample size is 1/10th. The on-site sample collection cost savings are expected to be delivered in one or more of the following ways:

a. Lower transportation and storage costs and time savings, which are particularly significant when exploration sites are in very remote locations, with limited access to courier services. Lower sample amounts are also expected to deliver significant savings in the cases of transporting samples from other parts of Australia and the world.

b. Ability to collect samples even when the soil is wet. For UltraFine+® sample collection, the soil doesn't need to be dry as required for the traditional process. This has been reported also to deliver time (and cost) savings.

| Stakeholder | Estimated additional benefits (vs traditional methods of soil sampling) |
|---|---|
| | **Initial Impacts** |
| **Gold exploration companies**<br>**Outcomes (in-focus):** On-site sampling cost and time savings | ↓ on-site sampling costs (time/effort/transportation costs savings)<br>↓costs from reduced need to resample/perform AC drilling program/ improved ability to better target AC drilling |

[15] https://www.alsglobal.com/-/media/ALSGlobal/Resources-Grid/Fee-Schedule-Geochemistry/2023/ALS-Geochemistry-Fee-Schedule-AUD-2023.pdf

### ii. Incremental cost savings from reduced needs to resample or perform Air Core drilling program/ improved ability to better target AC drilling (B3)

Traditional sampling frequently returns null results. The confidence rating in the sampling results is significantly low and hence requires the exploration companies to undertake resampling and expensive AC drilling in >50% of cases. AC program typically costs ~ $1500/sample, requires additional labour costs, and additional approvals for drilling and leads to a significant environmental and cultural disruption.

The use of UltraFine+® reduces the need to resample/ perform the AC program, as the robust geochemical analysis imparts a high degree of accuracy in results. UltraFine+® generates well-defined anomalies in transported sand and part of the sample collected that is unsuitable for analysis. This helps to bypass intermediate stages of exploration (such as AC) and move directly to the RC process in some cases (also See Section 4 – Outcomes (ii)). Resampling is only required in cases where targets are identified.

In cases where the exploration companies still choose to perform AC drilling, it helps to target the drilling better (be more precise with more confidence on drill spacing) as the highlighted structures from UltraFine+® are significantly better. This speeds up the process while delivering cost and time savings.

**Table 4: UltraFine+® CSIRO revenue and royalties**

| Project | Actual | |
|---|---|---|
| | Revenue | Royalties |
| **MRIWA M462 -Ultrafine Au for exploration**<br>Duration: 3 years<br>CSIRO WBS: MRIWA M462 | **510,000** | |
| **De Grey UltraFine+®Surface Geochemistry**<br>Duration: 6 Months<br>CSIRO WBS: R-15090-01 | **91,749** | |
| **LabWest Technology & Trademark Licence_F**<br>Duration: Ongoing since FY2020<br>CSIRO WBS: R-90068-03 | | **410,504** |

### iii. CSIRO Benefits (B4)

CSIRO Minerals BU provided data on the outlays for the UltraFine+®initiative from FY2015-FY2021 (Table 1). These program costs are included in the CBA. In addition, the data on own-source revenue generated by the initiative that includes revenue from contracts with customers, royalties and licence fees have also been provided to Tractuum for inclusion in the analysis. This data provides direct evidence for CSIRO revenue in the form of royalties and flow-on work from the reputational gains attributable to UltraFine+®. However since the CBA is being performed from Australia's perspective, these transfer payments between stakeholders have not been included in the analysis.

| Stakeholder | Estimated additional benefits (vs traditional methods of soil sampling) |
|---|---|
| | Initial Impacts |
| **CSIRO** | ↑CSIRO revenue from royalties and flow-on work attributable to UltraFine+ |

## B. Economic Model

This section quantifies potential incremental economic benefits against incremental costs, from the adoption of UltraFine+® for mineral exploration and discovery in Australia. The net impact is estimated by comparing estimated expected benefits with the base reference point, i.e., a hypothetical scenario in the absence of this intervention (namely, with traditional processing technology).

Table 5 below highlights the benefits assessment model. As there is a large component of the prospective assessment of benefits in this analysis, all estimates presented in the following Results section are to be interpreted as probable, should adoption, impact, and use cases emerge as hypothesised. Overall, it is recommended to focus on the direction of benefits rather than on the specific quantitative value. The Sensitivity Analysis in Part D of this section considers low, medium, and high i) impact scenarios and ii) adoption scenarios, for the estimation of benefits in cases where assumptions have been made to conduct the analysis.

**Table 5: CBA: Costs and Benefit streams**

| Background | Assessment of Economic Benefits | Value | Source of Data and Assumptions | Comments |
|---|---|---|---|---|
| **i. CSIRO R&D Investment/ Costs (C)** | FY2021<br>Σ (Project Costs) in PV ($ AUD)<br>n=FY2015 | $1.38 mil | – CSIRO (Table 1) | – The costs have been recalculated to express PV ($ AUD) using CPI and real discount rate of 7 % |
| | Costs with deadweight loss of government (added 20%) | $1.66 mil | | |
| **ii) LabWest Usage/Adoption Costs (A)** | **Usage/Adoption Costs - A**<br>Incremental UltraFine+® adoption costs | Not available | NA | – Information on incremental adoption costs is commercial in confidence (CIC) and not available for analysis. |
| **iii) Benefits Stream 1 - LabWest Benefits (B1)** | **Benefits - B1**<br>**i. New income from incremental – gross profit/sample and new demand enabled by UltraFine+® soil sampling process for the assessment period:**<br>FY2033<br>Σ ($O_n$*10) + ($O_n$'-$O_n$)*($U_c$) in PV ($ AUD)<br>n=FY2020 | See Results section | | – Gross profit margins for UltraFine+® are marginally higher than traditional technique, as reported by LabWest.<br>– The indicative new income is from incremental gross profit, premium on soil sample processing and new demand that is over and above the traditional soil sampling, enabled by the adoption of UltraFine+®.<br>– The actual sample processing profile from FY2020 (last 6 months ONLY) to FY2023 (first 6 months ONLY) as provided by LabWest is given in Appendix A<br>– For the purpose of CBA average cost of UltraFine+® analysis was calculated based on overall samples processed and cost of each package.<br>– Overall samples processed for FY2023 (last 6 months) is assumed to be the same as the first six months for the purpose of this analysis.<br>– Adoption from FY2024 to FY2033 is based on the conservative assumption of a YoY increase of 10% during the first 5 years (FY2024-FY2028) and 5% during the next 5 years (FY2029-FY2033). These have been estimated on the basis of inputs from LabWest. Both domestic and international markets are expected to offer growth prospects.<br>– Any $ benefits to LabWest from improvement to baseline traditional analysis enabled by UltraFine+® have not been estimated. |
| | $O_n$-Overall samples processed/ expected to be processed using traditional soil sampling technology in the absence of UltraFine+® in year n(#)<br>$O_n$'-Overall samples processed/ expected to be processed using UltraFine+® soil sampling technology in year n(#) | – Incremental Gross Profit - $10/sample<br>– Baseline Year - FY2020<br>– Overall samples processed/ expected to be processed:<br>• For FY2020 (last 6 months)-FY2023 (first 6 months)<br>• For FY2024 to FY2028: 10% YoY increase<br>• For FY2029 to FY2033: 5% YoY increase<br>See comments | LabWest<br>LabWest estimates an overall sampling rate increase of at least 50% attributable to UltraFine+® | |
| | Uc- LabWest Sampling income with UltraFine+®($/sample) | – UltraFine+® Full-suite: $61.60/sample<br>– UltraFine geochemical-only: $45.80sample<br>– Weighted average: $52.5/sample | LabWest, Dreadnought, GeoSpy | |
| | Tc- LabWest Sampling income with traditional methods ($/sample) | Tc = $45 | | |

| Background | Assessment of Economic Benefits | Value | Source of Data and Assumptions | Comments |
|---|---|---|---|---|
| **Benefits Streams: B2 and B3 – Mineral exploration companies** | **Benefits – B2**<br>**i. Incremental costs saved on-site (from reduced time, effort, transportation and storage required)/sample collected for the assessment period**<br>FY2033<br>$\Sigma (O_n * X * Y * Z)$ in PV ($ AUD)<br>n=FY2020<br><br>X- On-site sample collection costs with the traditional method ($/sample).<br><br>Y – Costs saved/soil sample (%) upstream of UltraFine+®soil sampling workflow step (i.e., from sample collection at mining site to LabWest).<br><br>Z-Overall samples (%) for which LabWest sample amount guidelines are adopted to unlock these savings. | – X = $50/sample<br>– Y = 5% (estimated)<br>– Z = 50% (estimated) | Capricorn Metals, Dreadnought, GeoSpy, Iceni Gold, LabWest, Lodestar Minerals | – The benefits include costs saved on on-site sample collection from factors discussed in the last section.<br>– The overall cost savings/sample is an arbitrary, but conservative, estimate based on inputs from industry experts.<br>– A dialogue with different customers from the industry highlighted that some of them still prefer to send the traditional sample sizes of 2kg for UltraFine+® analysis to LabWest 'just to be safe', even though it is unnecessary. LabWest guidelines indicate sample requirements of 200 grams ONLY. Hence it is assumed that these savings are only realised for 50% of samples processed using UltraFine+®. This is again an arbitrary, but conservative, estimate based on inputs from industry experts. It also highlights an opportunity to improve awareness about sample collection guidelines among the customers to realise this benefit to a greater extent.<br>– Since the new demand has been assumed to be induced by UltraFine+® On is used to calculate incremental cost savings in this case instead of On' i.e. for the 'without program' scenario. This also keeps estimated benefits conservative. |
| | **Benefits – B3**<br>**i. Incremental cost savings from reduced needs to resample or perform Air Core drilling program/ improved ability to better target AC drilling (B3)**<br>FY2033<br>$\Sigma (O_n * D * E)$ in PV ($ AUD)<br>n=FY2020<br><br>D – AC drilling costs/site ($/site)<br><br>E - Overall samples (%) for which UltraFine+® mitigates the need for AC drilling (%) | D = $1500/site<br><br>E = 1% (estimated) | Dreadnought | – The benefits include costs saved from the ability to bypass AC drilling in some cases as discussed earlier in the assessment.<br>– A dialogue with different customers from the industry highlighted that the need for AC is eliminated in selected cases; however, in cases where resourcing is not a constraint (such as with bigger mineral exploration companies), they prefer to still perform AC drilling after UltraFine+® sampling to ascertain the commercial viability of the site.<br><br>Hence it is estimated that UltraFine+® eliminates AC drilling for only 1% of the overall samples processed. This is arbitrary, but a very conservative estimate considering inputs from industry experts.<br>– Any benefits from UltraFine+® to enable a better targeted AC program (thereby saving costs and time) have not been accounted for, to keep the assessment conservative. |
| **Overall Value Generated** | B1+ B2 + B3 - A | | | |
| **CSIRO Attribution** | CSIRO cost contribution/ Overall Investment | 40% | | |
| **BCR** | (B1+B2+B3-A)/C | | | |
| **NPV** | (B1+B2+B3-A) - C | | | |

### Assumptions

i. The R&D investment and adoption costs are assumed to have been incurred at the beginning of the period.

ii. Any benefits are assumed to have occurred at the end of the period.

iii. The discount rate has been assumed to be 7% based on CSIRO's Impact Evaluation Guide.

iv. For other assumptions, please see the comments section in Table 5 above.

## Other Comments

The strong growth in uptake between July 2020 and June 2022 can be attributed largely to the initial wave of interest in the UltraFine+® technique following a significant marketing effort and technical publicity by Ryan Noble (PI), CSIRO.

Growth has levelled off as market awareness has approached saturation, especially in WA, and underlying demand for regional exploration analysis has decreased, following global minerals exploration cycles.

It is anticipated that the growth in uptake of the technique will resume, depending upon factors such as:

i. companies who have undertaken orientation studies decide to proceed with the technique in their larger programs

ii. interest in the Stage 2 (Next Gen Analytics tool) project once completed, and the resulting products made commercially available, notwithstanding UltraFine+® is not dependent on the Next Gen prototype.

iii. there is a significant 'smoking gun' discovery of a commercially attractive deposit attributable directly to the UltraFine+® technique

iv. growth in demand from other parts of Australia as well as overseas markets.

## Limitations

As such, our analysis is limited by the constraints and uncertainties within the information used. To account for these limitations, where possible, any assumptions have been based on scientific and/or economic literature. However, in some cases, limited information exists for reference. These cases have been subject to sensitivity analysis in Section D below and/or discretion explicitly advised in the report.

*Source: nsenergybusiness*

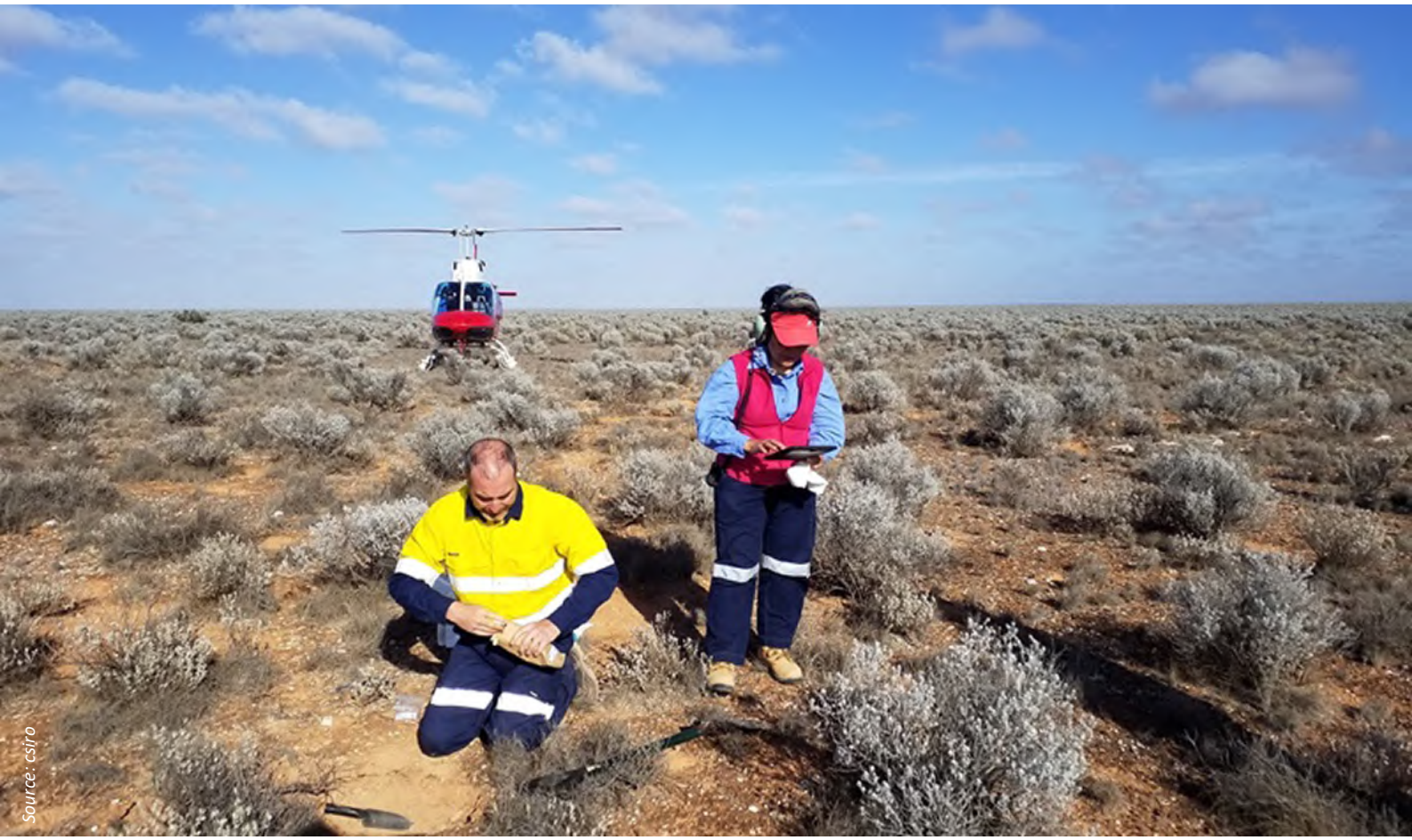
## C. Results

Table 6 below presents the results of the CBA, using two-key metrics – BCR and NPV.[16,17] The CBA measures the benefit to Australia (for Project scenario, See Section 5) and private net benefits for CSIRO as a result of this work. To keep the analysis conservative, this assessment also accounts for deadweight loss of government taxation for the Project Scenario. These CBA results are determined on the basis of assumptions outlined in Table 5 above and form basis for Sensitivity Analysis discussed in the next section.

**Table 6: Results of Cost Benefit Analysis**

| | Base Case | | | |
|---|---|---|---|---|
| | **Incremental Costs** ($ in million, FY2023 AUD) | **Incremental Benefits** ($ in million, FY2023 AUD) | **BCR** | **NPV** ($ in million, FY2023 AUD) |
| **Overall (Project Scenario)** | 1.38 | 50 | 36 | 48.6 |
| **Private Net Benefits - CSIRO** | 0.56 | 21.75 | 39 | 21.2 |
| **Overall** (with deadweight loss of 20%) | 1.66 | 50 | 30 | 48.3 |

As indicated in Table 6 above, the anticipated benefits to Australia from UltraFine+® R&D are estimated to significantly outweigh overall investment costs. Similarly, benefits attributable to CSIRO outweigh CSIRO's investment costs.



Source: csiro

[16] *See Section 5 Methodology, CBA*

[17] *BCR: The ratio of the present value (PV) of economic benefits to PV of economic costs over the evaluation period*
*NPV: The PV of economic benefits delivered by the UltraFine+® less the PV of the costs incurred.*

## D. Sensitivity Analysis

The CBA is necessarily based on a series of assumptions which implies that there is a degree of uncertainty around the results. Sensitivity testing has been undertaken to clarify which assumption can materially change the results and has been undertaken on the key parameters that include Real discount rate, LabWest demand, Sample collection cost savings (variable Cost savings/client adoption of LW on-site sample collection guidelines), elimination of AC drilling. The analysis is conducted to reduce uncertainties through identification of inputs that cause significant fluctuations in the outcomes of interest. It considers low and high scenarios for these variables and compares it against the Project Case, covered in Table 6.

**Table 7: Sensitivity testing results (each parameter range tested individually; all others held equal; all $ in million, 2022/23 AUD)**

| | Base Case | | | |
|---|---|---|---|---|
| | **Incremental Costs ($ in million, FY2023 AUD** | **Incremental Benefits ($ in million, FY2023 AUD)** | **BCR** | **NPV ($ in million, FY2023 AUD)** |
| **Discount Rate** | | | | |
| Pessimistic -10% | 1.66 | 44 | 26 | 42 |
| Optimistic -5% | 1.22 | 55 | 45 | 54 |
| **LW Demand** | | | | |
| Pessimistic: BC -5% | 1.38 | 41 | 30 | 40 |
| Optimistic: BC +5% | 1.38 | 61 | 44 | 60 |
| **Sample collection cost savings (variable - cost savings)** | | | | |
| Pessimistic: BC -5% | 1.38 | 49 | 36 | 48 |
| Optimistic: BC +5% | 1.38 | 51 | 37 | 49 |
| **Sample collection cost savings (variable - client adoption of LW on-site sample collection guidelines)** | | | | |
| Pessimistic: BC -10% | 1.38 | 49.7 | 36 | 48 |
| Optimistic: BC +10% | 1.38 | 50.3 | 36 | 49 |
| **Elimination of AC drilling** | | | | |
| Pessimistic: BC -0.5% | 1.38 | 45 | 33 | 44 |
| Optimistic: BC +0.5% | 1.38 | 55 | 40 | 53 |

Based on the above results, the variation in a) Discount rate and b) LW demand will have most significant effect on overall benefits delivered by this research. In other words the prospective economic benefits from the development and adoption of UltraFine+®are most sensitive to these factors.

# 7 Qualitative assessment of impacts

## i. UltraFine+® Next Gen Analytics tool

*Precious, base and critical metals*

### *The Outputs - UltraFine+® Next Gen Analytics*

The UltraFine+® Next Gen Analytics workflow infrastructure is an outcome of the foundational UltraFine+® work. The broader Next Gen Analytics research project consists of three main components:

- refining the UltraFine+® soil analytical method designed to extract mobile element signatures from the ultrafine fraction (<2 µm) of a given sample by lowering detection limits and adding additional soil properties (pH, electrical conductivity, soil sizing and spectral mineralogy) to the standard soil analysis;
- developing the Next Gen Analytics workflow using machine learning to create landscape context from spatial data features for soil geochemical interpretation; and
- providing a comprehensive data package to project sponsors.

### *Prospective benefits*

- If successful, the tool has the potential to deliver a paradigm shift in precious, base and critical metals exploration in Australia by combining UltraFine+® soil analyses methods with intelligent data integration tools, adding value to routine soil sampling in frontline exploration and shaping mineral exploration approaches for decades, while delivering the information in a user-friendly form.
- Access to reliable, cost-effective, regolith information as a part of the workflow is significant in the era of declining regolith expertise.

  Under the current scenario, these analyses have to be conducted by expert consultants and can take up to a months. The access to a platform is expected to improve access to the information, knowledge, and interpretation to support the consultants in their decision-making and accelerate analysis by >50%.
- These potential capabilities can assist the entire industry by improving the speed of the determination of the viability of discovery (successful/unsuccessful) and its efficacy. As per the available information, there is no comparable ML-based end-to-end solution available within Australia or globally. Some bigger companies deploy ML experts to analyse past data, interpret data and optimise workflows in ML value chain to inform upstream and downstream processes. However, most of the off-the-shelf solutions are manual and there are no suitable technologies that can be imported. A solution like Next Gen Analytics particularly benefits smaller mineral exploration companies (SMEs) that do not have in-house expertise, rely on external consultants, and have limited resources.

Based on interviews conducted for this review, there is significant enthusiasm within the industry to test and try the capabilities of this new platform to prioritise target areas for exploration, simplify and accelerate the ability of explorers to review their data and potentially test and utilise it for the detection of critical and high-value rare earth elements.

### *Roll-out plan*

CSIRO's brand recognition as a trusted advisor is expected to help drive confidence in the adoption of this service that is expected to involve the exchange of commercially sensitive information with the exploration companies. As mentioned earlier in the report, the platform is expected to be rolled out for commercialisation in FY2025.

## ii. Employment Contributions / Jobs

Prior to UltraFine+® commercialisation, LabWest had 15 employees. The business has rapidly grown since then to its current headcount of 25. As reported earlier, 80% of the staff is dedicated to UltraFine+® operations and hence the work has led to the creation of new jobs.

There is insufficient data to determine any evidence of indirect employment benefits, e.g., in backward linked industries or induced employment (forward linkages).

It should be noted that, although estimates of job creation opportunities are generally of interest to decision-makers and can be reported separately from the CBA to provide a comprehensive outline of expected impacts, any additional employment (typically described as 'jobs created') is not an economic benefit. For more details see Appendix C.

### iii. Environmental

UltraFine+® requires lesser sample amount (1/10$^{th}$) and generates relatively lower drilling footprint (vs traditional soil sampling). In the cases where it can reduces the need for re-sampling or AC drilling, there are expected to be additional benefits from lesser environmental and cultural disruptions. However in most cases the incremental environmental benefits are estimated to be minor and hard to quantify at this stage due to limited data.

### iv. Collaborative initiative

UltraFine+® Next Gen Analytics is being led by CSIRO in collaboration with >30 industry sponsors and state geological surveys. The development brought together Minerals BU with Data61, the digital arm of CSIRO, to provide deep regolith expertise through digital solutions to drive minerals exploration.

For LabWest, the uptake of technology has led to greater depth and breadth of communication with customers. Earlier, the services of LabWest were used as a commodity simply to get the soil analyses done. However, with the uptake of UltraFine+®, the information sharing of clients with the SME has increased considerably. The interviews highlighted that the clients regularly share wider levels of information - including sensitive information such as location coordinates of samples with LabWest to improve quality control. Hence the uptake of technology has helped weave greater trust between key stakeholders.

The new networks with other BUs within CSIRO, private and public sector mineral exploration companies, SMEs and likely Universities (in future) are expected to contribute towards raising the benchmark of the industry's collaborative ecosystem through knowledge transfer, and the sharing of capabilities that may have otherwise remained highly localised. These shifts also help with delivering improved creativity, expanded networking, enhanced strategic leadership and management structures, and expedited capacity-building which are all critical but hard to quantify.

### v. Export revenue

UltraFine+® has created prospects to open opportunities for global collaborations and exports. These avenues can generate new revenue streams; diversify risks (from expanded markets); and drive larger economies of scale and better profit margins for CSIRO and LabWest, while highlighting Australia's competitiveness in global mineral exploration markets. As mentioned earlier, the technique has recently been tested by users from six countries with efforts underway to attract customers from other regions. The export revenue, although not quantifiable at this time, should be closely monitored as a critical benefit stream from this research if traction is realised from overseas markets.

### vi. Other applications

UltraFine+® has potential applications beyond those highlighted in the economic analysis. The technique is being deployed by DEM, SA to improve state-wide geochemistry knowledge. Stakeholders reported that the technique provides a cost-effective way to deliver more knowledge about the environment, with higher accuracy and reliability to support other industries such as environmental management, and ecological studies (national parks, etc.). Some sample libraries are also being re-sampled to obtain wider analysis data that can render better insights about the existing systems; create baselines; measure changes over time; and plan future interventions.

*Source: CSIRO*

# 8 Conclusions and confidence rating in impact assessment

The UltraFine+® R&D is aspirational with the potential to address existing challenges in greenfields mineral exploration in Australia and globally. The CBA conducted with conservative assumptions indicates a BCR of 36 and NPV of ~49 mil AUD (in PV). Based on key stakeholder interviews, the most significant benefits to the exploration industry are derived from greater confidence in soil analysis results imparted by the technique and quicker ability to determine the commercial viability of deposits. The future adoption interest in the technique would significantly depend upon the discovery of a commercially attractive deposit attributable to UltraFine+®. The adoption of UltraFine+® in overseas markets and future offerings of the Next Gen Analytics tool also have the potential to offer new growth prospects. Improved support for the core R&D team and greater involvement of BD and Commercialisation teams are critical elements to improve impact performance of this initiative.

The current assessment is largely ex-ante, with a small ex-post component. Data that underpins the CBA is based on the CSIRO's internal information, LabWest data, advice from external stakeholders, literature review, and calculated assumptions. In all instances, lower-bound estimates and conservative assumptions have been used. The benefits included under qualitative analysis (which includes environmental and social impacts) are covered as additional benefits. Hence, although the results are informed approximations, the benefits from UltraFine+® R&D are expected to significantly outweigh the costs.

Due to inherent ambiguity associated with how the future might unfold, and the longer-term time frames, the confidence rating in the benefits assessment for this study is rated as medium-low by Tractuum.

This impact assessment provides a significant blueprint to conduct impact management for UltraFine+® in the future. Future monitoring and measurement of the adoption of the technique and tracking the ultimate benefits to initial/end-users would help generate the necessary evidence to support a more robust impact assessment in the coming years while addressing data constraints and bottlenecks in the impact delivery process.

# APPENDIX A Samples Processed

| Period | UFF Samples Processed* |
|---|---|
| 01/01/2020 to 30/06/2020 | 5,021 |
| 01/07/2020 to 30/06/2021 | 50,696 |
| 01/07/2021 to 30/06/2022 | 125,248 |
| 01/07/2022 10 31/12/2022 | 47,920 (i.e., 6 months) |

Note: these figures include the full UFF+ analysis package, as well as a reduced-cost option that only includes the geochemical analysis, which is preferred by many smaller explorers.

# APPENDIX B References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CSIRO UltraFine+® team – UltraFine+

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https://www.csiro.au/en/about/strategy

https://www.csiro.au/en/about/challenges-missions/challenges

CSIRO (2020) Impact Evaluation Guide

# APPENDIX C Employment Contributions

It should be noted that any additional employment (typically stated as 'jobs created') is not an economic benefit. Just as for any other resource, use of additional labour resources imposes an opportunity cost on Australian society because those workers cannot be used elsewhere to produce goods or services. In addition, some workers will simply transfer from other jobs (potentially including from CSIRO positions), so the net creation of jobs will be zero. Those workers who are employed in new positions will obtain a wage, but the cost of the wage is borne by employers, so the net benefit to society is zero, except for any additional profit (producer surplus) that is generated. Nevertheless, estimates of job creation opportunities are generally of interest to decision-makers, and they can be reported separately from the cost-benefit analysis to provide a comprehensive outline of expected impacts.

In principle, the engagement of an unemployed worker with no other clear job prospects imposes no opportunity cost on society. In a situation of structural (i.e., non-cyclical) unemployment, therefore, society can benefit from the creation of new jobs that are filled by the unemployed. But this benefit can only be realised if the skills of the currently unemployed workers match the competencies required in the newly created jobs. Further, any benefit to the newly employed workers, and hence society, would be offset to some extent by their loss of leisure (i.e., non-work) time, which can also result in social benefits through activities such as child-minding, gardening, relaxation, exercise, etc, that are valued by the worker.

Taxes have a depressive effect on the economy by reducing aggregate demand and/or output. They, therefore, reduce job opportunities and profits. To the extent that the UltraFine+® R&D is funded by CSIRO and other funding sources through government taxation, there will be some potential loss of jobs in the economy. In other words, it cannot be claimed without qualification that there will be a straightforward increase in employment levels attributable to the UltraFine+® project.

# APPENDIX D ULTRAFINE+® sponsors and users

## Sponsors

Geological Survey of Queensland, Geological Survey of South Australia, Geological Survey of New South Wales, Northern Territory Geological Survey, Geological Survey of Western Australia, Kalamazoo Resources, MCA Nominees, Iceni Gold, Siren Gold, Dreadnought Resources, De Grey Mining, Carnavale Resources, Fortescue Metals Group, Newmont, Northern Star Resources, Kairos Minerals, Emmerson Resources, Independence Group, Western Gold Resources, Capricorn Metals, Hexagon Energy Materials, Monger Gold, Strategic Energy Resources, Barton Gold, Ozz Resources, Anax Metals, Lodestar Minerals, Anlgo Gold Ashanti, Antipa Minerals, Encounter Resources, First Quantum Minerals, Gold Road Resources and Southern Gold. In-kind support for the project was provided by CSIRO and LabWest.

## Users

### Domestic

ASX releases referring to LabWest UltraFine+® analysis

Regional map showing UltraFine+® projects in Australia

### Global

Finland, Japan, Tanzania, Burkina Faso, New Zealand and Namibia.