UNLOCKING AUSTRALIA'S HIDDEN POTENTIAL.





An industry roadmap.





Delivering solutions through collaboration



Coordinated by AMIRA International August 2017

In collaboration with UNCOVER



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FOREWARD – MAKING A DIFFERENCE

A great many people have been involved in the preparation of the AMIRA Roadmap for Exploration Under Cover. The collective wisdom of the contributors has created a blueprint that, if successfully executed, will make a difference to the success rate of exploration.

In Australia we have effectively sterilized some 30% of the landmass where the majority of the historical discoveries have been made, at or near the surface. Although, it is true that we are likely to find additional resources and reserves near or below existing mines, these are likely to be lower grade and more complex thus more energy and water intensive to extract, unless new technologies come along that will make a difference. So the truly big and untapped opportunity lies in areas of cover, the remainder 70% of Australia's landmass, where the next Olympic Dam, Mount Isa, Broken Hill or Kalgoorlie's Golden Mile is waiting to be discovered. If only half of this area under cover is explorable and mineable it will double our area to search.

The approaches and the exploration toolkit of the past 60 years are unlikely to be sufficient to help us discover this hidden wealth. Indeed this has been the rational for the development of this Roadmap. It is clear, as the UNCOVER initiative demonstrated, that we face some important challenges before we can significantly de-risk exploration in areas of cover. During the roadmapping process these challenges were examined in depth and led to a programme of work that addressed research, technology development and new data acquisition that collectively are necessary to make a difference to our chance of discovery in areas of cover.

So the Roadmap is a call to arms, to address critical issues that if neglected will severely erode Australia's future ability to maintain a leading role as exporter of mineral resources, together with mining technology and services, which have significantly underpinned Australia's economic growth and wealth creation since the 1960s.

The publication of the Roadmap must now be followed by collective action. As the Roadmap implies we need to be thinking differently, less partisan, and more of a "Team Australia" approach. The successful implementation of the Roadmap will require the active support and participation of all sectors of industry: explorers, miners and METS suppliers. This support will come in many forms, from providing co-funding; active monitoring and guidance of research activities; and provision of data and information.

To deliver the necessary solutions to the challenges identified by the Roadmap in a timely and cohesive way will require a new structure, one that has a clear path to realizing the vision of the Roadmap. AMIRA International stands ready to assist in the development of such a framework as part of the Implementation Task Force.

AMIRA International is proud to be involved in this important and truly unique initiative and commends all the many personnel, too many to mention here, who contributed to the Roadmap. Particular thanks to Robbie Rowe, Adele Seymon and the other team members who contributed to writing of the Roadmap.

Lets Carpe Diem – let's unlock the hidden mineral wealth, and position Australia as the global leader in exploration in areas of cover

Joe Cucuzza Managing Director AMIRA International Limited



Unlocking Australia's Hidden Potential: An industry roadmap.

EXECUTIVE SUMMARY

Roadmap Vision: Delivering Australia's major new mines by locating and unlocking future mineral wealth, positioning Australia as the global leader in exploration beneath post-mineral cover rocks

Reversing the decline in mineral discovery in Australia, transforming modern exploration and re-setting the country's exploration maturity clock is now urgent. The challenge represents an industry imperative and a critical national priority.

This AMIRA International Roadmap (Roadmap) progresses the UNCOVER vision providing a way forward by combining new knowledge and innovative technology, integrated with state of the art geoscience data. When enacted the Roadmap presents an opportunity to unlock Australia's hidden mineral potential and positively impact future cycles of exploration and mining. Transforming exploration and opening the under cover search space will only come when existing barriers, gaps and challenges are successfully navigated. Delivering on the Roadmap Vision and realising Australia's hidden mineral wealth will require major structural and behavioural changes. Over the last three decades as a sector we have not made national decisions or marshalled resources required to address multi-sector, all-encompassing change, but of course perhaps this may not have been an imperative in the past. The Roadmap has catalysed and deepened the conversation initiated by UNCOVER, pointing the way by guiding the Australian geoscience community on how and what is needed to be transformed in order to achieve the Roadmap Vision.

| Change Required | | Resulting Transformation |
|-----------------|----------------------------|--|
| | Priority | Elevate overcoming the cover challenge to highest strategic importance |
| * | Approach | New entity, open operating model, greater collaboration, better thinking, innovation adoption, maximise knowl- edge-technology diffusion and rapid transfer |
| | New knowledge new toolkits | Better science, new knowledge, higher quality data, new technology and tools, increased collaboration, improved integration |
| | People investment | New training, future skills, gender balance, increased diversity, boundary spanning |
| \$ | Economic outcomes | More high-quality discoveries, increase exports, create jobs, enhance regional infrastructure, technology commercialisation and export new technologies and services, improved efficiency and performance, generate more wealth. |
| | Social outcomes | Employment growth, targeted regional development, self-sustaining communities |
| 90 | Environmental outcomes | Smaller environmental footprint right across the minerals val- ue chain, better targeting, increased effectiveness, responsi- ble development. |

The period in the 20th century when mineral discoveries were at their peak, contributed significantly to nation building and the prosperity of the country. This period of discovery was made possible not only because Australia was prospective and a desirable investment destination but also because the tool kit and exploration approaches available to explorers were designed for the nature of the mineralisation that essentially was outcropping or easily detectable. However, the challenges that have been identified by the Roadmap mean that we need a transformation in the way we collaborate, in the way we explore, a better toolkit and in the way we do business. By embracing change, we can improve performance and in turn increase our chances of discovery in over 70% of Australia's landmass that hitherto has been almost closed to us

Australian mining sector

The mineral resources sector has been and still is a key pillar in the national economy, supporting and sustaining Australia's ongoing economic prosperity. The sector dominates the nation's economic landscape providing substantial direct and indirect employment along with massive investment in regional infrastructure and supporting service industries. Above all, the sector directly and indirectly delivers an essential revenue stream to governments, contributing to and benefitting the broader Australian community.

In 2015–16, mining directly contributed around 6 per cent of Australia's GDP, employed more than 220,000 people and generated 50 per cent of the nation's export earnings.

The indirect contribution for the same period is estimated to have added a further \$103.6 billion to the economy and over 650,000 jobs directly related to exploration, mining and the Mining Equipment Technology Services (METS) sector^{1,2}.

In the last 20 years, half of Australia's share of global exploration investment in Australia has moved offshore to countries where the technical risk of exploration is considered lower by Major, Mid-Tier and Junior explorers alike³.

Breaking the under cover barrier will reverse this trend and reassert Australia as a preferred global greenfield exploration destination.

The Big opportunity

The vast majority of Australia's economically viable, non-ferrous mineral near surface deposits have already been discovered. To a large extent these deposits have either been exhausted or are currently being mined. Existing reserves are being depleted, and are not being replaced not only because of the increased production over last few years but also because of the steady decline in the discovery of new and commercially exploitable resources. The latter has been the case the past 20 years, despite an increase in exploration investment over the corresponding period. The major contributing factor to reduced discovery performance is the increasing maturity of the near surface environment, which comprises only about 30% of Australia landmass and where the vast majority of exploration has focussed.

Re-setting and turning back Australia's exploration maturity clock is possible by moving into the new frontier 'under cover' areas representing over 70% of Australia's landmass. Post-mineralisation cover represents a major technical barrier for the discovery of new mineral deposits. The conventional tool-kit and way of exploration have been adequate in the past but these are not adequate in areas beneath cover. New technologies, data, information and business models are now required

UNCOVER and Roadmap

UNCOVER and the Roadmap are already recognised as being hugely successful in catalysing the start of the transformation by changing the detection only approach to a mix of prediction followed by detection. The philosophy has been enthusiastically embraced as a way forward by many within the collective exploration geoscience community.

Over the last 30 months, a unique and ambitious roadmapping effort has led to the identification key elements that will deliver tangible performance improvement in minerals discovery. The Roadmap proposed a blueprint on how this could be achieved. The blueprint describes a possible structure, the co-funding, skills, and human resources required, and key activities in a single 15-year integrated programme. The Roadmap articulates a plan that will see new knowledge, technologies and data to start being delivered within two years from commencement of the programme. To achieve the Roadmap Vision, a consolidated investment in excess of \$900M over 15 years is required in addition to funding of existing programmes currently in place by the Federal, States and Territory agencies. New funding is to fund new research, enhance and develop new technologies and significantly accelerate delivery of existing data acquisition programmes.

The three focus areas have been prioritised based on the potential impact of the outputs in the short term:

- Understand type, ages and depths of cover, compile and produce 3D Geology and paleosurface Maps and Layers (Theme 1.1)
- Characterise and map major Mineral System "footprint" signatures through data compilation of geology, Geochemistry and Geophysics (Theme 4.3)
- Improve understanding of mineral systems across scales for different deposit types and commodities (Theme 4.1)

The remaining programmes represent either staged acquisition of new knowledge or longer term research objectives needed to support a decadal outlook for discovery of new mineral deposits inaccessible to current exploration.

Building capacity in human capital will be vital to success, requiring the recruitment of the very best talent; a mix of new knowledge and advanced skills that will certainly evolve but don't yet exist. Success will re-position Australia at the forefront to take advantage of an increasingly global challenge, exploring under cover.

The new national Australian structure, herein called the Australian Centre for Under Cover Exploration (ACE), that will need to be set up to implement the Roadmap must be able to engage the talent to match the challenge. It must have the flexibility to engage the right people which may require recruiting from overseas, collaborating with overseas organisations as well embedding experience and expertise from the industry and METS sectors.



P1162A ROADMAP - CONSOLIDATED RESOURCING

The scale, degree of coordination and integration necessary to implement the Roadmap requires an overarching management entity the nature of which does not currently exist. The optimum entity envisaged is a single virtual centre, centrally managed, with lean management structure, best-practice governance and outsourced back-office functions ensuring maximum resources are directed to outputs. Importantly coordinated external linkages are embedded to ensure that the new research and technology development programmes leverage off the new 'big data' initiatives.

Similar knowledge- and technology-intensive endeavours in other sectors around the world have been successful in addressing strategically important and complex problems of national or even global significance.

It is an ambitious approach and focused application that has resulted in transformational disruptive change rather than incremental evolution.

When considering sources of funding the primary consideration is that of the end-user benefit. By recognising that all stakeholders will be direct beneficiaries and that the broader Australian community will be the single major beneficiary via royalties on production and taxation - the Roadmap proposes that co-investment proportional to benefit should be the central principle determining the funding arrangements for the new entity. In terms of the expected public investment in a completely new national centre, a relatively small investment now (compared to current revenue benefit) will ensure a sustainable revenue stream for future Australian generations. Options for public and industry co-investment in the Roadmap programme were explored and are detailed herein.

Implementation of the Roadmap:

A great deal of effort that has been put into the preparation of the Roadmap, but absolutely critical will be the implementation to ensure that this effort has not been in vain. Implementation will require a step-change, cross-sector collaborative effort by the Australian geoscientific community. And it is critical that industry plays a dominant role in determining the way forward. To develop the latter an executive level Roadmap Implementation Taskforce will be formed. A 6-8-month task force is planned to commence in late 2017.

- 1. Deloitte Access Economics 2017 (Mining and METS: engines of economic growth and prosperity for Australians)
- 2. Minerals Council of Australia 2015 (The Whole Story: Mining's contribution to the Australian community)
- 3. Richard Schodde 2017 (PDAC presentation "Recent Trends and Outlook for Global Exploration")



AMIRA INTERNATIONAL - ROADMAP FOR EXPLORATION UNDER COVER

"The uncertainty of not knowing something appears to be disappearing. We expect answers to exist rather than to emerge from our searching (science not just exploring). We need leadership, not from those with answers, but those with questions"

Dr Steve Beresford, Independence Group

"UNCOVER is a key element in the National Mineral Exploration Strategy, which shapes the minerals-related work of geological surveys across the country including Geoscience Australia. The highest and high priorities identified by Industry in AMIRA Roadmap 1 played an important role in setting the scope and activities of the Exploring for the Future programme"

Dr Richard Blewett, Geoscience Australia

"The Uncover initiative and the two AMIRA Roadmaps that encapsulate it together represent the needed vision to make a step change in mineral exploration success in Australia"

Dr Chris Wijns, First Quantum Mining Limited

"The technologies listed as needed in the UNCOVER roadmap provide an opportunity for research, industry and the METS sector to drive a new wave of innovation for the global minerals industry"

Dr Rob Hough, CSIRO

"The Roadmap has brought forward the language, culture and readiness for action many years. Without it we would still be doing what we have always done - scratching and paddling around the shallow end of the cover pool"

Dr Steve Hill, Geological Survey of South Australia

"Provided the opportunity to network with peers from government, research and industry to discuss, troubleshoot and identify potential collaborative opportunities that align with the Roadmap's key themes and sub themes"

Mr Cam Cairns, Geological Survey of Victoria

"Eye-opening in terms of the range of scientific challenges identified by industry, and how a large number of them can be resolved using the prioritised roadmap. The challenge is to garner unified support in terms of funding this large body of science that can only be enabled through a nationwide initiative"

Dr Cam McCuaig, Geoscience Centre of Excellence: BHP

"The AMIRA roadmap established and maintained a firm strategic focus and an emphasis on the need for a much closer national collaboration necessary to successfully resolve major challenges of effective mineral exploration under cover"

Dr Vladimir Lisitsin, Geological Survey of Queensland

"This has been an open and meticulous process to lay out the menu of challenges required to improve Australia's declining discovery rate and declining share of global mineral exploration expenditure"

Prof Richard Hillis, Deep Exploration Technologies CRC

PHOTO IS DRILLING AT INVINCIBLE PROJECT, LAKE LEFROY, WESTERN AUSTRALIA. SOURCE, GEOLOGICAL SURVEY OF WESTERN AUSTRALIA "In any human endeavour, it is important to focus one's efforts on the issues that really matter. Right now it is critical that we address the issue of providing the knowledge and technologies that will allow humans to locate and access those mineral resources that are critical to our future, resources that are buried under cover and difficult to find. This is what the UNCOVER initiative is about and what the Roadmap articulates.

Australia has the geology together with the intellectual capacity and the political, legal, financial and social structures to be the perfect laboratory in which to create the vital knowledge and technologies. Australia is, at the same time, unique in that with this roadmap we not only have a clear identification of what it is that has to be developed to make a real difference but we also have a plan of how to create it.

Australia now has the opportunity, and indeed the responsibility, to lead the world in developing the capability to provide those critical resources to fuel our future."

Dr Phil McFadden AO FAA: Australian Academy of Science

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80% OF AUSTRALIA'S CURRENT MINERAL PRODUCTION IS DERIVED FROM MINES DISCOVERED PRIOR TO 1980, MORE THAN 30 YEARS AGO.

BACKGROUND AND INTRODUCTION TO THE ROADMAP

UNLOCKING AUSTRALIA'S HIDDEN POTENTIAL - STAGE 2



1.1 BACKGROUND

It is recognised that the vast majority of Australia's easily-found, economically viable, non-ferrous mineral deposits in the near surface environment have already been discovered and, to a large extent, exploited. Despite Australia's demonstrated mineral endowment, exploration performance — measured by discovery of new world-class, Tier 1, economically significant greenfield mineral deposits — has been in steady decline in the last 20 years. These large high quality Tier 1 discoveries are critical to maintaining Australia's, and indeed the global, mineral resource inventory.

Accelerated reduction in the known economic mineral resources inventory at current mining operations due to high production rates, combined with low mineral exploration success for new mines, will result in the decline in production and revenue from mined resources in the medium to long term (the next 15–20 years). In the Australian context, mineral resources constituted approximately 50% of the nation's exports and 7% of GDP in 2016. Importantly, 80% of Australia's current mineral production is derived from mines discovered prior to 1980, more than 30 years ago.

With this in mind, it is now commonly accepted that the majority of the large or giant deposits in Australia — with a detectable surface expression and located in the conventional search space (that represents approximately 20-30% of the Australian land mass) — have been found and are either exhausted, currently being mined or in development. Significant new discoveries are becoming less common. This is because the remaining prospective, underexplored areas, which are likely to be as well-endowed in mineral wealth as the conventional search space, are obscured by a post-mineralisation veneer of regolith and sedimentary basins of various depths and ages. This post-mineralisation layer reduces the effectiveness of traditional detection based search methods. Future world-class non-ferrous mineral discoveries will most likely occur in the large portion of Australia that is under post mineral cover where predicting the location of mineral systems represents the most urgent and difficult challenge.

To meet these challenges and 1 the opportunity of re-setting Australia's mineral exploration 'Maturity Clock', a truly integrated and innovative approach to mineral exploration science needs to be developed and embedded into the modern exploration process of methodical and systematic exploration scale-reduction decision making. The primary driver for this change is to improve exploration performance and stimulate greenfield exploration discoveries of new mineral provinces and mines under post-mineralisation cover. If this change is not embraced then using previous discovery history as a guide, it is likely that mineral exploration performance for new deposits in Australia will continue to decline. Australia would then attract a decreasing proportion of global minerals exploration investment as the industry continues to explore and exploit the conventional near-surface search space elsewhere. Reduced exploration success will inevitably result in decreased minerals production in Australia, lower export levels, and a falling revenue stream from minerals for the Australian economy in the medium to long term.

Resetting Australia's 'Maturity Clock' by improving mineral exploration performance through both detection in exploration technologies and prediction performance through research now represents a national priority and strategic imperative: developing the country's rich natural resources endowment advantage to deliver growth and future proof the economy.

CURRENT PERCEIVED MATURITY



TECHNOLOGY RESET



- Cheap deep drilling
- 3D Seismic Systems mapping
- Distal footprints
- Airborne IP

SEARCH-SPACE RESET



- Under salt sakes
- Under lithified basis
 and volcanic cover
- Research community
- Technology commodity
- Systems conceptual

The mineral exploration conversation in Australia is one of maturity, reduced opportunity and lack of success.

Maturity can be **reset** through technology advances, but even more so by initiatives like UNCOVER to improve effective exploration under cover....to double the unknown, untested half of Australia

SOUTH AUSTRALIA, BACKGROUND PHOTO SOURCE: STEVE HILL, GEOLOGICAL SURVEY OF SOUTH AUSTRALIA

1.2 UNCOVER INITIATIVE

Early in the development of the Industry Roadmap — *Unlocking Australia's hidden mineral potential* — it was agreed by the industry and government sponsors to use the outputs from the UNCOVER initiative (UN-COVER) that arose from the 2010 Theo Murphy Think Tank, as a starting point for the roadmap process.

The formation of UNCOVER led to the preparation of the report *Searching the Deep Earth: A vision for exploration geoscience in Australia*¹. The vision proposed a national strategy that calls for the creation of a new researcher network and a focus on the genesis, spatial distribution and discovery of the nation's mineral wealth and to integrate scientific research into current technology research and pre-competitive data acquisition. The aims of UNCOVER were to identify high level challenges and then focus the minerals exploration geoscience community to develop scientific research and exploration technologies on the highest impact activities targeted at improving exploration performance, especially in areas of cover.

UNCOVER was established to provide a forum to stimulate a collaborative partnership between all minerals exploration stakeholders, to benefit all stakeholders and in the Australian national interest. More information on UNCOVER is available at http://www.uncoverminerals.org.au/ At present, in 2017 UNCOVER is an unfunded initiative led by the Executive Committee, a multi-stakeholder representative group from the exploration geoscience community including industry, government and academic research organisations.

Four core themes were identified by the Theo Murphy Think Tank that need to be addressed to improve exploration performance in the covered environment. The UNCOVER Executive Committee subsequently proposed the following four core themes:

Theme 1. Characterising the cover: New knowledge to confidently explore beneath the cover.

Theme 2. Investigating Australia's lithospheric architecture: A whole-of-lithosphere architectural framework for mineral systems exploration.

Theme 3. Resolving the 4D geodynamic and metallogenic evolution of Australia: Understanding ore deposit origins for better prediction.

Theme 4. Characterising and detecting the distal footprints of ore deposits: Towards a toolkit for minerals exploration.



¹ http://www.uncoverminerals.org.au/__data/assets/pdf_file/0018/31284/uncover-report.pdf

1.3 AMIRA INTERNATIONAL'S ROADMAP

Stage 1 of AMIRA International's *Roadmap for Exploration Under Cover* delivered a consensus view from key stakeholders on what needs to be change for potential undiscovered mineral wealth in areas of cover to be realised in Australia. Stage 1 of the Roadmap successfully expanded and progressed UNCOVER. Priority areas delivered in Stage 1 of the Roadmap defined the basis for designing programmes via Stage 2 of the Roadmap to deliver on the vision originally outlined by UNCOVER. Stage 1 commenced in late 2014, and was released in July 2015 *Unlocking Australia's hidden potential: An Industry Roadmap*².

Prompted by a positive response from the broader Australian geoscience community, Stage 2 of the Exploration Under Cover Roadmap commenced in June 2016.

Stage 2 offered Australia's mineral exploration geoscience ecosystem, comprised of the mineral exploration industry, government geological survey organisations and the research community, a strategic opportunity of to be directly involved in the design and implementation of a transformational geoscience programme. Effective ecosystems bring about the translation of thinking into tangible programmes by articulating clear purpose and deliberate design. Recognising that such an ambitious and urgent initiative would be a world-first attempt to design and implement a fully integrated geoscience programme, the geoscience community embarked on an unprecedented national scale collaborative effort. The overall aim being to complete the Roadmap focussed on requirements for creating a step change in the performance and success rate of mineral exploration in areas of Australia concealed under post mineralisation cover.



AUSTRALIA'S FUTURE MINERAL EXPLORATION GEOSCIENCE ECOSYSTEM

² http://www.amirainternational.com/WEB/site.asp?section=activities&page=ExplorationUnderCover

The guiding vision of UNCOVER as developed in Stage 1 provides the overarching principle: **Delivering Australia's major new mines by locating and unlocking future mineral wealth, positioning Australia as the global leader in exploration beneath post-mineral cover rocks.**

Outcomes of the Roadmap, if implemented now, represent an opportunity to re-position the Australian exploration community at the forefront of exploration in covered terrains via an open collaboration approach. The Australian exploration community have demonstrated their ongoing commitment to a shared future through Roadmap participation, with contributions provided by industry together with the associated Mining Equipment Technology Services (METS) and geoscience research sectors. Industry's resolve to develop a sustainable future in Australia and help to create the means to achieve this is currently being tested after a sustained low in the commodity cycle. Recent signs of a recovery represent a significant and valuable opportunity to open the undercover search space through improved exploration performance and deliver benefits to the mining industry, the METS sector and ultimately to the country. The aim is to ensure Australia has a long term sustainable resources industry that will continue to be an important and underpinning pillar of the national economy and our continued collective prosperity.

At the outset, the principal aims of Stage 2 were to develop specific time sequenced and realistic costed programmes focussed on the priority activities identified in Stage 1, and to investigate suitable funding models and appropriate vehicles to implement a broad integrated programme. Although outputs will be central to the success of the vision of UNCOVER, no less important is that the completed AMIRA International Roadmap will serve as a new blueprint, guiding investment decisions by both State and Federal Governments, ensuring that the UNCOVER vision **is realised.** As such the completed Roadmap maps out what is required and when, converting the original vision into tangible programmes resulting in improved exploration performance to deliver tomorrows large scale, economic mines.



DISCOVERY FROM IDEAS TO TARGETS THROUGH PROGRAMME IMPLEMENTATION

Ultimately, the long-term success of this completed Roadmap will be measured by the number of new deposits discovered and mines developed. In the shortterm however, the development of partnerships, and the focusing of academic research towards addressing industry problems through the creation of a national exploration research programme must be recognised as important measures of success.

A further two key overarching themes were identified early in Stage 1 of the Roadmap: risk reward for covered economic resources; and research, education and training capacity and capability. Risk reward for covered economic resources was added to drive and focus future research projects, data compilation and new data acquisition activities. Research, education and training was added as an underpinning and high-priority sixth focus area to better understand Australian geoscience research education and training capacity and capability required to ensure a sustainable geoscience education and training sector and to provide geoscience capacity in the disciplines required for future needs. An outline of Roadmap Stage 1 and 2 representing the origins, roadmap process and outcomes is presented in the figure below.

AMIRA International's focus has included leading the Australian geoscience ecosystem to discover, invent, and demonstrate new knowledge and new technologies that will allow the geoscience community to improve. Exploring better, delivering new mines and continuing to contribute to the economy and through this deliver an improved quality of life.



AMIRA INTERNATIONAL ROADMAP OUTLINE

AMIRA's focus has always been leading the Australian geoscience ecosystem to discover, invent, and demonstrate new knowledge and new technologies that will allow our geoscience community to improve. Exploring better, delivering new mines and continuing to contribute to the economy and through this deliver an improved quality of life.

FALSE COLOUR CATHODOLUMINESCENCE (CL) IMAGE OF THE CORE OF A DIAMOND CUBE. SOURCE: DR DANIEL HOWELL, ANU RSES Stage 1 of AMIRA International's Roadmap for Exploration Under Cover delivered a consensus view from key stakeholders on what needs to be done if undiscovered mineral wealth in areas of cover is to be found in Australia. Priority areas were defined that will require a well-designed and executed plan in order to deliver on the vision.



GRAPHIC IMAGE SUPPLIED BY GEOSCIENCE AUSTRALIA 2015 PHOTO FROM MT FORT CONSTANTINE, ERNEST HENRY TO NORTH. SOURCE: R. ROWE 2005

ROADMAP STAGE 1

"The impact of the UNCOVER Stage 1 roadmap is already being felt. We are seeing Federal and State government geoscience organisations and geoscience research groups aligning their research and data acquisition activities with UNCOVER priorities across the Nation"

Mr Paul Agnew, Rio Tinto Exploration

"I would have betted heavily against Stage 1 of the Roadmap, which was an underfunded effort to build consensus on the challenges to mineral exploration, getting anywhere. Why would any of the sectors, better known for being ultra-competitive than collaborative, work to build consensus. I'd have lost my bet. It proved that while collaboration is challenging, it's worth it and this industry can do it"

Prof Richard Hillis, Deep Exploration Technologies CRC

"The impact of Stage 1 has been profound, especially across government where it has set an industry endorsed agenda for our programs, it has not only influenced what we do but it has helped drive a contemporary and relevant organisation structure where we now have programs specifically designed to meet to major themes of UNCOVER"

Dr Steve Hill, Geological Survey of South Australia

"In Stage 1 of this Roadmap we now have, for the first time ever, a prioritised identification of where we should be putting our effort to improve significantly our success rate in mineral exploration"

Dr Phil McFadden AO, FAA, Australian Academy of Science

"High level industry, government and academic personnel, initially talking at cross purposes regarding the types of geoscience data, knowledge and research required to improve exploration success under cover, shifting viewpoints to adopt a broader industry wide perspective through the roadmapping process and agreeing on shared sense of purpose and common goals"

Dr Cam McCuaig, Geoscience Centre of Excellence: BHP

"While Mount Isa Mines has continued ongoing support for diverse research initiatives; the Roadmap process certainly strengthened our resolve to focus on Footprints and regional vectoring within NWQ"

Mr Trevor Shaw, Mt Isa Mines – A Glencore Company

"The Geological Survey of NSW has utilised the Stage 1 Roadmap heavily as a guideline for prioritisation of data acquisition and delivery programs that are targeted at exploration under cover"

Dr Chris Yeats, Geological Survey of NSW

"The roadmap provided the foundation to unify and realign the geological surveys and CSIRO towards 'our' common goal. The soft alignment of thinking has been incredibly successful as a whole, and for each stakeholder. Geological Surveys and CSIRO are benefiting from this alignment. This would not have been possible without an independent group from the nexus between government, research and industry"

Dr Steve Beresford, Independence Group

BACKGROUND IMAGE: SCOTT KELLY EARTH ART FROM AUSTRALIA. PICTURE 2 OF 17. YEAR IN SPACE. SOURCE: NASA 2015 "LEARNING HOW TO UNDERSTAND HOW TECHNOLOGY EVOLVES, USING TOOLS LIKE A TECHNOLOGY ROAD MAP, IS WHAT YOU NEED MORE THAN ANYTHING TO RIDE ON TOP OF THE TSUNAMI INSTEAD OF BEING CRUSHED BY IT"

PETER DIAMANDIS, FOUNDER AND EXECUTIVE CHAIRMAN OF THE XPRIZE FOUNDATION

MINERAL SYSTEMS DRILLING PROGRAMME, SOUTH AUSTRALIA. COURTESY DEEP EXPLORATION TECHNOLOGIES CRC

2 ROADMAP DEVELOPMENT PROCESS

Matching AMIRA's experience in developing Roadmaps with a willingness by the geoscience community to collaborate and contribute will make realising the UNCOVER vison possible

2.1 ROADMAP STAGE 2 ACTIVITIES

Stage 2 activities engaged sponsors, additional organisations and identified experts in the broader geoscience community to undertake a methodical evaluation of historical work and current national multi-stakeholder geoscience activities with a specific focus on under cover exploration. This review commencing in June 2016, was then followed by a process of formulating multidisciplinary programmes to address the task of improving under cover exploration performance. A series of multi-stakeholder workshop activities followed up and enhanced with targeted one on one meetings were an effective process at optimising open engagement and importantly direct involvement from members of the Australian geoscience ecosystem community.

| Roadmap Stage 2: 2016-17 | | | | |
|---|--|--|--|--|
| Current State Scan (CSS) | Engage and involve the national geoscience community, throwing a net to capture historical work and progress of current research, technology development and data initiatives specific to sub themes identified in Stage 1, 2015 | | | |
| National geoscience capability and capacity | First national capability and capacity map of geoscience from universities, CSIRO and Australian geological agencies | | | |
| Expand knowledge through research and capability through exploration technology | Documented work programmes with required output deliverables, to tackle research and technology development and commercialisation activities. Includes identifying current work needing to be accelerated in order for subsequent programmes to be successfully completed within required time frame | | | |
| Accelerated data compilation and new acquisition | Programmes to accelerate current and propose new data compilation and acquisition to impact knowledge research and exploration technologies | | | |
| Whole of programme — Time mapping, costing and dependencies | Realistic timeframes, costs and interrelated dependencies of fully integrated knowledge research, exploration technologies and data portfolio | | | |
| Research and technology vehicles | Explore appropriate vehicles to undertake new research and develop new technologies including structural governance and management/ coordination models | | | |
| Funding mechanisms | Explore appropriate funding model options for new research and develop new technologies | | | |

The first Australian geoscience capacity map from the research and geological survey communities was completed in parallel with the activities to progress programme designs.

The roadmapping process also explored potential vehicle and funding options to deliver the resulting combined research, technology and data portfolio identified in the Roadmap.



- Identify research departments
- Identify researchers
- Develop geoscience disciplines
- Researchers complete 'self assessment' of expertise against geoscience disciplines

Commonwealth, state and territory government geological surveys - Geoscience capability & capacity mapping

- Identify survey departments
- Surveys complete 'self assessment' of expertise against geoscience disciplines
- Consolidate and report

Explore appropriate research and technology vehicles



Consolidate vehicle and funding options

2.2 ROADMAP STAGE 2 TEAM – EXPEREINCE TO CALL ON

The team assembled to assist AMIRA International for the Roadmap contributed a combined 206 years of experience in Australia and across the globe. Eight individuals from the mining industry and research community committed extensive time and effort, working on pulling together contributions from across the ecosystem in Stage 2. The experience called-on to develop and design the Roadmap came from across the range of mineral exploration geoscience disciplines with a track record in mineral discovery.

| Roadmap Team | Area of Expertise | Experience |
|-----------------|---|---|
| Graham Begg | Project generation for minerals exploration, tectonics, mineral systems science and mapping the evolution and lithospheric architecture of continents. | 33 years in exploration, mining, and research. Current: Principal Consultant, Minerals Targeting International Pty Ltd |
| Steve Beresford | Mineral exploration geoscience, volcanology and nickel systems | 26 years in mining industry and academia. Ex Professor and Chief Geologist. Current: Chief geologist, Independence Group |
| Barry Bourne | Mineral exploration geophysics, mineral exploration targeting and project generation | 26 years in mining industry. Ex Chief geophysicist. Current: Principal consultant, Terra Resources. |
| Tim Craske | Project generation, exploration management, discovery of base metals under cover, mineral systems and counter heuristic thinking | 30 years in mining industry. Ex Chief Geologist and VP Exploration. Current: Director and Principal consultant, Thînkercafé |
| Scott Halley | Mineral exploration geochemistry, lithogeochemistry and mineral exploration targeting | 30 years in mining industry. Ex Chief Geologist. Current: Director, Mineral Mapping Pty Ltd |
| Sophie Hancock | Mineral exploration geochemistry, hydrogeology mineral exploration, and uranium systems | 14 years in exploration, research and consulting Current: Principal consultant, Geo-Logic Resources Consulting |
| Robbie Rowe | Mineral exploration targeting, economic geology and project generation | 30 years in mining industry. Ex Chief Geologist and VP Exploration. Current: Principal consultant, NextGen Geological Pty Ltd |
| Adele Seymon | Application of research and technology to mineral exploration, mining and sustainability | 20 years in minerals exploration, government and mining industry research. Current: Program Director, AMIRA International Ltd |

DR STEPHAN THIEL, GEOLOGICAL SURVEY OF SOUTH AUSTRALIA WORKING IN THE FIELD IN SOUTH AUSTRALIA USING MAGNETOTEL-LURIC (MT) EQUIPMENT, AS PART OF THE AUSCOPE AGOS PROGRAM.

ROADMAP STAGE 1

"Stage 2 has provided a globally unique opportunity for Industry, Academia and Government organisations to engage with each other and discuss in detail the research and data required to lift the discovery rates in areas of post-mineral cover in Australia"

Mr Paul Agnew, Rio Tinto Exploration

"Stage 2 of this roadmap was dominantly about identifying, again in consultation with the exploration community, targeted programmes and projects to address and resolve those issues identified as high priority in Stage 1. This is about how to resolve the important issues"

Dr Phil McFadden FAA, Australian Academy of Science

"Has allowed sharing of key technical concerns or scientific obstacles in successfully taking on exploration under cover and has provided an industry-wide research roadmap that can be measured against individual companies' internal priorities in terms of research support"

Dr Cam McCuaig, Geoscience Centre of Excellence BHP

"Having a technical roadmap for UNCOVER, with industry support, sets us on the right path to meet Australia's cover challenge"

Dr Rob Hough, CSIRO

"Stage 2 has been the reality check and started to develop the details and costings of what we have needed to do. It not only addresses the immediate needs but in years to come will be a legacy that sets the agenda for mineral exploration success"

Dr Steve Hill, Geological Survey of South Australia

"Involvement with Stage 2 highlighted the broader challenge, quantum of funds required, significant complexity of project interactions, as well as reaffirming the long lead times necessary to plan for success. As an industry; we have identified the problem, scoped our national research capacity in partnership with research institutions, and prioritised the building blocks necessary to meet the challenge"

Mr Trevor Shaw, Mt Isa Mines - A Glencore Company



"GSWA has been managing the Western Australian Government' Exploration Incentive Scheme (EIS) since 2009, and we have adjusted our precompetitive geoscience acquisition and mapping programs in 'real-time' as the UNCOVER Road mapping process with industry, Geoscience Australia, other state and territory geological surveys, CSIRO, and university researchers has developed"

Dr lan Tyler, Geological Survey of Western Australia

"A spotlight has been shone through the fog of self-interest in order to identify the key priorities that need to be addressed in order to improve Australia's declining discovery rate and declining share of global mineral exploration expenditure"

Prof Richard Hillis, Deep Exploration Technologies CRC

BACKGROUND IMAGE: SCOTT KELLY EARTH ART FROM AUSTRALIA. PICTURE 10 OF 17. YEAR IN SPACE. SOURCE: NASA 2015

2.3 ENGAGEMENT - CONTINUING THE CONVERSATION

Stage 2 of the Roadmap saw many in the Australian exploration geoscience community again demonstrate a commitment to re-engage and collaborate, coming together to continue the conversation started in Stage 1. The collective ecosystem was challenged via early cross-sector workshops to contribute to the design of an ambitious programme to improve exploration performance under cover. Early engagement followed by numerous one on one meetings with the Roadmap team involving interactions with industry, research and governments enabled productive input across the age, gender and experience profile. Diversity of people involved in the engagement, often identified as a core requirement in collaboration initiatives increased during the roadmap process through repeated interactive follow-up sessions.




2.4 ROADMAP OBJECTIVES AND OUTPUTS

To develop an ambitious and fully integrated research, technology and data programme aimed at improving exploration performance, the roadmapping process expanded the Stage 1 sub themes and delivered a portfolio of individual research, technology, data compilation and new data acquisition strands.

This extensive programme of individual strands will be required to be designed, implemented and executed to develop a pathway for exploration performance improvement over the next 15 years.

Individual strands developed within the Roadmap identified and documented the work required, realistic time frames, time sequencing of activities, personnel resourcing, the required skills and experience profiling for executing individuals strands and finally a costing.

Specific deliverables for Stage 2 of the Roadmap include:

Current state scan. A compiled electronic listing of historical research, technology development and data associated with sub themes identified in Stage 1 to be made available to the roadmap sponsors and later to the broader geoscience community. The current state scan provides the starting point, initiating development of the individual programme strands.

Strand summaries. Information compiled from the extensive engagement for each sub theme programme was collated into standard strand summaries, bringing together key information required to further expand and develop individual and executable projects from the broader sub themes. Strand summaries were separated, based on the required activity:

- Knowledge research. New research to develop knowledge to assist with new technology development or for direct use in new greenfield exploration
- Exploration technology development. New technologies to develop new data layers and for use in new greenfield and brownfield exploration
- Data compilation required to deliver into new research, technology development and direct use in new greenfield exploration:
 - » Initiating new data compilation activities identified through the roadmap

- Accelerating existing data compilation activities to deliver data for research and exploration technology development
- Accelerating existing data compilation activities to determine new data acquisition requirements
- Data acquisition required to deliver into new research, technology development and use in new greenfield exploration.

Single compiled roadmap programme. Individual strand programmes developed across all roadmap activities integrated into a single, first-time overall national geoscience portfolio:

- All activities time-mapped based on expected required work
- All activities cost-mapped based on expected required work
- All activities dependencies mapped based on required inputs and on expected outputs into an integrated dependency map

National geoscience capability map. To demonstrate Australia's world leading geoscience capability and to measure capacity to undertake proposed research, technology and data programmes, a first-time national geoscience capability map was compiled and released.

Research vehicles. A compilation of current and possible future vehicles representing the best options to be setup and employed to undertake the research and technology programmes outlined. Includes options and recommendations on suitable management and governance arrangements to best deliver on the Roadmap vision

New research vehicles and funding mechanisms. A compilation of current and possible future funding model(s) allowing the required research and technology programmes to be carried out in a systematic and synergistic manner in a National Research Programme for Exploration Under Cover.

3 REASSERTING THE ROADMAP VISION AND MISSION

FUTURE FOR UNDER COVER EXPLORATION

Participating sponsors were canvassed to revisit the overriding vision for the future of undercover mineral exploration at the outset of Stage 2. Rapid endorsement from the collective geoscience community reaffirmed the vision and mission developed and used as guiding principles in Stage 1.

C. C.

P1162A ROADMAP

Vision

Delivering Australia's major new mines by locating and unlocking future mineral wealth, positioning Australia as the global leader in exploration beneath post-mineral cover rocks.

Mission

Champion and inspire transformational geoscience through collaborative and coordinated alignment of industry, academia and government to maximise Australia's intellectual and institutional capabilities by driving integrated advancement of science, technology development and new national data acquisition.

- Within 10 years, facilitate the discovery of new major economic mineral deposits in Australia beneath post-mineralisation cover rocks.
- Within 20 years, discovery performance in the concealed search space will be at least comparable to modern-era, first-pass surface exploration.

MINERAL SYSTEMS DRILLING PROGRAMME NORTHERN EYRE PENINSULA SOUTH AUSTRALIA 2016: SOURCE DET CRC "THE SECRET OF CHANGE IS TO FOCUS ALL OF YOUR ENERGY NOT ON FIGHTING THE OLD BUT ON BUILDING THE NEW"

SOCRATES

HELITEM AEM TAKEOFF PHOTO COURTESY CGG AVIATION (AUSTRALIA) PTY LTD

EXPLORATION PERFORMANCE

TRENDS, DRIVERS AND CHALLENGES

Compared to the rest of the world, investment in mineral exploration in Australia has halved over the last 20 years, falling from 21% in mid-1990's to 10% in 2016. Breaking the under cover barrier will reverse the trend and reassert the nation as a preferred exploration destination.

The global exploration and mining industry is facing a significant task, to meet an anticipated exponentially increasing demand for mineral commodities. This is driven by global urbanisation, industrialisation and population increase. The challenge is to meet this demand at a time of dropping performance in minerals exploration for new discoveries to replace resources and economic reserves.

Current demand and supply for many commodities remains in-balance, however it is forecast that future demand will not be met with current remaining known economic reserves and known resources. For the mining industry to meet the anticipated increasing demand a new generation of large, high-quality economically extractable mineral resources need to be discovered.

The trend of mineral discovery in Australia over the last 65 years, since the start of 'modern exploration',

is largely a story of two halves. During the early adoption of new geophysical technologies coupled with new geological and ore deposit knowledge from the late 1950's, the industry embarked on a major era of discovery. Continually opening up new areas of Australia through new greenfield exploration the industry found the high quality mineral deposits at or near to the surface and quickly developed these into new mines. This period of arowth in new discoveries peaked in the late 1980's. Post 1990, despite increasing investment in mineral exploration, the trend of exploration performance to deliver required commodities from new discoveries, especially non-bulk commodities levelled out and since 2000 the numbers of new discoveries steadily dropping. The trends in new mineral discovery is presented in the below figures.

AUSTRALIAN EXPLORATION PERFORMANCE LAST 65 YEARS (ALL COMMODITIES SPENDING AND DISCOVERIES), SCHODDE, 2017



>1Moz Au, >100kt Ni, >1Mt Cu, 2,5Mt Zn+Pb, >25kt UyQ0, >100Mt Fe, >200Mt Thermal Coal >6Moz Au, >1Mt Ni, >5Mt Cu, 12Mt Zn+Pb, >125kt UyQ0, >500Mt Fe, >1000Mt Thermal Coal

Source: MinEx Consulting © March 2017

"Giant"

AUSTRALIAN EXPLORATION PERFORMANCE LAST 65 YEARS (NON-BULK SPEND AND DISCOVERIES), SCHODDE, 2017



Note: Excludes Bulk Minerals (such as Bauxite, Coal and Iron Ore) "Moderate" >100koz Au, >10kt Ni, >100Kt Cu, 250kt Zn+Pb, >5kt U₃O₈ "Major" >1Moz Au, >10kt Ni, >1Mt Cu, 2.5Mt Zn+Pb, >25kt U₃O₈ "Giant" >6Moz Au, >1Mt Ni, >5Mt Cu, 12Mt Zn+Pb, >125kt U₃O₈

Source: MinEx Consulting @ March 2017

Economic impact of a maturing search space.

It is anticipated that the divergent trends and expected imbalance in the medium to long term, between an ever-increasing demand for minerals on one hand, with lower replacement discovery rates on the other will result in a shortfall in the supply of some mineral commodities. This imbalance, most pronounced in the non-bulk commodities, will be exacerbated by a reduction of grades currently being experienced as currently operating mines mature. It is expected that lower quality/grade in currently undeveloped identified resources will result in lower conversion rates of known previously discovered resources into new mine developments.



OLYMPIC DAM, SOUTH AUSTRALIA. DISCOVERY DRILL SITE RD1, COMPLETED 31ST JULY 1975. COVER-BASEMENT DEPTH 335.7M, SOURCE, R ROWE 2005

Additionally, the widening supply deficit will also result from the trend of an increase in the time taken in developing new mines from known resources and new discoveries; and a trend towards smaller brownfield discoveries and mines as the exploration maturity within known districts and the "near-surface search space" increases.

The majority of current base and precious metal production is from a small number of maturing Tier 1 deposits, most of which were discovered at least two decades ago. This situation is a trend globally but is more pronounced in Australia. To meet the expected demand for minerals, the mining industry needs to discover and develop new Tier 1 deposits to replace supply as the current Tier 1 mine reserves become exhausted and are eventually closed. Such discovery rates need to be improved and accelerated in the next two decades to avoid an expected future collapse in Australian non-bulk commodity minerals production.

Trends contributing to an expected shortfall in Australian future minerals production in the medium term include:

Trends in Mineral Exploration and Mining



Declining mining grades in current mines across almost all commodities (Mudd et al., 2009; Guj & Schodde, 2013). This trend results from maturing mines (where deeper and peripheral ore is being mined) and from the impact of grade engineering or high-grading impacts on residual reserves.



Improvements in mining and mineral processing technology have enabled lower grade ore to be exploited. However, in the absence of new step-changing mining or processing technologies, it is expected the economic low- to medium-grade ore will at some point be exhausted



Declining conversion of newly discovered mineralisation/deposits into economic production, related to a reduction in discovery size, scale and quality. Larger resources have a higher conversion rate compared to smaller resources through development into mines (Schodde, 2013)



Of the resources that are economic, there is a trend of increasing delays between deposit discovery to development and production. This is commodity-specific on absolute delay increases; however, the trend within a given commodity is an increase in average time from discovery to development.



Proportional increase in brownfield exploration in known mineral districts and consequential decrease in greenfield exploration activity. As historically new Tier 1 mines are discovered through new greenfield exploration the move to brownfield exploration reduces the frequency and new large discoveries.

Despite increases in exploration spending, discoveries are becoming smaller as exploration maturity in the near-surface environment increases within the brownfield environment. The number of discoveries is being sustained and in some cases, there are increases in the number of individual resources; however, total contained economic metal in resources has decreased per exploration expenditure

AVERAGE ORE GRADES FOR COPPER, GOLD, ZINC AND NICKEL FOR AUSTRALIA FROM THE MID-19TH CENTURY TO 2009. MODIFIED AFTER MUDD (2009); (MUDD ET. AL., 2009)



These combined trends indicate that exploration in Australia is quickly reaching a point of advanced maturity of the surface search space for easily discoverable, directly detectable, near-surface and large, quality Tier 1 and Tier 2 economic resources. Continued mining of the known reserves and reducing grades within known resources will put continued downward pressure on productivity and reduce profit margins in the mining sector. Simply put, mining ever lower grades is not sustainable and new large, high-quality Tier 1 economic resources are required to replenish Australia's production pipeline.



TELFER MINE, WESTERN AUSTRALIA. COPPER GOLD ORE SOURCE R ROWE 2006

Global demand for commodities continues to rapidly rise, if Australia cannot deliver commodities to meet this demand through new, high quality mine production it will continue to lose market share in production of many nonbulk commodities, continuing the decline that commenced in the five-year period 1995-2000.





AUSTRALIAN SHARE OF GLOBAL PRODUCTION (SELECTED COMMODITIES COPPER, GOLD, IRON ORE, NICKEL, ZINC)

A new search space for Australia's future mines.

There is no reason to expect that Australia's mineral endowment is confined to the 'near-surface search space' environment (which is estimated to occupy the best explored 30% of the continental landmass). A large portion of the remaining 70% of the country is considered underexplored but is prospective to host new, high-quality, large economic resources to replace the currently depleting operations. This potential endowment remains hidden, concealed by postmineralisation cover of varying depth and type in a new "covered search space". In effect the exploration geoscience ecosystem needs to collaboratively work on resetting Australia's exploration 'Maturity Clock'. An increasing amount of work continues to understand and quantitatively outline the economic and minable portion of this undercover search space. Mine engineering research also continues on identifying improvements in mining technologies to expand the mineable portion of the undercover search space to extract current known reserves and future new discovered resources. Understanding the economic portion of the under cover search space significantly will progress exploration by

focussing exploration investment where future exploitation is realistically possible.

It is often overlooked, but this prospective endowment has already been confirmed by a proportionally small number of high-quality mines now being exploited underneath post-mineralisation cover. Examples include Ernest Henry (Cu Au), Olympic Dam, (Cu Au, U), Century (Zn), Nova (Ni).



INDICATIVE DEPTH OF COVER

DEPTH OF COVER AND MINES OF AUSTRALIA

Excludes Mineral Sands and Bulk Minerals (such as Coal, Bauxite and Iron Ore)



Exploration performance and investment.

History shows there is a relationship between the cyclical trends in commodity prices and investments in mineral exploration as a whole (magnified especially in greenfield exploration). Higher commodity prices translate into increased mineral exploration investment and activity for commodities at the time of higher commodity prices, reacting to short term market sentiment not driven by longer term supply and demand trends or recognition of delay from discovery to development. An additional trend that has developed over the past 20 years has been the move away from early stage greenfield exploration to brownfield exploration around existing deposits and mature mineral districts. The overriding driver in the move in exploration environment, (greenfield to brownfield) is a reaction to investment risk. There is a perception that brownfield exploration provides a better, lower risk investment option than higher risk greenfield exploration. This trend can be measured both in terms of exploration investment and in drilling, a critical activity in mineral resources discovery. Both the relationships of commodity prices on exploration activity and move away from greenfield exploration as shown on adjacent page.

Over time mineral exploration has been a highly successful value adding investment, especially in the successful period on modern exploration. However return on investment or 'bang for buck' in Australia across many commodities over the last 10 years is well below par as shown on adjacent page. Given that the return on investment ratio has been negative over the last 10 years, it can be reasonably argued that minerals exploration for new deposits in Australia over this time period, as exploration maturity increases has moved from a value creation investment to an overall value destructive one.

Combined reducing or negative return on investment and declining rates of new major and high quality economic discoveries in Australia explain the trend in mineral exploration investment, especially greenfield exploration moving offshore and out of Australia. Compared to the rest of the world, investment in mineral exploration in Australia has halved over the last 20 years, falling from 21% in mid 1990's to 10% in 2016.

Continued reduction in exploration investment in Australia will also translate into reduced investment and utilisation of the METS industry and ultimately result in lower minerals commodity production. This is a longerterm trend but inevitable. In the medium to long term, lower non-bulk minerals production will yield lower minerals-based revenue through taxation and royalties for the country's economy. To address this expected decline in mineral exploration investment within Australia, it is essential that exploration performance improves in the higher technical risk and covered environment. If higher returns on investment can be demonstrated, greater investment will be attracted back into the minerals exploration sector in Australia.

Commodity Prices and Exploration Expenditures for Australia 1990-2016 (by commodity sector)

1

3



Commodity Prices and Exploration Expenditures for Australia 1990-2016 (by commodity sector)



Australian Mineral Exploration Drilling Trends 2006-2016



Australian exploration expenditure and commodity prices by commodity sector 1990-2016. Supplied by R. Schodde 2017

Australian exploration type expenditure and commodity prices by commodity sector 1990-2016. Supplied by R. Schodde 2017

 Greenfield – brownfield exploration drilling trends, supplied by AMEC 2017

MINERAL SYSTEMS DRILLING PROGRAMME NORTHERN EYRE PENINSULA SOUTH AUSTRALIA 2016: SOURCE DET CRC

| Commodity | Explo Spend (2 | ration 016 US\$b) | No of Discoveries # | | Tier 1+2 Discoveries | | Estimated Value (2016 US\$b) | | Value / Spend |
|-----------|-------------------|----------------------|------------------------|------|-------------------------|------|---------------------------------|------|------------------|
| Gold | \$5.34 | 23% | 41 | 19% | 0 + 4 | 33% | \$2.80 | 23% | 0.52 |
| Copper | \$2.37 | 10% | 16 | 7% | 0 + 1 | 8% | \$0.81 | 7% | 0.34 |
| Nickel | \$1.79 | 8% | 15 | 7% | 0 + 3 | 25% | \$2.03 | 16% | 1.13 |
| Zinc+Lead | \$0.79 | 3% | 6 | 3% | 0 + 0 | 0% | \$0.21 | 2% | 0.26 |
| Uranium | \$1.23 | 5% | 4 | 2% | 0 + 0 | 0% | \$0.04 | 0% | 0.03 |
| Diamonds | \$0.09 | 0% | 0 | 0% | 0 + 0 | 0% | \$0.00 | 0% | 0.00 |
| Iron Ore | \$6.03 | 26% | 76 | 34% | 0 + 1 | 8% | \$2.37 | 19% | 0.39 |
| Coal | \$3.51 | 15% | 33 | 15% | 0 + 2 | 17% | \$2.57 | 21% | 0.73 |
| Other | \$1.89 | 8% | 30 | 14% | 0 + 1 | 8% | \$1.61 | 13% | 0.85 |
| | | | | | | | | | |
| TOTAL | \$23.02 | 100% | 221 | 100% | 0 + 12 | 100% | \$12.43 | 100% | 0.54 |

Discovery performance by commodity in Australia 2007-2016

Note: Estimated value of discoveries is based on average notional value (in 2013\$) of \$2000m, \$500m, \$80m & \$10m for Tier 1, 2, 3 and unassigned discoveries respectively. Valuations are indicative only, and exclude unreported discoveries

Source: MinEx Consulting © March 2017

AUSTRALIAN DISCOVERY PERFORMANCE BY COMMODITY 2007-2016, SUPPLIED BY R. SCHODDE 2017



GLOBAL EXPLORATION EXPENDITURE 1975-2016, SUPPLIED BY R. SCHODDE 2017

Scale reduction - research, technology and data priorities.

The technical challenges associated with improving exploration performance in the under cover search space, are associated with a systematic scale-reduction, exploration targeting and decision-making process. The key scale-reduction steps to make transformational improvement in performance and encourage a re-entry into greenfield exploration activity are documented in Stage 1 of the roadmap. The greatest potential contribution in improving performance is in predictive capability, locating mineral systems in the first regional to camp scale area reduction. Once mineral systems are located these are then followed using a mix of prediction AND detection of new mineral camps. It is this key regional to camp scale reduction where the targeting process transitions from prediction to detection in the covered search space. Exploration requires an improvement in prediction prior to this crossover from prediction to detection to be more successful at this scale. A step change in predictive capability represents the biggest challenge. If addressed this will result in a major breakthrough in improving exploration performance, reset the

maturity clock and re-modernise exploration specifically designed for the undercover search space.

Stage 1 recommended that programmes that address both the prediction and detection of mineral camps in this important scale-reduction step, regional to camp scale step should be prioritised. These Stage 1 programmes encompass new geoscientific knowledge from research, new detection technologies and associated data compilation and acquisition.

Dependency mapping of themes and scale reduction undertaken in Stage 1 evolved in Stage 2, with the greater level of detail in the programme designs and further mapping of the linkages between all the activities. For example, the improved understanding of distal mineral footprint signatures in locating new mineral camps under cover was identified and prioritised; this understanding would also improve locating mines within larger mineral systems through improved vectoring knowledge and technologies.



PREDICTION AND DETECTION IN SCALE REDUCTION DECISION MAKING PROCESS (MODIFIED FROM MCCUAIG ET AL., 2010)

| Scale reduction & Roadmap themes – Dependency mapping | | | | | | | |
|---|---|---|--|--|--|--|--|
| Theme | Scale Reduction | | | | | | |
| | Terrane to Regional 300,000 – 30,000kms² | Regional to Camp 30,000- 3,000kms ² | Camp to Deposit 3,000 -3 kms ² | | | | |
| Characterising the Cover | Stage 1 Dependency mapping | | | | | | |
| Whole lithospheric architecture | Stage 2 Dependency mapping | | | | | | |
| 4D Geodynamic evolution and metallogenesis | | No. of Concession, Name | | | | | |
| Distal mineral footprints | | | | | | | |
| Risk/reward for covered economic resources | | | | | | | |
| Research education and training | Research, education and training is an underpinning and high priority focus area. As it maps across all scales it was not mapped in the Scale Dependency Matrix | | | | | | |

RELATIVE UNCOVER THEME INPUT INTO SCALE REDUCTION – UPDATED EVOLUTION DEPENDENCY MAPPING FROM AMIRA INTERNATIONAL P1162 ROADMAP, 2015

National infrastructure - impacts and impediments to development.

In order to sustain current minerals production and to support further growth it is important that an inventory or pipeline of new economically viable multi-commodity mineral resources is maintained. Highest quality mines are those that can make a material contribution to the country production levels, and consequently must be large and of sufficient grade to sustain large-scale mining operations at the same or increased production rates for decades into the future. These quality mines are often referred to as world-class or Tier 1 mining operations.

A critically important factor to consider in converting resources into new mines, especially for lower quality and/or smaller Tier 2 or Tier 3 resources, is the availability of supporting infrastructure. Tier 2 or Tier 3 resources cannot independently support the capital cost of this infrastructure development throughout the mining cycle. Australia has a large number of these remote, smaller resources which are currently uneconomic due to required new capital infrastructure, and will remain "infrastructure stranded" until investment into required infrastructure is committed or in the long term, cheaper alternative mining methods can be developed. Higher quality Tier 1 resources are less constrained by infrastructure due to their scale and longevity, which can support the required capital investment in infrastructure as part of a Tier 1 mine development.

A better understanding of the impact of infrastructure on remote greenfield exploration, as a barrier (where the infrastructure does not exist) or enabler (where it does exist) is required. This will lead to an improved understanding the impact of new infrastructure on new mining from exploration and contribute to future national infrastructure planning and development. This is especially required in areas of high-potential covered terranes. It will inform how national infrastructure impacts economic attractiveness of current resources and will assist in planning/modelling of new infrastructure to unlock value from the currently stranded resources.



Geoscience workforce.

As identified in Stage 1 of the Roadmap there has been a sustained move away from greenfield to brownfield exploration activities by the mining sector over the past 20 years. This trend is particularly pronounced during commodity price downturns and in the last 'mining boom' (2003-2012) did not rebound during sustained increased commodity prices. As a consequence, there has been a steady decline in the number of industry geoscientists exposed to large-scale targeting programmes in greenfield exploration. This trend has resulted in a steady diminution in overall workforce experience, and exposure in targeting and greenfield exploration was identified as a structural deficiency and a key gap. This is a global trend but is exaggerated in Australia, Canada and the USA. Large-scale regional targeting activities are increasingly being undertaken by a smaller and ageing group of specialist geoscientists. This gap in skill level is expected to widen further as these experienced specialist geoscientists leave the workforce over the next 10-20 years at the very time when it is anticipated these skills will be required to discover new mines in the greenfield exploration environment.

Additionally, as mineral exploration moves from surface prospecting to predictive exploration under cover, it is anticipated that the need for specialist geochemists and geophysicists will increase at a time when it is expected the availability of personnel and, importantly, experience in these two disciplines will be in decline. Increasingly, given under cover exploration requires integrated skill sets, it is recognised that new targeting will need to draw on these disciplines and indeed structural geology guided by economic principles, to improve capability to cross scales and make discoveries. The need for specialist skills will affect companies, service providers and even government surveys as end users, it is also expected that a shortage of specialised skills will impact research institutions since fewer graduates are available that will take up an academic career. The key challenges to be addressed are how to attract an increased number of geoscientists to specialise in required disciplines, and for the mining and exploration community how to build and nurture internal specialist capacity. These challenges are difficult ones for the collective geoscience community to address.

Workforce demographics.

Across the exploration community, it is recognised that a trend is developing within the workforce, skewing it into two broad generations of geoscientists, with reduced numbers in the bridging mid-career 10-25-year experience level. Unfortunately, when combined with the cyclical nature of the industry, this trend makes it difficult for long-term, sustained efforts by many organisations to complete formal training programmes for geoscientists to be exposed to required experience before moving into senior, decision making levels in their careers. A collaborative approach between industry, educational/academic sectors and government is required to address this deficiency in capacity and to ensure the impending shortage in exploration targeting and leadership skills is addressed. The shortage may be addressed both through upskilling and exposure to exploration targeting and leadership skills in the current workforce, and in the longer term through development of geoscience disciplines and (qualifications). "COMING TOGETHER IS A BEGINNING, STAYING TOGETHER IS PROGRESS, AND WORKING TOGETHER IS SUCCESS."

HENRY FORD

5 THE CASE FOR COLLABORATION

A NEW DAWN FOR MINERALS EXPLORATION GEOSCIENCE

Many solutions to common and complex problems are beyond the capacity of individual organisation to developand are best tackled through collaborative partnership



The Australian minerals exploration industry has survived until now with very low levels of collaboration between companies, government and research organisations. Whilst companies are keen to access free government support for joint-funded drilling and other shared initiatives promoted by the States in recent years, there has been very little open company to company collaboration, even when the companies have been in Joint Venture with each other. In short, the levels of trust and sharing have been low and the levels of suspicion and data hoarding have been high. These behaviours have become engrained in corporate cultures, yet to be successful in the under-cover search space they have to change. The age of walking in on new exploration frontiers and guickly grabbing easy near surface discoveries is over. It perhaps belongs to a last-century "colonial" mentality to exploiting mineral exploration potential. Those days are gone, not just in Australia but in most producing mineral districts globally.

Since 2006, the world-wide discovery rate for Tier 1 deposits has fallen to half the previous rate. Worse still there have actually been no Tier 1 discoveries in Australia in the last decade. These success rates, combined with the extreme challenge of exploring under cover ahead of us, means that now is the time for a structural and technical transformation for our industry.

There is a New Dawn of whole scale precompetitive collaboration and open innovation. The Oil industry went through this transformation in 1970's and 80's when they started exploring deeper and deeper offshore. The parallels for the minerals industry as it embarks on deep-cover onshore exploration are both clear and profound. New geophysical, geochemical and drilling technology will be required. New service companies will arise; and junior, medium and major resource companies will need to work together to be effective in this search space. Government too will need to do things differently, in the technical data and support they provide though regional datasets and metallogenic studies and in facilitating more rapid land access and smoother passage of discoveries through statutory approval processes. At the end of the day, it is the nation, the people of Australia, who will own the resultant success or failure of this transformation. They have every right to expect that the resources sector will continue to deliver a standard of living that embodies the notion of the Lucky Country. It is the minerals geoscience ecosystem that collectively have the responsibility and ability to continue to deliver on that promise. To do so, we will need to change our attitudes to collaboration and sharing of information in the precompetitive space. Without high levels of collaboration, the vision of the Roadmap will not be delivered on

How to usher in the new era of collaboration and open innovation required to deliver the UNCOVER vision?

When UNCOVER was first envisioned by the Theo Murphy Think Tank in 2010, they focussed on progress in science to solve the issues identified. Whilst new science will create tools that are used in under cover exploration, it will need much more than that for us to be successful discoverers under cover. There are numerous opportunities to share existing knowledge and understanding and turn this into new technology for mineral discovery. There are also opportunities for industry to stop duplicating effort in the early greenfield search spaces, in much the same way the pharmaceutical companies have stopped duplicating early stage genetic studies and biological target identification. Most early stage R&D in the pharmaceutical industry is now done under co-funded company-government consortia, leaving the drug companies to focus on their core business of drug development, manufacture and marketing. This paradigm shift in industry collaboration has opened up new search spaces for pharmaceuticals. With a backbone of govern-

ment co-funding, research has begun to work on previously intractable problems like insect borne diseases that were previously not profitable enough research areas to attract "Big Pharma" investment. This has led to a rehiring of thousands of researchers (explorers) who now work on truly inspirational pharmaceutical projects. These structural changes have almost certainly resulted in the saving of the pharmaceutical industry in Europe.



Collaboration intensity

INFOGRAPHIC SHOWING THE PREREQUISITES FOR COLLABORATION IN ANY INDUSTRY SECTOR AGAINST THE COLLABORATION INTENSITY THAT IS REQUIRED OR THAT CAN BE ACHIEVED. TO DELIVER ON THE ROADMAP VISION SUCCESSFULLY BY OPENING UP A NEW COMPETITIVE SPACE (DEEP COVER AREAS), SHARING AND COLLABORATIVE BEHAVIOURS NEED TO UNDERGO MAJOR PARADIGM SHIFTS. THE OIL AND GAS EXPLORATION SECTOR HAS ALREADY UNDERGONE THESE SHIFTS DUE TO IMPERA-TIVES OF WORKING IN DEEP WATER OFFSHORE.

Image credit: John Kapelerlis

The Australian exploration industry has pioneered many innovations to support successful mineral exploration. The state geological survey organisations, led by South Australia, pioneered acquisition, compilation and freely sharing of their regional and exploration data, that can now be interrogated on line through GIS portals and are made available for free download. In spite of this leadership from government, companies have remained reluctant to share data that did not have to be reported and released under the terms of their mineral exploration tenements. Much key data that will be required to build mineral systems models and distal mineral footprints is held confidential to the companies holding mining leases over these key datasets. Unfortunately, despite security of tenure these companies often consider data relating to these resource assets to be sensitive and core to their IP. Through the roadmapping, it is acknowledged that access to this data is urgently required to generate transformational knowledge to improve performance across the all sectors in the mining industry. Enacting this change will require a new conversation, one focussed on delivering new knowledge that benefits the original owners and the broader geoscience community. As an example, this is how "Big Pharma" approached gene sequencing and biological targets before they adopted the new paradigm of precompetitive collaboration. The advantages of collaboration include the savings and increased investment the pharmaceutical companies can attract to this early stage work allowing them to focus instead on what they have always done best, development and marketing.

A trend that has developed over the past 25 years where most of the world's mineral exploration and discovered value is undertaken and delivered by junior exploration companies. In a cyclical industry, (especially in downward trend in the investment cycle) medium and major companies facilitate the success of the juniors by funding then and buy into projects at strategic stages where their skills in project development can capitalise on the initial discovery value. On the upward part of the cycle the medium and major sectors then return to greenfield exploration where investment is justified. Over the longer term it therefore makes sense for large companies with huge legacy datasets and access to physical samples, mine exposures and drill core to open their doors and share these with people who can use them to make discoveries. Whilst major companies have tried sharing datasets through concepts like strategic alliances and joint ventures, there is no evidence that these have increased discovery rates above the performance of the general junior exploration sector. This may be due to only limited collaboration in these alliances. Collaboration is not a spectator sport. You must stand side by side your Sherpa and travel with him all the way, to reach the summit.

Consolidation of the industry in the mid 2000's resulted in a smaller number of larger companies, and many excellent explorers formerly employed and trained by progressive medium sized companies either moved to leading junior exploration companies or operated as consultants and project generators feeding opportunities in to the junior portfolios. Over this time period major companies have significantly reduced in house generative and greenfield exploration, implementing an advanced project acquisition strategy of projects de-risked to feasibility stage by the junior sector.

Over this period junior explorers effectively became the early exploration arm of the majors. It is thus in the interest of the majors to share their data, knowledge and resources with the juniors to allow them to fill the early stage project pipeline. Many of these juniors have the ability to think like a major, but not the financial resources or scale of available resources to act like one. Major companies with these data resources now have a huge opportunity to effectively fund exploration through generous and open sharing of their data and previous investment in R&D programmes as proposed in this Roadmap. An open approach to collaborative early stage exploration will allow the best minds and ideas to impact on the best opportunities which should facilitate better results than picking winners through a limited number of strategic alliances.

Junior companies do not have the ability fund massive R&D programmes like those proposed in this Roadmap. It is the larger companies that are able to fund, provide in kind support and to second workers to these programs. Some consultants have the knowledge to impact greatly on such programmes, but lack an incentive to give their time and ideas unless others similarly contribute. The New Dawn of collaboration must encompass the whole mineral industry. How we work and the rules under which we operate as well as the science and technology that we use, must be transformed. Concepts like open-source must be truly embraced and the stakeholders of the exploration ecosystem must openly share the data relevant to the precompetitive R&D and early greenfield exploration. These new behaviours can then leverage matching funds from government and result in new collaborative working relationships, encouraging the best and brightest innovators from around the world to get involved to find rapid solutions to our problems and knowledge gaps.

Many people claim that the birth of the Internet (since 1969) started the open source movement, but it really took off in the late nineties when Linux and Netscape made their source code freely available. The following are the six key rules for establishing a truly open sharing project (Robertson et al, 2013):

- 1. All data are open and all ideas shared
- 2. Anyone can take part at any level of the project
- 3. There will be no patents
- 4. Suggestions are the best form of criticism
- 5. Public discussion is much more valuable than private email
- 6. The project is bigger than, and not owned by, any given participant.

In spite of the spectacular success of open source prize initiatives like The Goldcorp Challenge, there is continued risk aversion in the minerals sector to sharing of data and slowness in deployment of new ideas and technologies. This is a major brake on collaboration, innovation and discovery. From the Stage 2 Roadmap sponsor and stakeholder engagement meetings the "Key Mental Blocker" was often expressed as: "Why would we want to give away information and thus competitive advantage?"

Long term confidentiality of data and information is not of itself a competitive advantage. Many databases are not being actively used, and when staff leave an organisation, knowledge about data and much of the tacit understandings leaves with them. The result is that the data commonly loses value over time.

Distal footprint studies necessitate sharing and collaboration between companies who own deposit data, governments who can bridge data between and beyond deposits, and researchers and consultants who can analyse and build knowledge to identify opportunities and targets. The needs of multiple parties must be reconciled. Each must gain a benefit and as many 'pain points' as possible, for as many stakeholders as possible, need to be addressed. A common barrier to progress is clash of cultures: universities want publications, industry is looking for tools and products (typically developed in the short-term), the government wants investment and jobs and the wider community is concerned about collateral impacts.

Successfully finding buried deposits will require a new paradigm of collaboration and sharing. As the largest sector by headcount and generation of economic value, industry needs to increase cross-sector engagement by reassessing its default behaviours of siloed collaboration and data confidentiality. Value can be added to data through creative thinking, application and innovation, to facilitate this, the collective geoscience community needs to consider a change by allocating 'thinking time' much like Google. They need to embrace the idea of openly sharing what is arguably a low value product, their data. We need a new approach, one where collaboration and sharing is the new normal, where effort and rewards are shared in win-win arrangements. Change is always difficult and risky, but if we are going to achieve the Roadmap vision in the timeframe that we have set ourselves, then addressing the research and technology development challenges will be necessary but may not be sufficient unless industry considers and commits to new business models.

Whilst very challenging, the full open source model of collaboration has many benefits. It has been shown to be very cost effective, it gets the global community involved and it gives motivation for the best to give their best. It means that the outputs are unencumbered by complex confidentiality, IP or patents and that during the work results can be released in near real time to immediate effect and reiteration. Open source means less money and time spent on the security of information and more time developing new understandings and breakthroughs. The younger generation will likely not challenge this, and it is they who must be invested in delivering on the vision of the Roadmap. It is important that the older generation engages in the robust conversations that will need to be had to be able to share the data that is urgently required to deliver on this vision.

Continued restriction on inputs risk strangling the process, resulting in delays and potentially further duplication of effort.

Successful exploration for minerals under cover will require a paradigm shift. As an industry we need to realise that data is a low value commodity and should be more readily shared so a more complete Big Data set can be built for collaborative precompetitive analysis. New business models for collaboration that could work for the implementation of the Roadmap programmes include: Discovery Enabling Consortia; Public-Private Consortia for Knowledge Creation; Open Source Research and Prizes for Innovation Breakthrough.

Open access to important data for new research programmes over some of the very deposits we are searching remains a key impediment to developing new knowledge required to now open the covered search space. The only viable future is a shared future, with co-investment from both governments and the whole of the industry. Success or failure of the implementation of the Roadmap will be judged by the number and quality of new Tier 1 discoveries that are made and the resultant community wealth that is generated from them. An opportunity now exists for this to happen more rapidly with a joint government-industry open innovation and high collaboration model and through the implementation of this Roadmap. The alternative is that it may not happen at all, or come far too late to result in improved performance.

DRILL CUTTINGS EULO 1 QUEENSLAND. COURTESY GEOLOGICAL SURVEY OF QUEENSLAND "FIRST, HAVE A DEFINITE, CLEAR PRACTICAL IDEAL; A GOAL, AN OBJECTIVE. SECOND, HAVE THE NEC-ESSARY MEANS TO ACHIEVE YOUR ENDS; WISDOM, MONEY, MATERIALS, AND METHODS. THIRD, ADJUST ALL YOUR MEANS TO THAT END."

-ARISTOTLE

NEAR BROKEN HILL NSW. IMAGE COURTESY OF GEOLOGICAL SURVEY NEW SOUTH WALES

6 ROADMAP AND RESULTS

NAVIGATING THE ROADMAP, PRODUCTS AND TOOLS

Fundamentally the Roadmap was designed to convert ideas to action, providing practical guidance to deliver tangible new knowledge, new technology and new state of the art data.

6.1 NAVIGATING THE ROADMAP, PRODUCT AND TOOLS

At the outset, the primary objectives of Stage 2 of the Exploration Under Cover Roadmap was to progress and complete the work commenced in Stage 1, split into two categories:

- Deliver individual detailed and a compiled portfolio of time sequenced and costed programmes focussed on the priority activities identified in Stage 1
- 2. Investigate suitable funding models and appropriate vehicles to implement the programme.

The collaborative process provided members of the exploration geoscience community an appropriate

forum to collaboratively contribute to various Roadmap activities and assist in building a new and innovative portfolio required for a new national research programme for exploration under cover, outlined in Stage 1. The various outputs from the Roadmap are delivered in formats designed to assist in the design of individual projects and the future implementation of such a new combined, fully integrated programme.

Outputs, products and tools delivered as per of the Roadmap and where to find them are outlined adjacent and on the next page.





NAVIGATING THE ROADMAP; OBJECTIVES -PRODUCTS

| Objective | Roadmap activity | Product & Delivery | | | | |
|--|--|---|--|--|--|--|
| Understand historical research, technology and data activity | Compile a listing of historical research, technology development and data associated with sub themes identified in Stage 1 provided by Roadmap participants. Results made available to the roadmap sponsors and later to the broader geoscience community. | Current State Scan is provided as a single compiled listing available electronically from AMIRA International www.amirainternational.com/P1162A- Roadmap/CurrentStateScan | | | | |
| Design required research, technology and data Strand programmes identified in Stage 1 | Compile standard strand summa- ries, bringing together key information required to further expand and develop individual and executable projects. Strand summaries separated, based on the required activity: • Knowledge research • Exploration technology development • Data compilation • Data acquisition | Roadmap Strand Summaries 45 Sub Theme Overviews and individual 159 Strand Summary documents in Appendix C and available electronically from AMIRA International www.amirainternational.com/P1162A- Roadmap/RoadmapStrandSummaries | | | | |
| Compile Roadmap programme inputs, outputs, costs and people requirements | Collate original UNCOVER themes, Roadmap themes, Sub-Themes and Strands into single products | Roadmap Programme Portfolio Collated Theme, Sub Theme and Strands outputs to be included in Roadmap report and via posters available in Appendix B and electronically from AMIRA International www.amirainternational.com/P1162A- Roadmap/RoadmapProgrammePortfolio | | | | |
| Apply innovative approach to better understand priorities and dependencies in complex challenges | Roadmap research technology and data dependencies mapped based on required inputs and on expected outputs into a new integrated dependency map. Complete dependency mapping within and across Roadmap themes and individual strands | Dependency Mapping Dependencies delivered via various outputs: Posters available in Appendix B Interactive online tool www.amirainternational.com/P1162A-Roadmap/DependencyMapping | | | | |
| Identify current and consider new Research vehicles & Funding options | Compile of current vehicles and identify future vehicles and funding options representing the best options to be implemented for setup to undertake new research and technology development | Implementation recommendations for NRP Current and future vehicle compilation with recommendations delivered in Roadmap report | | | | |
| Demonstrate Australia's national geoscience talent in research technology and data delivery | Complete and release Australia's first geoscience capability and capacity map of national research and geological agencies | National Geoscience capability- capacity map Compilation available electronically and via posters available in Appendix B www.amirainternational.com/P1162A- Roadmap/NationalGeoscienceCapability- CapacityMap | | | | |

6.2 CURRENT STATE SCAN – A STARTING POINT

Building an effective new, national scale and truly integrated research, technology and data programme depends on identifying a starting position. Collecting and collating previously completed work then combining with progress in current initiatives best positioned the Roadmap in developing and designing a future required activity. It is envisaged that the research, technology development and data programmes will be a combination of newly identified activities that are not currently being addressed, accompanied by the acceleration of current, high priority initiatives and programmes. The Roadmap is premised on building on what has been done, or what is currently being done, not on duplicating effort.

The minerals exploration geoscience community assisted in building a Current State Scan (CSS) of historical work, status of current research, exploration technology and a multitude of data compilation and new data acquisition programmes. The CSS was built through two major workshops and then augmented with a number of one on one face to face meetings.

A total of 1,140 separate entries are included in the CSS database which is available via the Roadmap Stage 2 project from AMIRA. Involvement in building the CSS and sharing results with sponsors, participants and the Roadmap development team enabled a far greater understanding and awareness of historical work undertaken and available. The CSS also raised cross stakeholder awareness of the current portfolio of activity focussed on mineral exploration under cover. The CSS process and product exemplifies one of the fundamental advantages of true crosssector collaborative research initiatives of raising the collective awareness. Further sharing and adoption of this resource will expand the greater understanding throughout the geoscience community, unlocking value from historical ground-breaking research and existing data.

'ONE OF THE MAJOR ACHIEVEMENTS OF THE ROADMAP PROCESS HAS BEEN THE CREATION OF A BROAD NATIONAL COMMUNICATION FORUM, BRINGING TOGETHER THE GOVERNMENT GEOLOGICAL SURVEY AND RESEARCH ORGANISATIONS, UNIVERSITIES AND INDUSTRY REPRESENTATIVES. OTHER EFFECTIVE COMMUNI-CATION CHANNELS EXISTED BEFORE - AND EXIST NOW. THE UNCOVER ROADMAP ESTABLISHED AND MAIN-TAINED A FIRM STRATEGIC FOCUS AND AN EMPHASIS ON THE NEED FOR A MUCH CLOSER NATIONAL COL-LABORATION – BOTH NECESSARY TO SUCCESSFULLY RESOLVE MAJOR CHALLENGES OF EFFECTIVE MINERAL EXPLORATION UNDER COVER'

DR VLADIMIR LISITSIN, GEOLOGICAL SURVEY QUEENSLAND





6.3 NEED FOR AN INTEGRATED NATIONAL APPROACH. A NATIONAL GEOSCIENCE PORTFOLIO

By combining forces in implementing the Roadmap, the minerals exploration geoscience community has the opportunity to significantly advance science knowledge and technology development that will improve industry's ability to discover Tier 1 deposits under cover. The integrated portfolio of new geoscience research, technology development and data programmes in the Roadmap used the CSS as a starting point.

The roadmapping consultation provided stakeholder input that greatly assisted in developing a blueprint to enable us to achieve the Roadmap vision.

The major inputs and programme design were guided by the leading principle of gap analysis. Learning from similar technology endeavours we know that new capabilities will emerge through new knowledge and development of new technologies. To be successful in navigating the complex task, an integrated approach in design was required to advance programmes to improve both predictive targeting capability and application of new or enhanced detection techniques and technologies to under cover mineral discovery.

All sub themes identified in Stage 1 were advanced by separating each sub theme and expanding into research, technology and data outcomes, then methodically designing parallel integrated streams or programme strands. A similar approach was successfully implemented by NASA in developing technology Roadmaps in 2015³. The 45 sub themes were expanded into 159 separate and uniquely identified strands, nomenclature of the strands are presented. For a breakdown of the separate strands by activity within each of the Themes refer to table and figure over the page.

To complete the design process into implementation and to commence execution of the programme it is now expected that the broad strand programmes will need to be expanded further and used to drive the development of individual research, technology and data projects to deliver new knowledge, new or enhanced exploration technologies and fundamental new data layers.

Each of the 159 identified strands were compiled into a standard 'Strand Summary' document, capturing information required to take each of the programmes to next level and design individual projects. In essence, the objective was to take the sub themes developed in Stage 1 and expand each into its constituent strands. Description of the standard document sub-theme overviews and then the individual strand summaries included are summarised in the below table.

A compilation of the research, technology and data strand summaries are available from AMIRA International in electronic format in Appendix C.



BACKGROUND PHOTO - FE IN CONCENTRIC PISOLITHS (SYNCHROTRON DATA) GARDEN WELL GOLD DEPOSIT, SOURCE - CSIRO



NAVIGATING THE ROADMAP - P1162A THEME TO STRAND TO FUTURE PROJECT EXPANSION



6.4 RESEARCH PROGRAMME SUMMARY

An extensive portfolio of new research is needed to develop new knowledge which will result in new capability in mineral exploration geoscience across all the six Roadmap themes. Expected outputs of the research programmes will be primary inputs for many other research or technology development or data initiatives. These dependent programmes will either run concurrently or sequentially with other programmes undertaken both within and across themes. Required research ranges from small, short timeframe programmes, delivering specific knowledge or data through to highly complex and very large multiyear integrated programmes. To ensure all requirements were mapped it was agreed early in the roadmapping process that no constraints in terms of timeframes or funding size restrictions were to be applied prior to developing the research and technology development programme portfolio.

Across all of the six themes, a total of 76 separate research programme strands were identified. Of the research related strands, the time frames estimated for delivery ranged from 0.5 to 12 years and financial investment ranged from \$0.5 to \$100m. The average time for delivery across all research related focus areas was 3.9 years.

For each, the Roadmap identified input requirements from other activities and major outputs or deliverables together with quantifying an estimate of time required, resources and costs for each of the programmes. These are outlined in the research programme summary figure. The critical next step, as with many equivalent roadmaps is to further expand the identified programme strands into separate individual projects through an implementation process by the collective mineral exploration geoscience community.

Details of the research strands are expanded in the individual Research Strand Summaries in Appendix C, identified using nomenclature adopted in 'Theme-Sub Theme-Strand' detailed in the figure above. The research programme strands are also presented on the Poster in Appendix B.


P1162A ROADMAP

| Ţ | | | Research Prog | ramme Timing | Research Programme Costs | | |
|--------------------|--|-----------------------|---------------------|-----------------------|--------------------------|----------------------------|--|
| Roadmap Theme name | | Research Strands # | Time Range Years | Average Time Years | Strand Total Cost \$M | Average Strand Cost \$M | |
| 1 | Characterising the Cover | 19 | 0.5-10.0 | 3.4 | \$63.1 | \$3.3 | |
| 2 | Lithospheric Architecture | 7 | 0.5-12.0 | 8.1 | \$13.3 | \$1.9 | |
| 3 | Geodynamic Evolu on and Metallogenesis | 6 | 0.5-12.0 | 2.9 | \$11.6 | \$1.9 | |
| 4 | Distal Mineral Footprints | 12 | 0.5-12.0 | 4.2 | \$170.9 | \$14.2 | |
| 5 | Risk Reward for Covered Economic Resources | 14 | 0.5-3.0 | 3.5 | \$26.2 | \$1.9 | |
| 6 | Research Educa on and Training | 17 | 0.5-6.0 | 1.1 | \$8.0 | \$0.5 | |
| | Totals | 75 | 0.5-12.0 | 3.9 | \$293.0 | \$3.4 | |





6.5 EXPLORATION TECHNOLOGY SUMMARY

The potential for new technologies to enhance the capabilities required in the Stage 1 sub-themes was explored in the current state scan process and expanded in the roadmapping process. Many proposed technology programme strands identify significant improvements or enhancements to existing technologies as well as new technologies and tools that rely on results from the research programme. New innovative exploration technologies that build on the latest advances in enabling technologies such as sensors for example, will improve both mapping and targeting in areas of cover. They may even offer the ability to acquire whole new data sets that were not possible to be acquired in the past because the technology was not available, e.g. airborne IP and gravity using UAVs for example. A sizeable percentage of the technology development programmes presented are new ideas designed to complement and extend the identified research needs.

As with research these dependent technology programmes will be either running concurrently or sequentially to the research being undertaken both within and across themes. Required technologies range from small, short time frame programmes, delivering specific enhancements through to highly complex and very large multiyear integrated technology programmes.

Across four of the six themes, a total of 25 separate technology programme strands were identified. Of the technology related strands, the time frames estimated for delivery ranged from 0.5 to 10 years and financial investment ranged from \$0.5 to \$20m. The average time for delivery across all research related focus areas was 2.9 years.

Technology development programmes are outlined in the technology programme summary, presented on adjacent page. The critical next step, as with many equivalent roadmaps is to further expand the identified programme strands into separate individual technology development projects through an implementation process by the collective mineral exploration ecosystem.

Details of the technology strands are expanded in the individual Technology Strand Summaries in Appendix C, identified using nomenclature adopted in 'Theme-Sub Theme-Strand' detailed in above figure. The technology programme strands are also presented on the Poster in Appendix B.



P1162A TECHNOLOGY PROGRAMME SUMMARY

| = | | | Technology Pro | gramme Timing | Technology Programme Costs | | |
|--------|--|-----------------------|---------------------|-----------------------|--------------------------------------|--|--|
| heme # | Roadmap Theme name | Technology Strands | Time Range Years | Average Time Years | Technology Strand Tot Cost \$M | Average Technology Strand Cost \$M | |
| 1 | Characterising the Cover | 18 | 1.0-10 | 5.6 | \$101.3 | \$5.6 | |
| 2 | Lithospheric Architecture | 1 | 2.0 | 2.0 | \$0.5 | \$2.0 | |
| 3 | Geodynamic Evolu on and Metallogenesis | 0 | | | \$- | \$- | |
| 4 | Distal Mineral Footprints | 3 | 0.5-2.0 | 1.5 | \$6.0 | \$1.5 | |
| 5 | Risk Reward for Covered Economic Resources | 2 | 20-3.0 | 2.5 | \$5.0 | \$2.5 | |
| 6 | Research Educa on and Training | 0 | | | \$- | \$- | |
| | Totals | 24 | | 2.9 | \$112.8 | \$4.6 | |





6.6 ROADMAP DATA INITIATIVES

Innovation and performance improvement in under cover mineral exploration will come by combining new knowledge from new research with new or enhanced technologies, routinely applied by the exploration and mining industry. Fundamental to delivering on this is access to new high quality regional data. In this context 'new data' is a combination of existing data previously acquired but not utilised with newly acquired data where existing data does not exist.

6.6.1 DATA COMPILATION SUMMARY

The roadmapping process clearly pointed to the conclusion that before developing plans for new and wide-ranging data acquisition programmes, dedicated compilation programmes of existing data and knowl-edge are required. Compilation of existing data is as much about getting full value from previous work as it is about eliminating potential duplication by re-acquisition. Additionally, compilation will not only identify where data does not exist, it will also identify where data exists but is not of the required quality and needs (in some cases) to be re-acquired or infilled.

Compilation of existing data may be a routine and non-glamorous task, but it is fraught with pitfalls. The metadata, data formats, accessibility, correct unit attributes, and compatibility with other sources of data are as important as the data itself.

Whilst Australia is globally recognised as a leader in the field of data acquisition, management, and public distribution; accessing and utilising this data is far from straightforward. To direct future data compilation exercises and to inform compilation decisions, the data compilation strand summaries identify the types of desirable data along with the anticipated uses together with resources and experience of personnel to complete the task.

These separate compilation programmes within the strands are either new data compilation initiatives or significant acceleration, streamlining and expansion to current programmes currently underway. Accelerating and expanding current compilation programmes is urgently required to accelerate new data acquisition. The intent of the data compilation identified in the Roadmap is to align and link datasets to streamline data access. The effort is not intended to create a single repository, but rather to ensure an appropriately complete compilation is achieved and that this increases overall data accessibility and thereby utilisation frequency.

The data compilation strands identify storage and data access requirements to some degree, and collectively encourage, by developing guidelines the alignment of formats and standards across Australia. The effort requires significant attention to detail to rectify unit corrections, appropriate data clean up and levelling etc., to ensure the historic data are usable. Further, since non-exploration focused organisations collect and store data relevant to mineral exploration, it is important that these data are scoped and mapped out, and that regardless of original reason for collection, any suitable data is made available to directly support exploration under cover in addition to access for research and technology.

The data compilation programme strands are also presented on the Poster in Appendix B Across five of the six themes, a total of 35 separate data compilation programme strands were identified. Of these strands, the timeframes estimated for delivery ranged from 0.5 to 12 years and financial investment ranged from \$0.5 to \$15m. The average time for delivery across all research related focus areas was 2.5 years.

Details of the data compilation strands are expanded in the individual data strand summaries in Appendix C, identified using nomenclature adopted in 'Theme-Sub Theme-Strand' detailed in above figure. The data compilation programme strands are also presented on the Poster in Appendix B.

P1162A TECHNOLOGY PROGRAMME SUMMARY

| The | | Data | Data Compila on Programme Timing | | Data Compila on Programme Costs | | |
|------|--|------|-------------------------------------|-----------------------|------------------------------------|----------------------------|--|
| me # | Roadmap Theme name C | | Time Range Years | Average Time Years | Strand Tot Cost \$M | Average Strand Cost \$M | |
| 1 | Characterising the Cover | 20 | 1.0-5.0 | 3.0 | \$78.2 | \$3.0 | |
| 2 | Lithospheric Architecture | 7 | 0.5-12.0 | 2.9 | \$25.5 | \$2.9 | |
| 3 | Geodynamic Evolu on and Metallogenesis | 4 | 1.0-3.0 | 2.3 | \$10.5 | \$2.3 | |
| 4 | Distal Mineral Footprints | 1 | 3.0 | 3.0 | \$7.2 | \$3.0 | |
| 5 | Risk Reward for Covered Economic Resources | 3 | 1.0-2.0 | 1.5 | \$1.6 | \$1.3 | |
| 6 | Research Educa on and Training | 0 | | | \$- | \$- | |
| | Totals | 35 | | 2.5 | \$123.0 | \$2.7 | |





6.6.2 DATA ACQUISITION SUMMARY

To deliver new data to the mineral exploration community for use in research, technology development and directly in greenfield mineral exploration activity in covered areas of Australia, new wide ranging data acquisition programmes were identified and proposed in the roadmapping process.

New data acquisition is complimentary to the existing data compilation activities proposed. Data acquisition is required in a variety of circumstances including where a new collection method or sensitivity or other quality consideration is available, where there is a data gap of a particular type geographically, or where another research or technology programme has particular data input requirements which cannot be met with existing data. New data acquisition programmes have been designed based on addressing specific issues either identified in Stage 1 of the Roadmap as single sub-theme programmes or parts of research and technology sub themes. New data acquisition strands each contribute to improving exploration performance by de-risking exploration decision making and encouraging exploration greenfield investment in areas of cover.

The data acquisition strand programmes fall into five broad categories:

- Coordinated reanalysis of existing archived samples using new analytical technologies that will deliver new data not currently available or higher quality data through higher sensitivity, and resolution, or lower detection limits in the case of analytical geochemistry
- 2. Re-sampling and analysis of available samples previously not analysed using new technologies or not sampled at all
- 3. Re-acquisition of new geophysical data using new or improved technologies

- 4. Acquisition of additional new geophysical data where it does not exist or exist at the required spacing using new technologies
- Acquisition of new geological samples for petrophysical measurement and geochemical analysis by surface sampling or via new drilling programmes.

One of the aims of the acquisition strand programmes is to optimise the national co-ordination of re-acquisition and new data acquisition. The objective is to ensure that new data is of a consistent, minimum standard and format for use across the geoscience community. The future outcome is to create a legacy of complete (as is practicable) data sets with improved continuity (may be seamless in some cases) with modern data attributes/detection limits etc. Such new data need to be good value for money, complimentary to existing options, and be useful to the geoscience community in both prediction and measuring geological prospectivity under cover across Australia. Further, the data acquisition strand summaries often indicate how such enhanced data sets would be used to create interpretive products, new tools etc.

Across four of the six themes, a total of 25 separate data acquisition programme strands were identified. Of these strands, the time frames estimated for delivery ranged from 0.5 to 12 years and financial investment ranged from \$2.0M to \$70M. The average time for delivery across all research related focus areas was seven years.

Details of the data acquisition strands are expanded in the individual data strand summaries in Appendix C, identified using nomenclature adopted in 'Theme-Sub Theme-Strand' detailed in above figure. The data acquisition programme strands are also presented on the Poster in Appendix B.

P1162A DATA ACQUISITION PROGRAMME SUMMARY

| The | Roadmap Theme name | Data | Data Acquisitio Tim | on Programme ning | Data Acquisition Programme Costs | | |
|------|--|------------------------|------------------------|-----------------------|-------------------------------------|----------------------------|--|
| me # | | Acquisition Strands | Time Range Years | Average Time Years | Strand Tot Cost \$M | Average Strand Cost \$M | |
| 1 | Characterising the Cover | 10 | 2.0-10.0 | 9.7 | \$208.0 | \$9.7 | |
| 2 | Lithospheric Architecture | 11 | 1.0-10.0 | 5.5 | \$100.0 | \$5.5 | |
| 3 | Geodynamic Evolu on and Metallogenesis | 3 | 5.0-7.0 | 5.7 | \$27.0 | \$5.7 | |
| 4 | Distal Mineral Footprints | 1 | 10 | 10.0 | \$70.0 | \$10.0 | |
| 5 | Risk Reward for Covered Economic Resources | 0 | | | \$- | \$- | |
| 6 | Research Educa on and Training | 0 | | | \$- | \$- | |
| | Totals | 25 | | 7.7 | \$405.0 | \$7.4 | |





FALCON AGG WITH STARS, PHOTO COURTESY CGG AVIATION (AUSTRALIA) PTY LTD

DR STEPHAN THIEL FROM THE GEOLOGICAL SURVEY OF SOUTH AUSTRALIA WORKING IN THE FIELD IN SOUTH AUSTRALIA USING MAGNETOTELLURIC (MT) EQUIPMENT, AS PART OF THE AUSCOPE AGOS PROGRAM. IMAGE COURTSEY OF AUSCOPE.



BOART LONGYEAR UDR650 DIAMOND DRILL RIG -STAVELY PROJECT WESTERN VICTORIA - PHOTO SOURCE GSV



RESEARCH, TECHNOLOGY AND DATA STRAND SUMMARIES BOTH COLLATE AND CONSOLIDATE THE ROADMAPPING COLLABORATIVE ENGAGEMENT. THE END PROD-UCT OF HUNDREDS OF MEETINGS AND THOUSANDS OF HOURS OF INVOLVEMENT AND CONTINUOUS INTERACTION.

P1162A Roadmap Sub-Theme & Strand Summaries

| Sub-Theme Overview |
|---|
| Identified barrier or problem overview: |
| Key goal to be addressed overview: |
| Current status overview: |
| Identified research, technology, data gap - overview: |
| Required research technology, data outputs/deliverables overview: |
| Identified individual required research, technology, data strands within sub-theme: |
| Research, technology, data expertise required overview: |
| Expected time frame to delivery overview: |
| Expected magnitude of cost to delivery overview: |

| Individual Strand Summaries | | | | | | | | |
|---|--|-------------------------------------|-------------------------------------|--|--|--|--|--|
| Research | Exploration Technology | Data Compilation | Data Acquisition | | | | | |
| Strand Summary | Strand Summary | Strand Summary | Strand Summary | | | | | |
| Research | Exploration Technology | Data compilation | Data Acquisition | | | | | |
| Needs and Priorities: | Needs and Priorities: | Needs and Priorities: | Needs and Priorities: | | | | | |
| Research Strand Name: | Technology Strand Name: | Data Compilation Strand Name: | Data Acquisition Strand Name: | | | | | |
| Research Strand Number: | Technology Strand Number: | Data Compilation Strand Number: | Data Acquisition Strand Number: | | | | | |
| Contribution of research strand to | Contribution of technology strand to | Contribution of data compilation | Contribution of data acquisition | | | | | |
| the Sub Theme: | the Sub Theme: | strand to the Sub Theme: | strand to the Sub Theme: | | | | | |
| How will the research strand | How will the exploration technology | How will data compilation strand | How will data acquisition strand | | | | | |
| contribute to improving exploration | strand contribute to improving | contribute to improving exploration | contribute to improving exploration | | | | | |
| performance undercover: | exploration performance undercover: | performance undercover: | performance undercover: | | | | | |
| Identified barriers or problems: | | | | | | | | |
| Key goal to be addressed: | | | | | | | | |
| Current status: | | | | | | | | |
| Identified gap to be resolved: | | | | | | | | |
| Identified risk(s): | | | | | | | | |
| Research knowledge outputs/ | Technology outputs/deliverables, | Data compilation outputs/ | Data acquisition outputs/ | | | | | |
| deliverables: | including stage (POC or commercial): | deliverables: | deliverables: | | | | | |
| Education and training outputs/delive | erables: | | | | | | | |
| Dependency Mapping: | | | | | | | | |
| Dependent on outputs from: | | | | | | | | |
| Results input into: | | | | | | | | |
| Research expertise requirements | Research and technology expertise | Data compilation expertise | Data acquisition expertise | | | | | |
| | requirements: | requirements: | requirements: | | | | | |
| | | Research & Technology input | Research & Technology input | | | | | |
| | | requirements in data compilation | requirements in data compilation | | | | | |
| Data input /requirements from; exist | ing data compiled 🗆 new data to be acqui | red 🗆 | | | | | | |
| New /additional hardware technolog | y infrastructure requirements: | | | | | | | |
| New technology software / code requ | uirements: | | | | | | | |
| Envisaged researcher (number) | Envisaged researcher(s) & technology | Envisaged compilation (number) | Envisaged acquisition (number) | | | | | |
| people to delivery: | developer [number] people to | people to delivery: | people to delivery: | | | | | |
| | delivery: | | | | | | | |
| Envisaged researcher(s) profiles | Envisaged researcher(s) & technology | Envisaged data compilation | Envisaged data acquisition | | | | | |
| (experience) | developer(s) profiles (experience) | personnel profiles (experience) | personnel profiles (experience) | | | | | |
| Expected time frame to delivery: | | | | | | | | |
| Expected magnitude of cost to delivery: | | | | | | | | |

WE CANNOT SOLVE OUR PROBLEMS WITH THE SAME THINKING WE USED WHEN WE CREATED THEM.

ALBERT EINSTEIN

LAKE DRILLING, LAKE LEFROY WESTERN AUSTRALIA. COURTESY OF GOLD FIELDS LTD

ROADMAP PRIORITIES AND DEPENDENCY MAPPING

AN INNOVATIVE APPROACH

Prioritisation and follow on dependency mapping deployed in the Roadmap is understood to be the first such analysis that has been attempted in the field of minerals exploration geoscience. New tools and a new approach demonstrates boundary-spanning, cross sector innovation.

7.1 PRIORITIES AND DEPENDENCIES

Setting priorities within complex and highly diversified but related multidisciplinary programmes is critical to optimise effort and resources necessary to ensure successful achievement of the Roadmap vision. Determining where to focus finite resources (human and financial) is a critical step in enabling an organisation or community to identify the key activities that will have the maximum impact and that need to be executed early.

Setting priorities on objectives or deliverables, although highly important is only half the story. As important to priorities in complex endeavours is understanding the sequencing and dependencies required to achieve successful delivery of the primary objective:

 Sequencing involves mapping out the timing of the many individual inputs and activities to successfully achieve the high priority objective(s) Understanding dependencies involves the mapping of many inter-dependent and related activities required as inputs to achieve the primary objective(s).

Sequencing undertaken as part of the overall programme design and dependencies was achieved through dependency mapping.

In summary, successful execution of complex programmes requires some lower ranked (and seemingly unrelated) activities to be undertaken to achieve higher profile objective(s). Stage 1 of the Roadmap identified a highly-varied and interrelated set of activities ranging from scientific research and related technology development through to data and knowledge compilation and new data acquisition.

7.2 ROADMAP PRIORITIES

In Stage 1 of the Roadmap significant effort was invested at determining which sub themes or activities to focus the collective geoscience community resources on considered to contribute most to positively impact and improve under cover exploration performance. The majority of these addressed the key step in the exploration workflow of area reduction from a regional scale to camp scale by improving predictive performance.

The roadmapping process expanded the original four UNCOVER themes to six and identified 45 focussed

areas or sub themes. The Roadmap presents prioritised and ranked activities to achieve the primary objective. The prioritisation process delivered a consensus ranking of activities to be addressed in Stage 2.

The highest and high priorities identified 16 of the 45 sub themes comprised a variety of research, technology and data programmes. These highest and high priority category sub themes are presented in figure on the adjacent page. A full ranking of sub-themes is available in Table 3, page 28 of the Stage 1 report.

http://www.amirainternational.com/P1162A-Roadmap/DependencyMapping/



Roadmap - Sub Theme (ST) Priorities 1-16

| 1.1 | Understand type age, depth of cover. Compile and produce 3D Geological & Paleosurface Maps & Layers | 1.10 | Targeted and prioritized cover / paleosurface horizons and basement sampling_Onshore Stratigraphic drilling initiative |
|-----|--|------|--|
| 4.3 | Characterise and mapping whole mineral system footprint signatures. Proximal to Distal through data compilation of Geology, Geochemistry & Geophysics | 2.3 | Data Acquisition - Australian Seismic Array ASA |
| 4.1 | Improve understanding of minerals ystems a cross s cales for different model/deposit types and commodities | 2.7 | Create and update a fully 3D current architectural interpretation of Australian lithosphere |
| 2.1 | Compile and integrate models and data to build 3D architecture and composition of Australian whole lithosphere (mantle-crust-surface) from current data and knowledge | 2.2 | Map metal fertility of lithosphere (Current state) |
| 1.8 | Depth-to-basement and cover-characteristics, imaging from new targeted airborne National (20km) EM surveys. | 3.5 | Targeted geochron data acquisition of mineral occurrences & priority basins and conœaled basement via Strat drill program |
| 2.4 | Acceleration and completion of national AusLamplong period MT (55km spacing) program | 4.4 | Maximise size of detectable signature and understand detection levels and capabilities |
| 1.7 | Improve and refine understanding of geochemical dispersion in post mineralisation cover sequences | 3.9 | Create new fertility tools to understand and map metal fertilities for specific geological, tectonic and metallogenic events over time |
| 2.6 | Acquire ~4kmgrid of gravity over continent | 3.8 | Increased understanding of genesis and development of major trans-lithospheric geodynamic faults / lineaments through time |

7.3 DEPENDENCY MAPPING

Expanding the sub themes to the strand programme level in Stage 2 provided another level of granularity, (i.e. defining actual programmes), it also provided a further opportunity to better understand dependencies across related activities. Linkages and required dependent inputs together with sequencing between various parts of the roadmap have now been identified at the strand level. As such dependency mapping allows an understanding in 'what needs to be done and in what sequence' to be successful.

The dependency mapping identifies prerequisite inputs to specific activities, the outputs of which will feed into other activities that can be run either sequentially or in parallel. Each of the six overarching themes has a high degree of interconnectedness between the 45 subthemes and now with the programme strands within them. However, there are also many cross-theme linkages which justify the rationale and need for the Roadmap programme to be delivered in a truly integrated and coordinated way.

The dependency mapping presented herein is understood to be the first such analysis that has been attempted in a national roadmapping initiative that has identified separate but related research, technology development, data and education activities in the field of minerals geoscience. Dependency mapping is used extensively in information technology, genomics and major engineering projects. The inter-dependency of programmes has two core sequencing aspects: tasks and time, with two resourcing consequences, cost and personnel. Since the strand programme summaries in Appendix C identify their mutual linkages, the global set of dependencies can be compiled into a single dynamic diagram to graph and link all the direct dependencies. Examples of the outputs are presented in chord diagram on adjacent page, theme Chord diagrams are displayed on Dependency mapping posters in Appendix B. A fully interactive tool to navigate the dependencies developed as part of the Roadmap is located on the AMIRA International website*4.

It is very appropriate given the collaborative imperative underpinning the Roadmap vision that such dependency mapping be completed to clearly demonstrate that the value of the whole is much greater than the sum of its individual components. The interdependency values are not only lodged in the state of the art programmes, but is also in the required future network of the geoscience ecosystem, which will need to perceive new opportunities and better ways of combining priority activities. The highly-interconnected nature of the ecosystem of individuals and organisations will need to be well matched and coordinated more than ever to deliver the intensity of inter-related programmes. Further discussion of the function, structures and options on implementing the Roadmap programme is outlined in Section 10.

Where a dependency exists, given the duration and cost estimates, a timeline of activity was generated based on the estimated number of personnel resources required. As a result, a cost curve for implementing that activity was also generated. By providing the analysis in this form, the potential opportunities to accelerate programmes by increasing personnel resources becomes evident. Understanding dependencies, timing and resources will be highly beneficial in terms of delivery timelines of programme outputs, especially when considering priorities mapped out in Stage 1. A dependency mapping analysis approach will be useful for scenario modelling and debottlenecking the delivery process of an overall portfolio the scale and complexity outlined in the Roadmap.

As progress towards delivering the constituent programmes of the Roadmap are realised, an updated web based version of the dependency map can be used to communicate what has been completed, being undertaken or remaining. Such a tool will be very useful for coordinating the overall research, technology and data programme.

ROADMAP - STAGE 2 DEPENDENCY MAPPING

Dependency mapping Chord plot Example 4.3.1R



| | Legend |
|--------------|----------------------------|
| | Identified Strand (4.3.1R) |
| | Strand inputs |
| GEOSOLUTIONS | Strand outputs |

"WE WANTED TO USE THE BEST SCIENCE AND TO DO THAT WE HAD TO HAVE THE BEST SCIENTISTS, AND THEY HAD TO REMAIN TOP SCIENTISTS. THUS, THEY KNEW THEY HAD A FAIR CHANCE OF BEING GRANTED STUDY LEAVE AFTER A PE-RIOD OF TIME WITH US. OVER MY 40 YEARS OF RUNNING THE PROGRAM, 30 OR 40 OF MY STAFF WENT TO UNIVERSITIES ALL OVER THE WORLD ON STUDY LEAVE – SOMETIMES JUST FOR A YEAR; SOMETIMES FOR A FULL DOCTORATE STUDY – TO MAKE SURE THAT THEY KEPT UP TO DATE AND THAT THEY BROUGHT BACK NEW IDEAS ALL THE TIME'..

DR ROY WOODALL.

COURTESY UNIVERSITY OF ADELAIDE

EXCERPT FROM AUSTRALIAN ACADEMY OF SCIENCE INTERVIEW 2008 HTTPS://WWW.SCIENCE.ORG.AU/LEARNING/GENERAL-AUDIENCE/HISTORY/INTERVIEWS-AUSTRALIAN-SCIENTISTS/DR-ROY-WOODALL-EARTH-SCIENTIST.

NATIONAL EXPLORATION UNDERCOVER SCHOOL NEXUS 2016

SKILLS TO DELIVER FUTURE MINES

MAPPING AUSTRALIAN GEOSCIENCE CAPABILITY AND CAPACITY

A new map for a new initiative. Australia's first national minerals exploration geoscience capability and capacity map.

- 19 Universities CSIRO
- 7 Geological Surveys



Australia has built a reputation as a world leader in geoscience and economic geology research, whilst developing new exploration technologies and tools. The State, Territory and Federal geoscience survey organisations are also leaders in the acquisition, collation and delivery of pre-competitive data. This reputation has resulted from a sustained investment in geoscience over the past 70 years.

This sustained investment has built an enviable geoscientific ecosystem community and infrastructure comprised university geoscience departments, CSIRO, Geoscience Australia, seven state and territory geoscience agencies, the Deep Exploration Technologies CRC, the ARC Centre of Excellence in Ore Deposit Research (CODES, University of Tasmania), the Centre for Exploration Targeting (CET) at the University of Western Australia and Curtin University, the Virtual Geological Observatory (VIRGO) in Sydney, the Sustainable Minerals Institute (University of Queensland), the Centre for Core to Crust Fluid Systems ARC Centre of Excellence and AuScope. Although this community has served Australia well, it nevertheless has not been unified by a common vision and thus research activities have been nationally disjointed, and based on individual interests and capability. The "Team Australia" approach by the

Geological Surveys, particularly at overseas events, has been laudable as the envy of the world, which was in part motivated and accelerated by the UNCOVER initiative. However, this only the start of what must change if we are going to become a coordinated and collaborative ecosystem to achieve the Roadmap vision.

It was recognised early that newly identified research and technology development programmes coupled with new and accelerated data initiatives as part of the roadmapping process would require a significant expansion of effort from the broader exploration geoscientific community. Furthermore, we need to bring to bear the best brains trust to come up with solutions to the challenges of exploring under cover.

In anticipation of these requirements, provision was made in Stage 2 to map out and report the geoscience capability and capacity of Australia. This exercise has resulted in the first ever national geoscience capability and capacity map. This work has built on other maps and useful resources such as the 'Directory of Geoscience Departments' published annually by the American Geosciences Institute since 1955⁵. These resources provided a guide to building Australia's first national capacity and capability map.



⁵ http://www.agiweb.org/pubs/pubdetail.html?item=800825

8.1 GEOSCIENCE CAPABILITY AND CAPACITY MAPPING METHODOLOGY

AMIRA International, assisted by the Centre for Exploration Targeting in Perth, completed a national first pass high-level audit of the geoscience capability and capacity as part of Stage 1. This initial mapping exercise specifically considered requirements to address the original UNCOVER core themes as well as those identified through the Stage 1 roadmapping process. Mapping geoscience capability and capacity was completed across the researcher and geological agencies with some additional inputs from industry sponsors, Intrepid Geophysics and Boart Longyear. A total of 920 geoscientists were identified. The broader exploration and mining METS sector was not included in the mapping. However, it is something that should be done, perhaps by METS Ignited, because this will identify relevant skills and capability that could be accessed outside of the universities, CSIRO and the government geological survey organisations.

Building on the initial review conducted in Stage 1, AMIRA International invited the research and geological survey organisations to self-assess the expertise capability in their organisations. The self-assessments used a standard set of 33 separate geoscience and mineral exploration related disciplines developed in Stage 1 (refer figure over page). The research and geological survey organisations were asked to assess their geoscience staff and current PhD student candidates in the case of the former. Of the 920 geoscientists identified, 890 were mapped via self-assessments. For a breakdown of geoscientists from each of the sectors mapped, refer to figure below.

It should be noted that in the self-assessment process, many geoscientists were mapped as experts across a number of geoscience disciplines. The average number of disciplines assigned as 'expert' to geoscientists in the self-assessment process, was 4.2.

Of the disciplines considered, 26 are from the geoscience fields of geophysics, geology geochemistry and economic geology. The remaining seven disciplines were added from associated miscellaneous disciplinary activities related to geoscience specific to mineral exploration.

Additional information collected as part of the mapping included individual experience levels; the portion of teaching and research related activity from the research community; and expertise separated by data acquisition and data compilation within the geological survey organisations.





GEOSCIENCE DISCIPLINES; ROADMAP, CAPABILITY AND CAPACITY MAPPING 2016/17

8.2 CAPABILITY AND CAPACITY MAPPING RESULTS

A first-ever comprehensive review of geoscience capability of Australia showed that Australia is generally well placed in terms of geoscience capability in the required geoscience disciplines to address knowledge gaps, barriers and challenges detailed by the Roadmap. Capability was determined by summing the 'expert' entries from self-assessment totals provided. Australian geoscience capability across the mapped disciplines is presented in figure below and in geoscience capability and capacity poster in Appendix B.



Geoscience Discipline

AUSTRALIAN NATIONAL CAPABILITY 2017, RESEARCH AND GOVERNMENT AGENCIES



AUSTRALIAN NATIONAL CAPACITY 2017, RESEARCH AND GOVERNMENT GEOSCIENCE AGENCIES

A measure of the national geoscience capacity (within each discipline) available to address the research, technology development and data initiatives from the Roadmap was determined by normalising the compiled selfassessment totals. This process is required in recognition of geoscientists being mapped as expert across multiple geoscience disciplines. The capacity as mapped is simply the same as the total number of identified geoscientists, but capacity is now assigned to specific geoscience disciplines.

Australian geoscience capacity across the mapped disciplines is presented in the figure above and in the geoscience capability and capacity poster in Appendix B.

A review of capacity against the mapped Roadmap requirements (determined by considering the individual strand inputs) raises significant potential future resourcing issues, specifically being able to resource the new or additional activity from the Roadmap portfolio in addition to work currently being undertaken from the current capacity. The total current national capacity of 900 geoscientists across all disciplines from the geoscience capacity map, including PhD candidates, compared to a similar capacity demand (more than 900 required in year 4 of the Roadmap) highlights a major shortfall of available geoscientists to tackle the research, technology and data initiatives detailed in the Roadmap.

The knowledge intensity required to resource the Roadmap research and technology development activities, in addition to new data compilation and acquisition, is such that it may require both the urgent re-deployment of current resources and recruitment of additional capacity. It is clear that the geoscience capacity from the research and government community within the ecosystem as a whole does not currently have any spare capacity.

The experience levels of geoscientists, within the research and geological agencies (including PhD candidates), highlights some trends not confined to geoscience. At first glance, the profile of experience levels represents an even mix of experience (refer figure on adjacent page). The profile however shows a weighting to more experienced older geoscientists and potentially could affect available capacity in the medium term, as older geoscientists retire in 10-20 years.



Roadmap Capacity Map 2017 Geoscientist Experience Profile

8.3 GEOSCIENCE CAPABILITY AND CAPACITY -CONCLUSIONS AND RECOMMENDATIONS

The first ever comprehensive geoscience capability and capacity map of the research and geological surveys has highlighted some important resource issues that need to be addressed. The principal outcome is that there will be a deficit in capacity both because existing resources are already utilised and a significant number of the older cohort of experienced geoscientists will be retiring in the medium term. This clearly points to the need to attract additional resources either in Australia from the industry sector or from overseas; and also, to collaborate with those overseas institutions who are also addressing some of the key themes of the Roadmap.

Additional work to better understand the geoscience capability and capacity required to develop a strategy to resource the research and technology development programmes that will help to realise the Roadmap vision is recommended.

Specific additional work to be undertaken includes:

 Completing a methodical review of selfassessments ensuring consistency in application and results

- 2. Ensuring all geoscientist resources have been captured across the research community and respective government geoscience agencies
- Quantifying the highlighted shortfall against all proposed geoscientific programmes in terms of resources within each discipline and experience. This includes but is not specific to the Roadmap programmes
- Engaging with the exploration, mining industry and METS sector to potentially expand the map to identify potential excess capability and capacity available for undertaking Roadmap activities
- Further expansion of the map to ensure all future geoscience capability and capacity is understood, specifically with respect to all PhD and MSc candidates and undergraduates currently within the researcher and tertiary education system
- Transfer of the geoscience mapping process and results to an appropriate agency or organisation in Australia, providing a similar product published annually by the AGI.

AN INVESTMENT IN KNOWLEDGE PAYS THE BEST INTEREST.

-BENJAMIN FRANKLIN

TABLE HILL, MERNINIE RANGE, SOUTH AUSTRALIA SOURCE: STEVE HILL, GEOLOGICAL SURVEY OF SOUTH AUSTRALIA

OMBINED NATIONAL INVESTMENT

EXPLORATION PERFORMANCE IMPROVEMENT FOR A SUSTAINABLE MINING INDUSTRY

A future investment profile was developed through the Roadmap. Outlining an integrated programme that assesses what is needed to beat the cover challenge and improve performance into the 2020s. In mapping and designing the future, it ensures alignment and national coordination to meet our future requirements. Extensive consultation with the exploration geoscience community, both via workshops and one on-one-meetings, during development of the strands facilitated the drill down to the next level of detail necessary to build robust and realistically deliverable programmes. Core considerations throughout the design stage centred around time and funding requirements. Consideration was also given to the personnel requirements to execute the programmes along with associated operational and infrastructure needs.

9.1 CONSOLIDATED FINANCIAL INVESTMENT TO DELIVER RESEARCH, TECHNOLOGY AND DATA INITIATIVES

As outlined in the programme summaries (Section 6), time cost mapping over a 15-year period allowed estimates of the minimum funding requirement for each research and technology development programme. It also enabled estimates of the cost to accelerate current compilation and acquisition of new geoscience data by the geological survey organisations, Geoscience Australia and CSIRO.

Allocation has been built into the cost mapping presented in this Roadmap in recognition of a ramp up period of 1-2 years. Nevertheless, it is expected the time cost profiles will change as personnel and infrastructure needs are finalised in the detailed programme to project design phase.

The consolidated picture presented by the Roadmap indicates that an investment of some is \$900M (2017 dollars) over a period of 15 years will be required to achieve the Roadmap vision. The breakdown and burn rate of this national investment, over the 15 year time period is presented on the adjacent page. This expenditure profile includes the ramp up phase built into the programme sequencing.





P1162A Roadmap Consolidated resourcing - Funding

CONSOLIDATED 15-YEAR FINANCIAL INVESTMENT FOR ROADMAP STRAND PROGRAMMES



Delivering on the Roadmap vision will require teams of the best and brightest young and older experienced personnel to develop the solutions to the challenges of exploring under cover. A feature of the programmes must be the inclusion of post-graduate students as much as possible combined with attracting experienced industry geoscientists as secondments or embedded researchers back in the institutions. Addressing the challenges will require mustering the right resources whether from the research community or the METS sector, or from a combination of both. The entity that will be responsible to implement the Roadmap must have the flexibility and resources to engage the very best talent for any given project, and this may require recruiting from overseas and/or collaborating with overseas organisations.

The roadmapping process allowed a preliminary estimate of the number of personnel required and also identified the expertise and experience required to execute each of the integrated activities designed in each of the strand programmes. It should be noted however, that delivery of solutions to some of the challenges, for example the technology challenges, may come from the private sector, and some may be delivered through public private partnerships. Details of people requirements for each strand activity are included in the Strand Summaries located in Appendix C.

As with funding requirements, allocation has been built into the people mapping presented in this Roadmap, in recognition of a ramp-up period of 1-2 years. Nevertheless, it is expected that the time personnel profiles will change as personnel and infrastructure needs are finalised in the detailed programme to project design phase.

A consolidated picture of the collective number of personnel resources required to undertake the activities identified in the Roadmap and delivering on the vision is of the order of 7,000 people years over the full 15-year period. In the first 10 years this averages to some 650 geoscience related positions, peaking at over 900 in year 4. The additional resources outlined are additional to those currently working within the research community and geological surveys. Not only will the personnel working on the Roadmap programmes deliver new knowledge, technologies and data to and for use by the exploration industry, the applied nature of many of the programmes will produce the very personnel with the required skills, experience and familiarity to transition and apply new knowledge and technology to the challenge of exploring under cover. This will be particularly true with the many students that are expected to be involved in the programmes - developing the future industry leaders, entrepreneurs and researchers. As with all successful innovation adoption, access to an available and skilled workforce is a core component to deliver on agreed strategic imperatives. Indeed, the students would be critical elements of the technology transfer and diffusion process necessary to ensure end-user implementation and possibly even commercialisation of the Roadmap outcomes.

Clearly investment in the Roadmap implementation will serve as a platform to invest in the development of human capacity in Australia. Additionally, the high profile of platform will help to position Australia at the forefront of research and development for exploration under cover. Furthermore, the solutions developed in the Roadmap programmes will provide future export opportunities by catalysing the creation of new METS companies or enhancing existing ones. Ultimately given that all the geoscience stakeholder community benefits from implementing these programmes, the community therefore bears responsibility to collaborate and invest for the common good. This of course also means co-investment by State, Territory and Federal governments.

A consolidated breakdown of this significant national investment in terms of people and resulting jobs by the geoscience community, over the 15 year time period is presented in presented on adjacent page.



CONSOLIDATED 15-YEAR PEOPLE INVESTMENT FOR ROADMAP STRAND PROGRAMMES



COLLABORATION IS VITAL TO SUSTAIN WHAT WE CALL PROFOUND OR REALLY DEEP CHANGE, BECAUSE WITH-OUT IT, ORGANIZATIONS ARE JUST OVERWHELMED BY THE FORCES OF THE STATUS QUO.

THE REPORT OF TH

PETER M. SENGE

ALIGNING COLLABORATIVE RESEARCH

VEHICLES AND FUNDING - A ROADMAP PERSPECTIVE

Future research and technology vehicle and funding options were primary considerations of the Roadmap. By simplifying design, re-configuration and scaling up investment, a new collaborative infrastructure and funding structure can successfully deliver the transformation in exploration geoscience.

The proposed consolidated programme outlined and prioritised in Stage 1 of the Roadmap and now quantified in Stage 2 will require an innovative and highly integrated delivery mechanism to deliver new knowledge and new technologies through research. As much of the research will be applied in nature it is envisaged the delivery mechanism or vehicle will need to be a truly collaborative effort involving the stakeholders within the exploration geoscience ecosystem. A collaborative approach is regarded as not only the optimal mechanism but the only way to successfully deliver the required new knowledge and technology coordinated with new 'big' data in a cohesive way. It is this collaboration with strong involvement and investment (financial and human) from the end user industry sector that will ensure early adoption and accelerated deployment in new greenfield mineral exploration.

Similar high intensity, combined knowledge and technology endeavours in other sectors around the world have been successfully implemented to solve complex and strategically recognised problems of national or global significance. It is ambitious approaches and focused application that has resulted in transformational disruptive change rather than incremental evolution. These transformative initiatives have resulted from the formation of new collaborative vehicles to prosecute complex and integrated programmes.

With respect to the overall programme it was regarded by the Roadmap sponsors as critical that an appropriate single vehicle or small number of centrally coordinated vehicles oversee the management and funding, including its disbursement in achieving delivery of the constituent strand components. This organisation or aligned consortia needs to be robust enough to manage a large funding pool, lead and manage internal agendas from vested interests, and be able to deliver the identified programmes in a timely manner.

Through the Roadmap, the collective geoscience community reviewed currently available entities and investigated options for collaborative research vehicles which could oversee the management and execution of the technical research and technology programmes outlined. Funding options were then considered for the research and technology development programme components.

Funding for the extensive accelerated and expanded data compilation and data acquisition programme portfolio outlined in the Roadmap was not considered in funding options, given the State and Territory geological survey organisations and Geoscience Australia currently undertake the acquisition storage and delivery of precompetitive data.

Although geoscience data compilation and data acquisition were not considered in the funding options, it was recognised that coordination and communication would be required to fully integrate new geoscience data into the research and technology programmes and to ensure delivery to the wider geoscience mineral exploration ecosystem.

The Roadmap defines the technical scope to be delivered and indicates the order of magnitude of resourcing required to deliver it fully, both in terms of funding and personnel.

10.1 CURRENT COLLABORATIVE ARC NCGP VEHICLES AND FUNDING PROGRAMMES

Developing over many years, the current landscape of Australian geoscience research has evolved to serve the exploration geoscience community, steadily delivering ongoing improvements in knowledge and new technologies. This evolution over the years has developed an extensive and somewhat complex network under the Australian Research Council (ARC), administered through National Competitive Grants Programme (NCGP).

A review of the current landscape of applicable research vehicle options to be considered for the Roadmap research and exploration technology development portfolio is presented in the table and figures on the following pages. This review in Stage 2 included both the type of research undertaken along with the time frames and breakdown in the scope of funding (government and industry contributions) within each vehicle.

Some of the research vehicles and funding programmes shown in the table on the following page are not currently available for research applicable to the exploration under cover challenge. Special Research Initiatives for example, provide funding for new and emerging fields of research and build capacity in strategically important areas. It would require recognition from the Federal Government that exploration is critical for the continuance of the contribution of the minerals industry to Australia for this funding to be made available. Funding levels can be significant. Three current examples of funding levels of 2014 SRI's include:

- Antarctic Gateway Partnership -\$24M over 3 years
- Tropical Health and Medicine -\$42M over 4 years
- Type 1 Juvenile Diabetes -\$35M over 5 years.

Additionally whilst there is currently an exploration focused programme co-funded by the Science and Industry Endowment Fund (SIEF), at this present time it is not intended that there are any further calls for Expression of Interest for SIEF Research Projects.



| Avetualian December Vahiele | DNAv | Data not | available | | NA# | | |
|---|-------------------|-----------------------------------|--|-------|-------------------|--|--|
| Summary 2017 | NA* | New veh introduc | New vehicle introduced in 2015 | | | | |
| , | NA** | New veh introduc | CRC# | | | | |
| | Veh | | Vehic | e fu | nding | | |
| | icle T | Vehic | e annual fu | Indin | g | | |
| 2017 Vehicles | ïme frame (years) | Gov Funding per annum (AUD\$M) | External (Industry) Funding per annum (AUD\$M) | | Total funding per | | |
| Grant Research Vehicles | | | | | | | |
| ARC Discovery Projects | 5 | \$0.5 | \$- | | \$0.5 | | |
| ARC Linkage Projects | 5 | \$0.3 | \$0.3 | | \$0.6 | | |
| ARC Research Centres of Excellence | 7 | \$5.0 | \$- | | \$5.0 | | |
| Industrial Transformation Research Hubs | 5 | \$1.0 | \$1.0 | | \$2.0 | | |
| ARC Special Research Initiatives | 5 | \$8.0 | \$- | | \$8.0 | | |
| Cooperative Research Centre CRC # | 10 | \$7.5 | \$7.5 | \$ | 15.0 | | |
| Cooperative Research Centre Project CRC - P | 3 | \$1.0 | \$1.0 | | \$2.0 | | |
| State funded research ie MRIWA | 3 | \$1.0 | \$1.0 | | \$2.0 | | |
| Industry Growth Centre (e.g. METS Ignited) | 2 | \$1.5 | \$1.5 | | \$3.0 | | |
| Science and Industry Endowment Fund (SIEF) | 4 | \$1.0 | \$- | | \$1.0 | | |
| AMIRA Multiclient Consortia | 4 | | \$3.5 | | \$3.5 | | |
| AMIRA 1 on 1 | 1 | | \$0.3 | | \$0.3 | | |
| Research Development Corporations | | | | | | | |
| Grain Research Development Corporation GRDC | 5 | \$68 | \$114 | | \$183 | | |
| Australian Grape & Wine Authority | 5 | \$12 | \$18 | | \$30 | | |
| Australian Coal Industry Research Programme ACARP | 20 | | \$11 | | \$11 | | |
| Fisheries Research & Development Corporation | 5 | \$17 | \$8 | | \$25 | | |

Legend

New 5 years strategic plan implemented 2015

Primary function to support industry collaboration. All have application to the minerals industry none are research or technology projects.

no specified maximum, limited by appropriation

| | New rese gra | earch & teo nts each y | chnology ear | Minerals related research & technology | | | |
|-----------------------------------|-----------------|---------------------------|-----------------|--|---|---|--|
| Vehicle funding total (AUD\$M) | 2017 | 2016 | 2015 | Number of minerals research or technology related projects in 2016/17 | Number of minerals research or technology exploration related projects in 2016/17 | Minerals related research or technology related projects as a proportion of all programs in 2016/17 | |
| | 62.2 | <u> </u> | | | | 22/ | |
| \$2.5 | 630 | 635 | 665 | 17 | 6 | 3% | |
| \$3.0 | DNAv | 252 | 251 | 18 | 4 | 7% | |
| \$35.0 | 9 | 0 | 0 | 1 | 1 | 3% | |
| \$10.0 | 3 | 0 | 5 | 5 | 1 | 23% | |
| \$40.0 | 0 | 0 | 1 | 0 | 0 | 0% | |
| \$150.0 | DNAv | 31 | 33 | 2 | 1 | 6% | |
| \$6.0 | 30 | 11 | NA* | 2 | 2 | 7% | |
| \$6.0 | DNAv | 11 | 9 | 20 | 12 | 100% | |
| \$6.0 | 5 | NA ** | NA ** | NA+ | 0 | 0% | |
| \$4.0 | 0 | 0 | 0 | 1 | 1 | 33% | |
| \$14.0 | 2 | 2 | 4 | 13 | 4 | 100% | |
| \$0.3 | 0 | 1 | 0 | 0 | 0 | 0% | |
| | | | | | | | |
| \$916 | DNAv | 898^ | 942^ | | | | |
| \$151 | DNAv | 12 | # | | | | |
| \$228 | DNAv | 64 | ? | | | | |
| \$125 | DNAv | 116 | 105 | | | | |



2017 AUSTRALIAN CURRENT RESEARCH VEHICLES, TIMEFRAMES AND FUNDING & ROADMAP NEEDS

Australian Science Research Vehicles 2017



ARC Discovery Projects

- ARC Linkage Projects
- ARC Research Centres of Excellence
- ARC Special Research Initiatives
- Industrial Transformation Research Hubs
- Industry Growth Centre (e.g. METS Ignited)
- Cooperative Research Centre CRC
- Cooperative Research Centre Project CRC P
- AMIRA Multiclient Consortia
- AMIRA 1 on 1
- State funded research ie MRIWA
- Science and Industry Endowment Fund (SIEF)
- Total Roadmap Research & Technology NEED

CURRENT AUSTRALIAN RESEARCH VEHICLES IN 2017, TIMEFRAMES AND FUNDING
10.2 CURRENT COLLABORATIVE INDUSTRY VEHICLE AND FUNDING PROGRAMMES INCLUDING RESEARCH DEVELOPMENT CORPORATIONS AND ACARP



CURRENT AUSTRALIAN RESEARCH VEHICLES AND RESEARCH DEVELOPMENT CORPORATIONS 2017, TIMEFRAMES AND FUNDING

In considering current vehicles for research it was pertinent to look outside of the minerals industry for examples. For over two decades, the agriculture and rural sectors in Australia have been supported by Rural Research and Development Corporations (RDCs). These RDCs are industry service bodies, and are not typically industry representative bodies.

There are 15 RDCs across agriculture, fisheries and forestry industries in Australia. Each one is tasked with delivering tangible and practical improvements for their industries in terms of productivity and profitability, sustainability, and the community. They do this through strategic and targeted investments in and partnerships for research, development and adoption, and in some cases, market access, market development and promotion.

Funding for the RDCs combines contributions from industry, usually collected as levies on production, and funding from the Australian Government. The government only provides funding for research, development and adoption activities, and the functions needed to support the research investment program. Everything, other than the research related components is fully-funded by industry.

The levies collection systems are operated by the government on a full-cost recovery basis. Levies are established and collected on an industry basis by commodity, with levy rates and collection points tailored to the particular circumstances of those industries and commodities. The government also provides a matching contribution (up to a capped limit). The scale of the resultant funding is shown in the figure above.

A similar mechanism for funding collaborative research is used by the coal sector in Australia, whereby a voluntary levy of 5c is applied per tonne of saleable black coal produced.

| Agriculture | Wine | Coal |
|---|--|---|
| 67 mandatory levies across 26 sectors | The Australian Grape & Wine Authority generated \$18M from mandatory levy payment, of which \$15M went to R&D | Voluntary levy - 5c per tonne of black coal produced |
| Levies generated \$111M in FY16 for Meat and Livestock Australia, of which 47% was spent on R&D | The Government contributed \$12M in matching contributions | Generated \$20M in FY15 |
| The grains industry generated \$110M from levies in FY16, directing \$100M to R&D | | \$273M funding 1,468 projects since inception in 1992 |

10.3 ROADMAP IMPLEMENTATION - EXPLORING OPTIONS IN WHICH TO HOUSE THE RESEARCH AND DEVELOPMENT PROGRAMMES

Innovation and innovative thinking is at the heart of an industry roadmap, exploring options and frameworks in which to house collaborative research and technology partnership(s) that are best able to address a set of agreed common challenges and deliver on the primary objective. This Roadmap has identified a set of research, technology and data needs that are focussed on translating the original UNCOVER vision and ideas into a range of tangible integrated activities whose outputs will improve exploration performance across the board in Australia, specifically in areas blanketed by post mineralisation cover.

The execution of the research and technology development programmes identified by the Roadmap can be undertaken in several ways depending on the nature of the activity, but in all cases a strong cooperative approach between various elements of the exploration geoscience ecosystem will be required. For example, it is conceivable that some of the technology development activities could be undertaken by METS companies who see a business opportunity in developing the necessary solution to the problem through a proprietary programme, but in collaboration with appropriate researchers as necessary. Smaller mechanisms like the CRC-P programme, or the ARC Linkage programmes can assist with these endeavours. And although some activities are currently in train that address some of the research themes identified by the Roadmap, these need to be brought into a more collaborative umbrella. Then there are those research and development activities that are not currently being addressed but are just as crucial in order to achieve the Roadmap vision. These make up the majority of the activities identified by the Roadmap. These unfunded activities will need to be housed in a suitable vehicle which will also ensure effective coordination and collaboration with the various external activities whose outputs they will also depend on. So, the challenge we face is how best to tackle a complex, long term and widely varied portfolio of new research and technology development whilst integrating and utilising extensive national new 'big data' from the Roadmap, received input through cross-stakeholder interactions. Whatever option is final adopted it must have some important attributes as outlined on the next page.

| Research ar | nd technology | vehicle design considerations |
|-------------|--|---|
| | | Vehicle type and vehicle structure to best align complexity and scale of challenge with the best geoscientific talent and assets to make optimal use of collective brainpower and infrastructure. |
| | Vehicle Type | People with appropriate skills may need to be brought in from overseas or alternatively a mechanism for collaboration needs to be put in place. |
| | METS companies must be encouraged to take on the challenges as potential commercial opportunities, and these could be via public-private-partnerships for example. | |
| \sum | Structure & Process | Best practice governance and lean management structure and process require- ments to develop, and manage the necessary research and technology develop- ment programmes and cooperate with the relevant external programmes, such as for example the national data acquisition programmes run by the Geological Survey Organisations. |
| | Network | An effective coordination and communication network that spans the geoscience ecosystem. Optimally connecting the geoscience ecosystem and programmes that would provide a multiplier effect thus creating greater value by tapping into collective creativity. |
| • | | Offers an important avenue for technology transfer, diffusion and commercialisation. |

ROADMAP RESEARCH AND TECHNOLOGY VEHICLE DESIGN CONSIDERATIONS

The extensive consultations during the roadmapping process identified four ways forward, although critical analysis points to only two that could possibly deliver on the Roadmap vision. One way of characterising each of these is by the degree of change from the status quo as summarised earlier.

The ways forward form a continuum, ranging from UNCOVER Light at one end that would require minimal change from current research design through to the setup of UNCOVER Accelerate-S (single), a purpose built large new and dedicated geoscience exploration research centre at the other. Between these two end members are much greater alignment of current research, technology and data community structures in **UNCOVER Align** and the formation of a new virtual single research centre **UNCOVER Accelerate- V (virtual).** Careful assessment of these leads to the conclusion that only two provide real options for the implementation of the Roadmap, namely **UNCOVER Accelerate- S** and **UNCOVER Accelerate- V**. Both of these options could give rise to what, for the purpose of this discussion, will be called the **Australian Centre for under cover Exploration (ACE).**

Governance & Coordination & Management **Vehicle Option Vehicle Type** Communication Structure and Network Process Mechanisms in place for internal and New co-funded single external coordination national physical New National and communication. research and technology UNCOVER Dedicated technology centre: incorporated: development centre Accelerate-S independent Board, lean transfer and diffusion (Australian Centre for mechanisms, along with management structure. under cover Exploration) data delivery mechanism with appropriate nodes. and commercialisation pathways. A new centre with its own Mechanisms in independent Board, lean place for internal and New co-funded single management structure, external coordination virtual research and and outsourced backand communication. technology centre utilising office systems. It could be UNCOVER Dedicated technology current existing national a separate incorporated Accelerate-V transfer and diffusion infrastructure (Australian entity, or avoid setting up mechanisms, along with Centre for under cover and compliance costs, by data delivery mechanism Exploration) being part of an already and commercialisation independent industry pathways. body for example. New independent and New broad based Formalised advocacy resources communication formalised entity to entity, with independent network as part of encourage alignment Board with minimal formalised entity. No **UNCOVER** Align between current research executive management, control over research, technology development infrastructure and existing advised by voluntary vehicles. Advisory Bodies. and data delivery programmes. No significant change to current status. UNCOVER Current research Continue status quo; infrastructure with existing remains informal. reliant on other parties **UNCOVER** Light **UNCOVER** Executive unfunded advocacy to provide secretariat influencing type approach type entity. Run by services and donated and activity. voluntary Executive and communication network. Geoscience committees.

ROADMAP VEHICLE OPTION SUMMARY

Ideally the research and technology development activities are best undertaken in a cohesive coordinated whole. This can only be achieved if there is one entity under which these activities can be undertaken and manage. This entity would also be responsible to liaise closely with all the Australian Geological Survey Organisations through an agreed mechanism to ensure that their activities can best support the research and technology development undertaken under the entity. The entity should be National centre, with a lean central administration and appropriate nodes across Australia. The Australian Centre for under cover Exploration (ACE) mentioned above could be designed for this purpose. The ACE may be may be an incorporated entity in its own right, engage a CEO and have a Board structure to ensure that the centre is compliant with modern governance principles. Important attributes to such a centre are outlined in the table below.

The Australian Centre for under cover Exploration (ACE) attributes

Lean management

Fit for purpose Board

Controls funding and resource allocation

Has power to engage the best teams to deliver on the Roadmap vision

Has appropriate mechanisms for engaging, coordinating and influencing external programs

Has appropriate IP and commercialisation models

May have many nodes

Outsourced back office

Secures office space from other organisations at no cost

Able to lobby as necessary

Incorporation of course comes with set up costs and ongoing ACCI compliance costs. These could be completely avoided, for example, if the ACE is part of an already independent, not-for-profit, industry body. In such a scenario transparency would be guaranteed via an agreed operational framework approved by industry. Furthermore, auditing would be handled as part of the parent industry body.

The ACE should also have a broader lobbying role to industry and government as well, incorporating the current UNCOVER Executive to expand on the good work already achieved. Expansion will ensure ACE will be more representative across the spectrum of the exploration geoscience community . It is fundamental to the successful implementation of the Roadmap that industry plays an influential role in the activities of the ACE.

As the Table above shows the ACE is envisaged to have some attributes similar to better run CRCs except it would need to have a wider base of support, focus on appointing the best researchers to work on a given project (this is critical, we must engage the best brains trust to address the challenges), work closely with the Geological Survey Organisations who are responsible of the data acquisition to complement the research and technology development, and would be designed with a minimum life of 15 years.

A strengths, weaknesses, opportunities and threats (SWOT) analysis of the four ways forward undertaken as part of the roadmapping process. The SWOT analysis is presented over the page. Although a new physical centre (UNCOVER Accelerate - S) may seem, at first glance, to be the most effective vehicle, setting up a new physical centre with new infrastructure, equipment and staffing is unrealistic in terms of cost and timeframe. Having said that, there are precedents for this in the Australian research landscape - most notably, the South Australian Health and Medical Research Institute (SAHMRI) facility established in 2009 with Federal Government investment of \$200M. This incorporated, independent Institute has been the recipient of significant government and private sector funding since establishment (www.sahmri.org/).

Recommended Vehicle - A consensus of the stakeholders indicates that the most appropriate vehicle to deliver new knowledge, accelerate the

enhancement and development of new technology timeframe required to make a difference, requires a new approach. Such an approach must also be able to ensure strong coordination with the geological survey's national scale data acquisition programmes. To achieve the required exploration performance improvement will require a different, more urgent and more cooperative approach that currently exists.

The most appropriate centre would be **UNCOVER Accelerate V**, but which has been preliminarily called the Australian Centre for under cover Exploration (ACE). A ranking of the four main vehicle options defined in the Roadmap is presented in the figure below. This model enables the most efficient and effective use of physical infrastructure and equipment from the current research and technology communities. An ACE operating under this scenario would have a number of options to set up quickly, including for example be part of an existing independent, not-for-profit, industry body. This scenario would certainly enable ACE to be set up and start operations quickly.



FUTURE VEHICLE OPTIONS RANKING BY THE ROADMAP 2017



WESTRALIA, MOUNT MORGANS GOLD MINE, WESTERN AUSTRALIA SOURCE COURTESY: R ROWE 2005

ROADMAP VEHICLE OPTION SWOT ANALYSIS

UNCOVER Accelerate - S

| Lean management layer, simplified administration. Outsourced back office systems Single, fit for purpose Board structure Funding management control & reallocation flexibility Fully coordinated internal structure Control of research and technology development Open source non-confidential new knowledge & flexible commercialisation of technologies Dedicated, streamlined external communication Maximum funds allocated to research Dedicated mechanism for technology transfer, diffusion and commercialisation | Disruptive, requires most change (new team & infrastructure building) Duplication of some existing infrastructure Time delay setting up new single centre will delay programme commencement Need to recruit and relocate best geoscience talent Single location will be distant from some major mining centres & industry New funding required for research & technology development programmes not being tackled Expensive to set up |
|---|---|
| New dedicated research & technology development focussed centre Deliver transformational new research & technology Maximum funds allocated to research Maximum research & technology collaboration Improved co-ordination between research, data & technology activities via a single entity Improved commercialisation of technologies Effort aligned with Roadmap challenges Reset and increase cross-sector collaboration Ability to engage optimal resources to undertake required research and technology development Framework for training future industry leaders, researchers & entrepreneurs | New funding required to build new centre New quantum of funding for expanded research & technology Short - medium term depletion of existing research centres Perceived duplication of effort Industry does not increase support & involvement Access to additional required talent, competing with existing research Availability of additional required talent in Australia Industry does not provide support & engage fully |
| UNCOVER A | ccelerate - V |
| Single central Board Current infrastructure in place Core research teams in place Consolidated coordination network Centralised management of research & technology programmes Centralised fund management & reallocation flexibility Open source non-confidential new knowledge & technologies Aligned external communication Build on past & existing research & development activities Flexibility to closely collaborate across existing network & overseas ecosystems | Existing layers of management & administration at current research organisations Duplicate reporting lines Higher national operational costs – travel & sample shipping New funding required for research & technology development programmes not being tackled |
| New dedicated undercover focussed centre Transformational research and technology Located close to major mining centres Leverage of current expertise in-place Able to commence quickly Quantum of effort really aligned with challenge Reset & increase cross-sector collaboration New cross-sector Working Group able to focus & flexibly reprioritise new data acquisition | Disruption to current research organisation structures will require operational changes Impact to existing research centres may require re-prioritisation of current research to take on new research New quantum of funding for expanded research & technology Industry does not increase support & involvement Availability of additional required talent in Australia, may have to recruit from overseas |

Unlocking Australia's Hidden Potential: An industry roadmap.

| | SWOT A | nalysis | |
|--------------------------------|----------------------|--|--|
| | Strengths | Weakness | Xo |
| 6 | Opportunity | Threats | |
| 1 | Yo | | |
| | UNCOV | /ER Align | |
| nt of re cation sector o | esearch & technology | Limited by size of cullevel mechanisms Disruptive nature of of permanent core s | rrent vehicles & small -moderate funding phased funding fundraising cycles & lack taff |

- Administration across multiple Boards
- ٠ Multiple layers of management
- Fragmented, confidential research programmes, low adoption by industry

 New Quantum of funding required Focus undercover geoscience research & technology on ٠ Reliant on voluntary contributions of advisory committees highest priorities New research & technology diluted with current programmes ٠ Increased size can result in transformational new knowledge ٠ Industry does not increase support & involvement & disruptive technology Insufficient collaboration Alignment will optimise incremental progress in knowledge & · Availability of additional required talent in Australia technology improvement New cross-sector Working Group able to focus & flexibly re-• prioritise new data acquisition

Promote greater cross-sector collaboration

Increased national alignme development programmes

Aligned external communi Increased internal & cross

data initiatives with Surveys

Increased research & technology development collaboration

duplication of effort

۲

.

UNCOVER Light

| Requires no real change, low disruption to current ecosystem | Limited by current vehicles & funding levels Current low level of cross-sector coordination of research, technology & data initiatives Industry identified new research & technology not prioritised a focus Historic knowledge & data largely inaccessible or digitised/ searchable in the next few years Administratively heavy, less funding to research & technology Fragmented, confidential research programmes, low adoption by industry |
|--|--|
| Continue to deliver incremental improvement | Priority new research & technology not delivered in required timeframe Industry does not increase support Current low level of cross-sector collaboration Major gaps of R&D not being undertaken remain Low focus & slow commercialisation of new transformational technologies Low adoption of new knowledge & technologies by industry Australia continues to decline in global exploration spend |

VEHICLE OPTION CONSIDERATIONS

Shape size represents proportional effort required by each function

| | Vehicle Type | Structure & Process | Network |
|--|--|---|---|
| Dessevel 9 | Research and t | echnology functional cor | nsiderations |
| Technology delivery options | Scale of research and technology programme | Structure of governance and management | Coordination within research, technology & data communities |
| | Location of research and technology infrastructure | Scope, scale and effectiveness | Coordination across research, technology & data communities |
| UNCOVER Accelerate S (Single centre) | | Board Board E Management • Single Centre Board • One internal lean management structure | Consolidated internal coordination network |
| K-WYER Y | k | Direct reporting lines | |
| UNCOVER Accelerate V (Virtual centre) | | Board Board Management • Single Centre Board | Consolidated centralised |
| | | Centralised multiple management structures & layers Multiple reporting lines | coordination network across multiple organisations |
| UNCOVER Align | | Multiple Boards | Consolidated coordination |
| | | Multiple management structures, types & layers Multiple reporting lines | network across multiple organisations & stakeholders |
| UNCOVER Light | | | |
| | | Multiple Boards Multiple management structures, types & layers Multiple reporting lines | Lowest coordination network across multiple organisations & stakeholders |
| | 1 Wett | | |

10.4 ROADMAP IMPLEMENTATION – EXPLORING FUNDING OPTIONS

The four vehicles articulated as options for the future delivery of research technology and data represent variations of vision, ambition, and funding requirements.

In sections 10.1 and 10.2 of this document the various models currently utilised in Australia to fund industrial relevant R&D are described. The challenge presented through the Roadmap, was how to adequately and realistically meet these funding requirements to enable successful implementation.

In the exploration sector, there are additional sources of funding in place that directly support the activities of the various Australian Geological Survey Organisations. Most of these activities focus on acquiring precompetitive geoscience data that are already aligned to some extent with the UNCOVER initiative. Additional funding for addressing the data initiatives identified in the Roadmap is assumed to come under the responsibility of these existing funding mechanisms. Whether all of this funding is being optimally invested or is totally aligned with the Roadmap is unclear, and whether any of this funding can be invested to accelerate additional data acquisition that is aligned with the Roadmap is also unclear.

Although developing a suitable structure for the ACE is not overly difficult, the real question is how will the centre be funded? A key factor of funding sources and proportion is best approached by consideration of the end-user benefit. All stakeholders within the exploration geoscience ecosystem are direct beneficiaries. It is also recognised that outside of the ecosystem the broader Australian community is a major beneficiary via royalties on production and taxation through companies and the workforce. With this in mind co-investment proportional to benefit must be central to funding the ACE and that some differential funding mechanisms based on organisational investment in exploration within Australia should be considered.



It is assumed that the research and technology development components of the Roadmap are funded through one mechanism, although METS suppliers should have an integral role in the latter. Co-investment means that ultimately, industry (which includes the METS sector) and the Australian community via state, territory and federal governments must collaborate in order for this centre to become a reality.

During the roadmapping process various options were considered for funding the implementation of the Roadmap, and they are outlined herein. However, during the preparation of this document other options have been identified that were not raised during the workshops. AMIRA International believes that it is important that these are also presented herein. For example, industry funding of the ACE may be through a direct, but differential, funding model that is based on the premise that those who benefit most should pay more. How this could be achieved is up for discussion but one way is to calculate the level of contribution on the global exploration spend of companies (greenfields + brownfields) - for example as reported by SNL Metals and Mining annual survey. The global spend rather than the Australian-only spend is used because the outcomes from the ACE will have applicability outside Australia.

This approach will enable companies that are not exploring or mining in Australia to participate in the ACE if they are interested in seeking to use the outcomes outside Australia. This will require a suitable mechanism that ensures that those that participate will benefit first, including providing commercialisation opportunities, but within an open framework that ensures rapid knowledge diffusion and commercialisation. How METS companies, who will be provide the route to market, will contribute is also up for discussion, but a model currently used by the DET CRC and other CRCs whereby they pay a modest annual fee is an obvious model to consider.

In the case of miners and explorers, individual exploration budgets could be normalised to the company with the largest global exploration budget which will then determine the individual contributions. Obviously, the contribution level of the company with the largest exploration budget will have to be set. Clearly in this model, junior explorers potentially end up paying less than the majors. It is possible to make this contribution voluntary but it is difficult to see how this would be able to guarantee funding continuity beyond one year, let alone raise the necessary funds required. An obvious question with this model is whether it would pass the equity test, i.e. that everyone contributes. It is for this reason that both greenfields and brownfields are included; some companies spend little on the former. It is also imperative that METS companies contribute. The amount collected through this model is likely to differ from year to year as companies alter their exploration budgets.

"It is important to understand that the reason there are gaps in data and knowledge regarding exploration in areas of post-mineral cover is, the challenge of successfully exploring these areas is so complex and high risk that individual companies have not been able to develop a sound business case to tackle the problem on the scale and breadth required, using the traditional collaborative industry-sponsored research model. Industry will have to contribute in some way to funding UNCOVER. We will need to be innovative and broad-based and fully leverage the investment every exploration company makes when they explore in Australia"

Paul Agnew, Rio Tinto Exploration

As outlined in Section 10.1, the current CRC and ARC linkage programmes do not provide the magnitude of sustainable funding, nor the framework that is necessary to execute a truly coordinated research and technology development programme identified by this Roadmap.

The models that fund industrial R&D in other sectors, or variants thereof, could potentially fund a National research entity such as the ACE that would be tasked with implementing the Roadmap outcomes (see Section 10.1). Which of these models are acceptable to all stakeholders is an open question. Pragmatism would suggest that these approaches will be difficult to implement at this juncture in the business cycle. However, given the strategic value of the sector to the national economy, an innovative approach to funding new research and exploration technology is now required to secure the long term sustainability of the mining sector to the economy.

In the current down trend part of the mining cycle, exploration and mining companies are still looking for ways to minimise costs, making securing substantial direct cash contributions, for the amounts required to really make a difference, problematic. In recognition of funding challenges, it is prudent to consider other funding approaches that will minimise the need for substantial direct voluntary industry cash funding.

An obvious way that this could be achieved is through a levy-based system. The Rural R&D Corporations and ACARP are examples where the levy is based on some measure of production outcomes (see Section 10.2 of this document). In the ACARP scheme for example 5¢ per ton of black coal produced is levied.

Although appealing, imposing a new or additional levy on production is fraught with obstacles, not the least of which would be industry viewing it simply as another impost. An in-principle option raised in the Roadmap was that additional imposts or costs could be removed or reduced if, for example, the amount raised by such a levy, or some agreed very small portion thereof, was to be deducted from current royalties' payable to the States & Territories. Directing a very small portion of the current royalty stream to research and technology development, identified in the Roadmap could be regarded as an investment now ensuring a sustainable minerals royalty stream for future generations.

A levy on production, similarly adopted from other sector RDC's, is but only one possibility of funding the ACE. Another approach considered in Roadmap discussions is a levy applied to land tenure for both exploration and mining. Applying a levy on tenure will also ensure funds raise are scaled to the company size, ensuring a differential funding mechanism; the larger the company the larger the landholding and therefore the larger the funds raised. Coal tenure would be excluded because it already has a levy in place to fund research under ACARP RDC. ACARP has been in place for 23 years under a voluntary mechanism, successfully funding new research and technology in the coal sector.

To evaluate this funding option as part of the Roadmap, AMIRA International commissioned a leading global consulting firm to undertake an analysis of this approach in each state and territory and build a model to forecast the amount funds that could be raised given a number of assumptions.

The model uses the number of licenses of various types that were current in the six States and Territory. The figure on the next page shows the number of such licenses as of March 2017.

Australian Mineral Tenements Mar 2017 Non-coal



In forecasting the potential revenue that could be raised, it is important to consider both the individual levy amount and how to apply it to the license or tenement. The model developed allowed two options, each with two scenarios to be investigated:

- Option 1: A levy applied on the size (in hectares) of the tenement
- Option 2: A levy applied per license/tenement.

In both of these options, two scenarios: were considered: applying a flat rate or a % increment on the current tenure charge. In the case of Option 2, the levy can be applied to either the application fee and/or the rental fee where applicable. No data is available in the model for tenement size in South Australia and Queensland.

A second scenario whereby the levy is based on % increment on current rental charge on was also modelled, resulting in a levy of 4.9% being applied each year to raise about \$10 million – the levy is assumed to be imposed on first year only). The difficulty with this approach is that South Australia and Queensland apparently do not apply a yearly rental charge. It would fail the equity test.

Summary of the Modeling & Implementation

A summary of the analysis is presented in the following.

| Option | Scenario | Levy rate required in order to raise about \$10m p.a. |
|---|--|---|
| 1. A levy applied on the size of the license / tenement | 1.0 Flat levy | \$1.18 per 100 hectares |
| 2. A levy applied per license / tenement | 2.1 Flat levy | \$365 |
| | 2.2 % increment on current application charge (for 1st year only) | 28.3% |
| | 2.3 % increment on current rental charge | 4.9% |
| | Combined levy on applications and rental charge | 3.25% on applications 10% on yearly rental |

Option 1: Levy applied on the size (in hectares) of the license/tenement

- Size of the tenement as the criteria upon which a levy is imposed
- Raising a minimum of \$10M a year would require a levy rate of \$1.18 per 100 hectares held

Option 2: Levy applied on the size (in hectares) of the license/tenement

- Size of the tenement as the criteria upon which a levy is imposed
- Raising a minimum of \$10M a year would require a levy rate of \$1.18 per 100 hectares held







Option 3a: A levy applied per license/tenement

- Levy rate is a % increment of the current tenure rental (application fee only)
- Raising a minimum of \$10M a year would require incremental levy of 28.3% to be added to the current tenure application charge

Different combinations could be considered, but the driving force must be to ensure that the schema is administratively practicable to implement.

Irrespective of the scenario, there are two end-member options for collection and consolidation of the levy funds:

- 1. Individual States collect the levy as part of their application/renewal process and forward the funds to the ACE.
- 2. Each company is billed directly by the ACE and this would avoid any changes to regulations required by the States to enact the arrangement.

Advantages of each approach would need to be considered in the design of a new funding mechanism if a tenure based levy is considered to be a viable option to raise required funding for research and technology development.

In addition, one-on-one projects could potentially be funded by companies, whilst the learnings from such projects would contribute to the common body of knowledge that the ACE will create.

Irrespective of funding model and mechanism implemented together with where the funding is raised and invested, it needs to be remembered the programme outlined in the Roadmap is national and the results will be applied to discover new mineral resources across Australia. The largest beneficiaries from successfully delivering on the Roadmap vision will be the States and Territory where the greatest potential for new Tier 1 mines exists and ultimately the broader Australian community.

Recommended funding mechanism - A consensus of the stakeholders indicates that the most appropriate funding mechanism to deliver new knowledge, accelerate the enhancement and development of new technology timeframe required to make a difference, requires a new approach. The approach of the mechanism, source and level of funding needs to be guided by the principle and alignment of eventual benefit.

Given the impact and required input from high levels in all stakeholder communities, the Roadmap recommended the choice of the most appropriate and practicable funding mechanism be a primary objective of the Roadmap Implementation Task Force (RITF). Details of the RITF are detailed in section 11.

EAST RIVER RECCE. Photo courtesy gsnsw.

YOU DON'T MAKE PROGRESS BY STAND-ING ON THE SIDELINES, WHIMPERING AND COMPLAINING. YOU MAKE PROG-RESS BY IMPLEMENTING IDEAS.

-SHIRLEY CHISHOLM

MOVING FORWARD

IMPLEMENTATION OF A WORLD FIRST COLLABORATIVE GEOSCIENCE ECOSYSTEM

Translating the Roadmap from ideas to action and realise a three-year community investment requires a mechanism, a plan. Implementation will require a step-change, cross-sector collaborative effort by the Australian geoscientific community. It is critical that industry plays a dominant role in determining the way forward.

Progressing from the design stage to coordinated execution of the many programmes embedded in the Roadmap, originally seeded by the original UNCOVER vision will now require a lift in the level of cross-sector collaboration and coordination by the collective Australian geoscientific ecosystem.

Successful cross-sector collaboration, if enacted, can deliver new data, knowledge and technologies that will catalyse a much-needed shift in value creation through the discovery of new and economically viable future mines and concomitant mining communities that support them. Importantly the AMIRA International Roadmap provides a mechanism to combine tangible research, technology and data activities with the required talent capability to develop new ventures able to deliver significant growth and strategic advantages for exploration here in Australia.

Expanding and accelerating current programmes as well as commencing new research to develop the next generation of knowledge and develop new innovative technologies needed to significantly improve mineral exploration success by overcoming the cover challenge, now represents a major opportunity for Australia. This opportunity lies in the creation of a truly National collaborative geoscience ecosystem in the form of an ACE, which will be unique in the world. If successfully implemented, the ACE will benefit all stakeholders both within the geoscientific ecosystem and importantly in the wider Australian community. It is clear that improved exploration success leading to Tier 1 discoveries will boost Australia's economy through increased mineral exports, and the further expansion the METS sector. In addition, Australia will regain its competitive strength that it once had in exploration geoscience R&D by leading the world in developing solutions to the challenges of exploring under cover – something that is not restricted just to Australia.

As highlighted herein, realising this opportunity, as with many landmark transformational initiatives will require a number of significant structural and behavioural changes. Navigating and managing change of the type needed to take exploration to the next level, will require the energy, skill and collective will of the Australian geoscience ecosystem. Delivering on the Roadmap vision will not only require true collaboration but it will need multidisciplinary science and technology integrators and cross-sector boundary spanners. Above all to affect the transformation it will require strong and focussed leadership and a collective sense of purpose and responsibility that will overcome any partisan bias that could derail achieving the Roadmap vision.

11.1 WORKING TO IMPLEMENT THE ROADMAP

AMIRA International has developed many industry roadmaps; it has found that an effective way of realising a pathway to implementation is to form a special committee of the highest executive level representatives from key stakeholders. As previously mentioned however, it is fundamental to the successful implementation of the Roadmap that industry plays an influential role determining the way forward. For the purpose of this discussion it will be called the Roadmap Implementation Taskforce (RITF). A handpicked group of individuals with a proven track record of delivering transformative initiatives is necessary to ensure that focus is not lost, diluted or derailed.

Such a task force is in effect an extreme impact, temporary organisation designed to fulfil the specific mission to establish and put in place the optimal mechanism to implement the Roadmap.



11.1.1 TERMS OF REFERENCE AND COMPOSITION OF THE RITF

The terms of reference of the RITF will have to be established. AMIRA International will be able to assist with this based on its experience. The composition of the RITF will also need to be determined through consultation and the necessary senior people brought on board. It is expected that the RITF must be a streamlined and most importantly a cross-sector representative team comprised of the highest executive levels of industry, government and research spheres as the key decision makers. Proposed members of the RITF are included in the table below.

| Major international mining companies State Government Geoscience CSIRO Mid-size mining companies Federal Government Geoscience Australian Research Council | Exploration and Mining | Australian Government | Australian Academia & Research |
|---|--|--|--|
| Mid-size mining companies Federal Government Geoscience Australian Research Council | Major international mining companies | State Government Geoscience | CSIRO |
| | Mid-size mining companies | Federal Government Geoscience | Australian Research Council |
| Junior exploration companies State Government Department Australian University sector of industry & science | Junior exploration companies | State Government Department of industry & science | Australian University sector |
| Mineral exploration services Federal Government Australian Academy of Science Department of industry & science UNCOVER | Mineral exploration services | Federal Government Department of industry & science | Australian Academy of Science UNCOVER |
| Exploration and mining Australian Academy of Technology industry advocacy and Engineering | Exploration and mining industry advocacy | | Australian Academy of Technology and Engineering |
| Mining Engineering Technology & Services (METS) | Mining Engineering Technology & Services (METS) | | |

AMIRA International

11.1.2 THE RITF SECRETARIAT

AMIRA International has had experience at setting up and managing committees of the type proposed herein. Furthermore, it has the wherewithal to provide the all important secretariat support. AMIRA International proposes to play a key role in implementing the Roadmap and an integral part of the entity that will be tasked to deliver on the Roadmap vision, and is thus prepared provide the necessary secretariat support. AMIRA International's core purpose, independence, facilitation skills, process and systems, makes it an ideal organisation to undertake this task.

11.1.3 TIMING AND NEXT STEPS

Given the significant investment into developing the Roadmap coupled with intense and growing interest in seeing the vision of the Roadmap delivered, it is proposed for AMIRA International to urgently commence with setting up the RITF with the objective of commencing the taskforce activities in late 2017. Initial planning indicates setting up and completing a task force will take 6-8 months. A proposed workflow process for the RITF is presented on the next page.

Roadmap Implementation Task Force Workflow - 2017





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OPERATING AN UNDERGROUND DIAMOND DRILL RIG, CONDUCTING GRADE CONTROL DIAMOND DRILLING IN A WESTERN AUSTRALIAN GOLD MINE. IMAGE COURTESY PERSEVERANCE UNDERGROUND DRILLING.

13 APPENDIX A

ROADMAP SPONSORS AND CONTRIBUTORS



13.1 ROADMAP SPONSORS

| Anglo American | Paul Cromie | Stage 1 |
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| AngloGold Ashanti Australia | Keith Martin Mark Doyle (Lead) Luke Bergin Tom Less Louis Gauthier | Stage 1 & 2 |
| Antofagasta Minerals | Craig McEwan | Stage 1 |
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| Aruma Resources | Peter Swann | Stage 1 |
| Association of Mining and Exploration Companies (AMEC) | Simon Bennison (Lead) Graham Short Jon Hronsky Neil van Drunen | Stage 2 |
| Australian Institute of Geoscientists (AIG) | Wayne Spilsbury (Lead) Steve Sudgen | Stage 1 & 2 |
| Australian National University | John Mavrogenes (Lead) | Stage 2 |
| Barrick Gold | Francois Robert (Lead) | Stage 1 |
| BHP | Jill Terry Colin Carey Simon Gatehouse (Lead) Campbell McCuaig (Lead) Arthur Maddever Paul Hodkiewicz | Stage 1 & 2 |
| Boart Longyear Australia | Peter Kanck (Lead) Anton Clarkson | Stage 1 & 2 |
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Geological Survey of Victoria: http://earthresources.vic.gov.au/earth-resources/geology-of-victoria/geological-survey-of-victoria

Geological Survey of Western Australia: http://www.dmp.wa.gov.au/Geological-Survey/Geological-Survey-262.aspx

Geoscience Australia: http://www.ga.gov.au/

Investigator Resources: http://www.investres.com.au/

Mineral Resources Tasmania: http://www.mrt.tas.gov.au/portal/home

Mt Isa Mines – A Glencore Company: http://www.mountisamines.com.au/EN/Pages/default.aspx

Newcrest Mining: http://www.newcrest.com.au/

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MOUNT SWAN GRANITE, AILERON PROVINCE, NORTHERN TERRITORY IMAGE COURTESY NORTHERN TERRITORY GEOLOGICAL SURVEY

APPENDIX B

ROADMAP STAGE 2 POSTERS A0

- 14.1 Roadmap Themes to sub themes to strands A0 Posters
- 14.2 Roadmap dependency mapping A0 Posters
- 14.3 Australian geoscience research capability map Version 1- A0 Posters





GEOSCIENCE RESEARCH, TECHNOLOGY AND DATA STRAND SUMMARIES

Theme 1: Characterising the Cover Theme 2: Lithospheric Architecture Theme 3: Geodynamic Evolution and Metallogenesis Theme 4: Distal Mineral Footprints Theme 5: Risk Reward for Covered Economic Resources Theme 6: Research, Education and Training







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