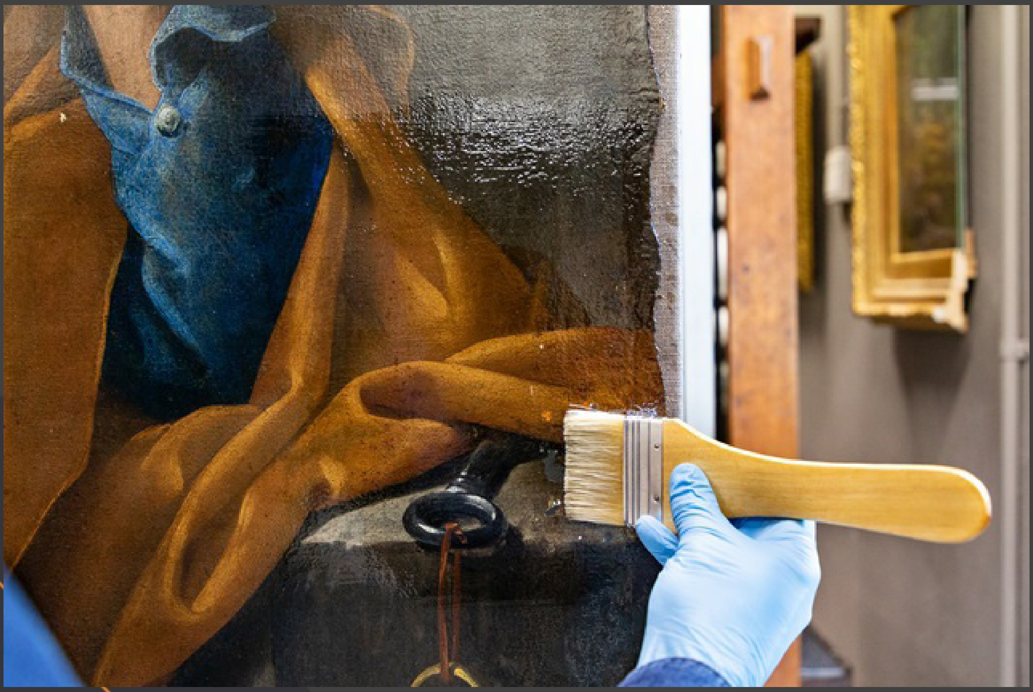
MS3 IMPACT EVALUATION



Source: National Gallery of Victoria

October 2020

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This case study uses the evaluation framework outlined in the CSIRO Impact Evaluation Guide. The results of applying that framework to the MS3 impact assessment are summarised in Figure 1.

Glossary

B2B	Business to business
B2C	Business to customer
BCR	Benefit cost ratio
Boron Molecular	Boron
CBA	Cost-benefit assessment
CSIRO	Commonwealth Scientific and Industrial Research Organisation
HSE	Health Safety Environment
LMW	Low molecular weight
NGV	National Gallery of Victoria
NDSU	North Dakota State University
SLO	Social licence to operate
TBL	Triple Bottom Line
P_{MS3}	Reservation Price MS3
P_{Mar}	Market Price MS3
P_{reg}	Regular varnish price
PoC	Proof of concept
PV	Present Value
ROI	Return on Investment Ratio
WDWL	With deadweight loss
WODWL	Without deadweight loss
wrt	With respect to

Note

Unless mentioned otherwise,

- all dollar figures are in AUD
- ‘profit’ means profit before taxes

2 Purpose of case study and intended audience

CSIRO developed MS3, a conservation grade varnish for the preservation of irreplaceable heritage assets. The R&D was conducted based on an initial request from the National Gallery of Victoria (NGV) and commercialised by Boron Molecular (Boron). The key goal was to address a significant market gap created by the cessation of the production in 2014 of the revered MS2A varnish. It was the preferred choice of conservators across the globe, so much so that its loss was described by Mary Kempski[1] as devastating to the community. MS3, a superior performer to existing resins, was developed as a third generation of the varnish.

MS3 emerged as a product of CSIRO's interdisciplinary expertise in chemical synthesis and continuous flow chemistry (**flow chemistry**). The speciality resin is reversible; does not yellow like natural resins as it ages; and is completely clear, thereby imparting it with high-performing properties compared with other products. It is utilised to protect invaluable art pieces by >40 customers globally since its commercialisation in December 2019. The purpose of this case study is to assess the benefits generated through the uptake of CSIRO's speciality resin for the protection, enhancement, and preservation of cultural heritage masterpieces in an extremely niche and cautious market.

The study also highlights the benefits of flow chemistry production process over traditionally dominated batch chemistry to improve the quality of products and the economics of manufacturing operations to solve Australia's greatest challenges and to create future industries (the CSIRO 'Challenge' in focus) for Australia.

CSIRO's research activities and their impacts are diverse and occur across many sectors of the economy. This evaluation has been conducted using the framework of social cost-benefit analysis (CBA). CBA is conducted from the perspective of society as a whole. Despite popular misconceptions, it does not deal solely with financial aspects. Because of its society-wide perspective, it automatically includes financial, social, and environmental impacts. It is sometimes difficult to quantify effects such as the conservation of cultural heritage; but it is not impossible to do so. Techniques such as Choice Modelling, Hedonic Pricing, and Contingent Valuation Methods are frequently used to determine the economic values of non-market goods and services. However, these techniques were not used here owing to the lack of requisite data. The case study also provides a list of lessons learned (as articulated in the learned, as articulated in the recommendations. These are designed to assist in catalysing the uptake of this work and to enable a more robust monitoring and evaluation assessment in the future.

This report can be read as a stand-alone item or alongside other CSIRO Manufacturing evaluations to substantiate the impact and value of CSIRO's activities against funds and resources invested in this program. CSIRO as a service provider to government and industry is highly focused on delivering value and impact through the scientific interventions that originate from its research activities. The information is provided for accountability, communication, engagement, continuous improvement, and future application purposes. The study is also intended to serve as a tool to underpin strategic investment decision-making. The intended audience includes Business Unit Review Panels; federal, state, and local governments; the National Gallery of Victoria; Boron Molecular; art conservators; CSIRO; universities; and the general public.

1 Radosław Chocha: Recollections of a career in conservation – an interview with tutor and mentor Mary Kempski; The Picture Restorer, No. 55 Autumn 2019, p.17.

3 Background

Varnishes are critical for painting conservators as they determine the success or failure of artwork in terms of appearance and longevity. A good resin can enrich the colours of a painting; give it presence as it hangs on a wall; and protect it from dust, dirt, and abrasion. However, varnish coatings can discolour and crack over time. To keep gallery paintings looking their best, dedicated and meticulous painting conservators must remove old varnish coatings and reapply new ones several times over a painting's lifetime.

For many years (1959-2014), painting conservators across the world relied heavily on MS2A, a cyclohexanone-derived varnish specially designed for the conservation of paintings. A great surface finish, convenient handling properties, and solubility in less toxic solvents imparted the varnish its uniquely superior properties that made it justifiably the top choice of conservators across the globe.

However, MS2A also had a reputation as a difficult and mysterious product to manufacture, in part due to the trouble in sourcing the base components. The inherent nature of the batch manufacturing process also resulted in occasional yellowness induced by batch to batch variations.

The challenge

In 2014, the company producing MS2A ceased trading, and with it, the critical technical knowledge behind this important conservation-grade resin began to blur out as well. Dwindling stocks of MS2A led conservators across the world to explore alternatives for the conservation of their invaluable artworks. Many professionals experimented other available varnishes but failed to gain consistently satisfactory results.

Currently, there are several low molecular weight (LMW) industry-grade synthetic resins adopted into conservation practices as varnishes (e.g., Dammar and Laropal A81; see Appendix A for more details). These varnishes were not developed specifically for high-end art assets and pose a significant risk of doing irreparable damage over time. Literature commentary and firsthand discussions also indicate that in the absence of MS2A, other commercially available varnish solutions tend to cause rapid ageing; do not provide the desired appearance; and involve exposure to toxic chemicals. These characteristics make the solutions less desirable to use on artworks worth millions of dollars.

To address the significant market gap created by the non-availability of MS2A, the NGV – Australia's oldest and most visited gallery – approached CSIRO in 2016 to examine the feasibility of reviving production of MS2A.

The response

In July 2016, CSIRO's team of experts in chemical synthesis used Vincent Routledge's published information on the chemical structure of MS2A to successfully demonstrate a proof of concept (POC) of replicating the resin chemistry by producing a small "test-tube" quantity of varnish. The team progressed the project to the next stage by adapting the batch process it developed into a continuous process by using a modern flow chemistry reactor rather than a traditional batch reactor. They thereby produced a more consistent and highly reduced resin – MS3. The name represented the third generation of the cyclohexanone-derived varnish family, that utilised a single cyclohexanone feedstock and a different manufacturing process.

Superior processing through flow chemistry imparted improved colour, chemical stability, and consistency between batches, resulting in a bespoke resin with minimal discolouration or cracking over time.

CSIRO worked in close collaboration with the NGV and local specialist chemical manufacturer Boron for development and production of MS3. Keeping the customer at the heart of innovation allowed the team to progress from POC to market sale within a span of only 3 years. Market assessment suggests that similar products on average take a minimum of ten years from R&D to commercialisation (See Section 5 for more details).

MS3 is a major contribution to high-end art conservation. It is a stable, consistent, safe to use, and aesthetically appropriate varnish solution that addresses the practical challenges of responsibly conserving paintings for the future through application of improved processing technology.

MS3 is now being used by some of the world's most high-profile galleries and is receiving very positive reviews. The NGV has used the resin in recent treatments of works in their famous collection, namely Rembrandt's *Two Old Men Disputing*, and van Dyck's portrait *Philip Herbert, the 4th Earl of Pembroke*.

4 Impact pathway

INPUTS

Investment

- CSIRO Business Unit (BU) funding and in-kind support
- External investment by Boron Molecular
- Grant from Victorian state government

Research Capabilities

- Background expertise in chemical synthesis and flow chemistry
- Access to high calibre, multidisciplinary capabilities (CSIRO and partners NGV, Boron and universities)

Infrastructure

- Access to infrastructure and resources to execute projects (e.g., FloWorks lab etc)

Partners and customers (Translation support)

- NGV's strategic position and existing relationships with art conservators across the world for testing and trials
- Boron's available infrastructure and expertise in flow chemistry

Regulatory and Legal Support: NA

SLO: NA

ACTIVITIES

Market Analysis

- Performed with support from NGV and CSIRO commercialisation team

RD&I Activities

- Lab testing and validation activities

Funding Proposals

- Grant applications to accrue funding for execution of project

Translation and commercialisation

- Translation and commercialisation activities in collaboration with project partners NGV and Boron

End-user engagement

- Engagement activities with conservators across the world for MS3 trialling, quality testing and validation
- Activities to build customer base and distributors for the niche product

Education and Outreach

- PhD and Post Doc training

OUTPUTS

MS3 resin

- Development of MS3
- Application of flow chemistry for production of specialty resin

Funding

- $60,000 grant from the Victorian state government
- $50,000 Industry Funding from Boron

MS3 validation

- Post-trial validation of superior properties of MS3
- Commercial feasibility analysis

Commercialisation

- Business plan
- Sales distribution network
- Identifying market segments

Engagement platforms

Postdoc recruitment

Publications and Awards

- Media reports
- Awards

  Knowledge Commercialisation Australasia 2020 award for Best Research Contract/ Collaboration

OUTCOMES

TBL impacts - Australia

- Uptake of superior MS3 resin as a new varnish of choice by conservators

Lift Australia's science capacity and capability

- New opportunities for Boron
- Evidence of shortened path to market routes through uptake of flow chemistry for specialty chemicals
- Engagement of interdisciplinary specialists from all around the world
- Demonstration of capabilities of CSIRO's world class FloWorks lab to develop a niche product - MS3 varnish

Sustainable operations, cultural health, safety, and wellbeing

- Market interest in utilisation of continuous flow chemistry
- Uptake of a commercial resin that does not require use of dangerous aromatic solvents
- Uptake of manufacturing process that is deemed safer, cleaner, and more efficient than traditional batch manufacturing.
- Demonstration of a highly successful collaboration among conservators, scientists, and industry

Revenue

- Licence to Boron
- New revenue stream for Boron through sale of MS3

CSIRO

- Recognition of CSIRO's competitiveness in niche art conservators domestic and global markets
- Saving of CSIRO's time and resources through proactive market investigation that ruled out commercial viability of MS3 in alternate markets.

IMPACT

Economic impact

- New product for niche markets
- Productivity and efficiency
- Australia's competitiveness

Environmental impact

- Lower energy footprint of manufacturing process

Social impact

- Management of risk and uncertainty
- Culture and heritage
- Health and wellbeing
- Innovation and human capital (creativity and invention)

FY2016 to FY2019 (Inputs, Activities, Outputs)

FY2020 to FY2030 (Outcomes, Impact)

Figure 1: Impact Pathway for MS3 Project

Impact Evaluation

Impact assessment approach

This section assesses the value created by CSIRO's MS3 work for its stakeholders to deliver positive impacts for Australia. The evaluation process covered in this section involves identifying the impacts to be evaluated and the impact pathway (see Fig. 1) which connects these impacts back to the research and innovation activities undertaken within the unit of evaluation, and their broader context. A combination of qualitative and quantitative methods was used to access the economic, social, and environmental impacts delivered by this research. Clients and other stakeholders were engaged to gain an assessment of CSIRO's attribution and validate the assumptions that underpin the impact assessment.

For this evaluation:

- Costs are considered for the period of FY2016-FY2020
- Benefits are assessed from FY 2019 to FY 2029

Project inputs

This section provides information on the key resources invested in the project. This includes (but is not limited to):

Investment

- For CSIRO and partner investment details, See Table 1

Capability

Access to high calibre and multidisciplinary CSIRO and partner capabilities, which include:

Technical

- Expertise in chemical synthesis and flow chemistry
- Analytical chemistry
- Chemical engineering
- Testing and characterisation facilities and instrumentation
- Painting conservation and polymer chemistry

Market assessment

- Commercialisation analysis

Infrastructure

Access to infrastructure and resources to execute projects

- Labs (CSIRO's world-class flow chemistry facility FloWorks, Melbourne)
- Accelerated ageing facilities
- NGV painting conservation laboratories
- Analysis and characterisation facility (CSIRO Clayton).

Partners and customers (Translation support)

- NGV conceptualised this work. Its strategic positioning and existing relationships with art galleries around the world played a key role in providing CSIRO with background information to conduct this work, as well as feedback on the performance of the newly developed resin, and presented network connections for the testing of MS3.
- Boron provided the expertise in flow chemistry operation, infrastructure for production scale-up, and experience in the management of similar specialty projects. They also provided funding support, business development, commercialisation, sales, and marketing expertise.
- Customers: Gallery conservators who provided testing support for MS3.

Regulatory and Legal Support: NA

SLO: NA

Table 1 lists the input costs.

Table 1: Investment (AUD) in MS3 research

CONTRIBUTOR / TYPE OF SUPPORT	FY2017	FY2018	FY2019	FY2020
CSIRO				
Switch Project time (D Lau Labour)		120,000		
OD-204503: Varnish for NGV conservation	51,230	39,762	89,439	191,613
EXTERNAL PARTNERS				
OD-210920: MS2A+ transfer to Boron		38,433	83,263	
Total annual investment (nominal)	**51,230**	**198,195**	**172,702**	**191,613**
Total annual investment (real)	**54,916**	**208,042**	**178,739**	**195,097**
Total in FY2021 $ (Real Discount Rate 7%)	71,984	254,861	204,639	208,754
Overall Program Investment (in 000' FY2021 $ without dead weight loss (WODWL))	740			
Overall Program Investment (in 000' FY2021 $, incl dead weight loss (WDWL)) *	888			
CSIRO Investment (in 000' FY2021 $ without dead weight loss (WODWL))	592			
CSIRO Investment (in 000' FY2021 $ incl dead weight loss (WDWL))	711			

The investment was spent on conducting activities listed in the next section.

*Since the MS3 project is mainly funded by the Commonwealth and state governments, the cost of the funds used for the research program should reflect on the rest of the economy. If it is assumed that funding for this work has been obtained through income taxation, there will have been negative effects on the private sector in the form of deadweight loss. It has been argued by several authors that research costs should be increased by about 20% to reflect the deadweight loss of income tax-based funding, although many Australian cost-benefit studies omit it.

Activities

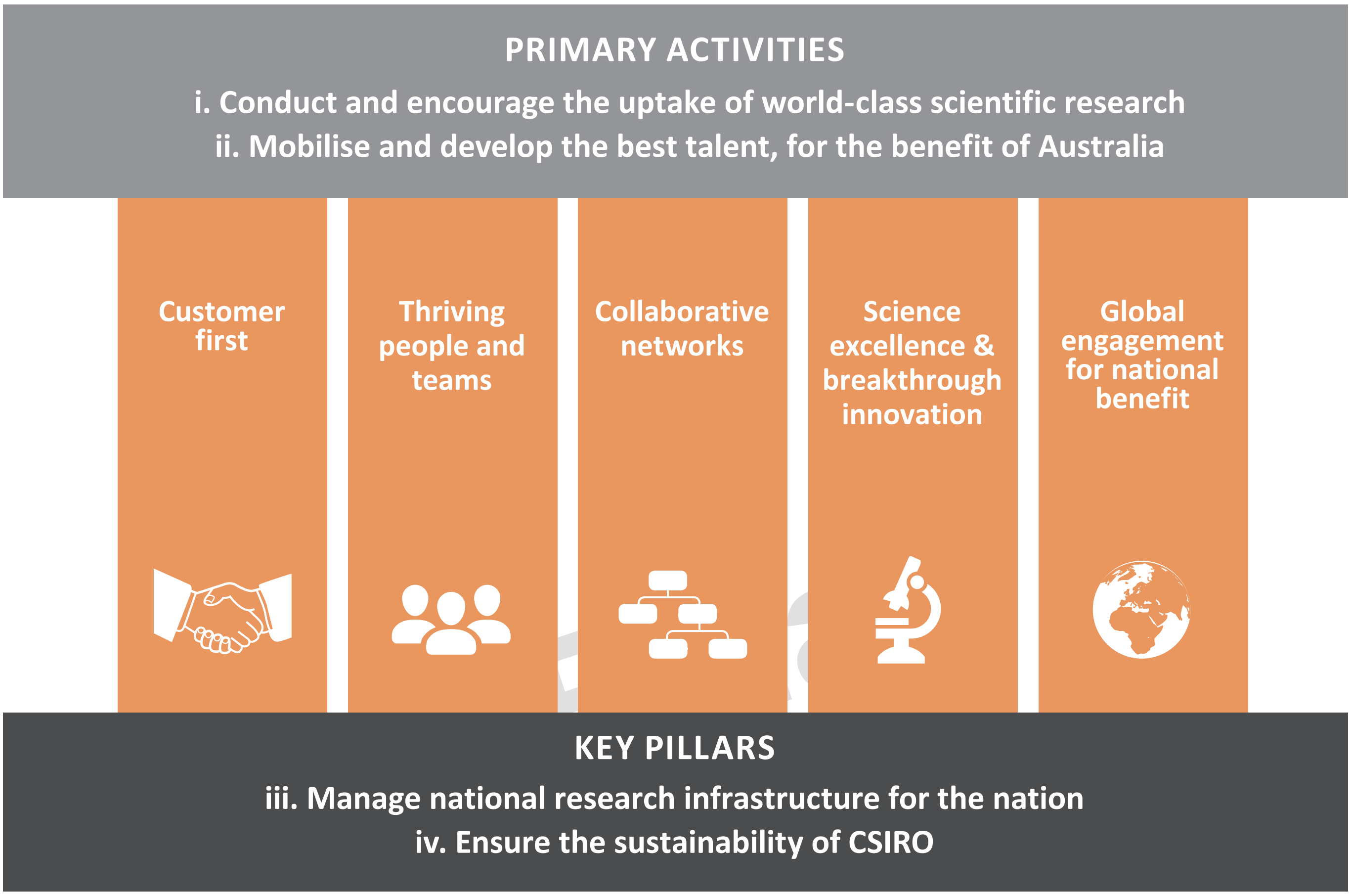


Figure 2: CSIRO primary activities and key pillars

Some of the key operational challenges that the team addressed through their activities included:

- Although chemical manufacture of industrial chemicals is an established industry in Australia, chemical manufacture of materials for fine art preservation is an unfamiliar and niche space.
- Lack of funds to design and operationalise the production process. This led the project to sit dormant for >1 year.
- Translation to industry partner to commercialise a low-scale speciality product for a niche market. This also included challenges such as difficulty in finding time for product development and process scale up within existing busy manufacturing schedule.
- Obtaining sufficient trust and acceptance for a varnish coating to be used on the most valuable paintings in the world.

This section provides the key actions taken by the project team to mobilise the available resources to achieve intended outputs for successful completion of the project. These include (but are not limited to):

Market Analysis

The work was conducted to address a significant market gap – that is, the need to create an effective varnish for the preservation and maintenance of invaluable gallery paintings for art conservators across the world. Key market assessment activities included:

- Literature studies
- Engagement with customers early in the project to identify products, proactively test assumptions, and ask directional questions about the intended path to market, costing and opportunities
- Development of supply chain – identification of, and engagement with, key customers and vendors
- Face-to-face meetings critical conservation community influencers (at conferences, trade shows, site visits, etc.,) to address key concerns during the development of the new varnish to drive uptake
- Working with CSIRO's Commercialisation team to explore alternate markets.

Technical (R&D)

- Leveraging of CSIRO's expertise in chemical synthesis to successfully replicate the chemical structure of MS2A
- Chemical analysis of samples for optimisation
- Application of flow instead of batch chemistry, to improve consistency of MS3 over its predecessor MS2A
- Optimisation of production parameters to provide the desired chemistry
- Development and testing of varnish prototypes for handling, visual, and chemical properties.
- Establishment of a manufacturing process that improves product quality while lowering the economic and environmental footprint of varnish production.

Funding proposals

- Writing funding proposals under different grant programs to secure funds for production scale-up and support marketing of MS3.

Translation and commercialization

- Performing extensive testing at the NGV
- Contacting high profile, respected, and experienced painting conservators to seek their assessment of samples provided for evaluation
- Face-to-face meetings with conservators to review their utilisation of the product and answer technical questions
- Translating technology from lab scale at CSIRO, to commercial production scale at Boron, a CSIRO spin-out
- Providing technical support and analysis to Boron during translation and scale-up.
- Licencing of technology to Boron
- CSIRO's participation in the recapitalisation of Boron to expand local manufacturing capability.

End-user engagement

- Coordinating trialling of the new varnish by conservators working in several of the world's major art institutions.

Education and Outreach

- Presenting technical findings from the work and networking at conferences globally
- Publications in conservation newsletters and peer-reviewed journals
- Responding to user enquiries during development and early distribution
- Media stories.

Outputs

Commercially competitive features of MS3

- Superior resin developed specifically for artwork conservation and cultural heritage applications
- Preferred handling and visual appearance
- Improved longevity and reversibility characteristics
- Consistent quality due to improved flow chemistry production methodology.

The section provides a snapshot of the research solutions, services, and/or capabilities that resulted from the performance of activities under the MS3 project. These include (but are not limited to):

MS3 resin

- Delivery in July 2016 of a test tube quantity of resin with the same chemical structure as MS2A
- Development of a bespoke resin MS3, a technically improved version of MS2A, that retained all its valued properties while addressing the deficiencies. Some characteristics of the protective coating included:
  - Ability to enhance visual aesthetics without causing any damage to the underlying paint layers.
  - Protecting the artwork for future generations by improving their colour, without changing the surface it is applied to
- Demonstration and validation of a specialty chemistry resin applied to the world's most expensive and valuable artwork.

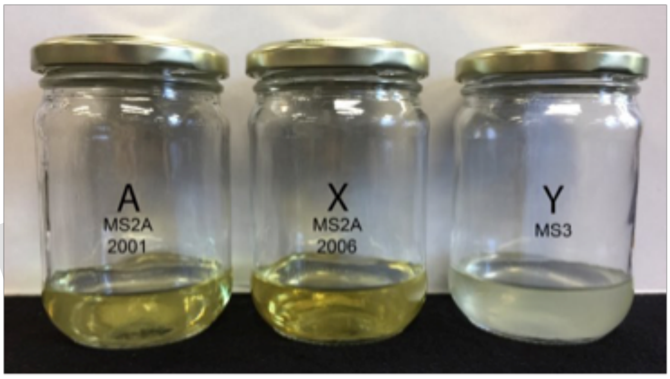


Figure 3: Test tube quantities of MS3 and MS2A grades (2001,2006)

New manufacturing technique

- Demonstration of emerging 'flow chemistry' technology for the manufacturing of speciality MS3 varnish, representing a shift from the traditional batch process
- Validation of continuous flow chemistry manufacturing process to furnish a more reduced resin (i.e., less yellow) and consistent product from one production run to another
- Demonstration of advantages of continuous flow chemistry in its ability to impart a higher control and quality product, with a lower economic and environmental footprint compared with traditional large-scale batch production methods
- A successful test case of a revolutionary manufacturing process that is deemed safer, cleaner, and more versatile and efficient than traditional chemical manufacturing for high-volume operations.

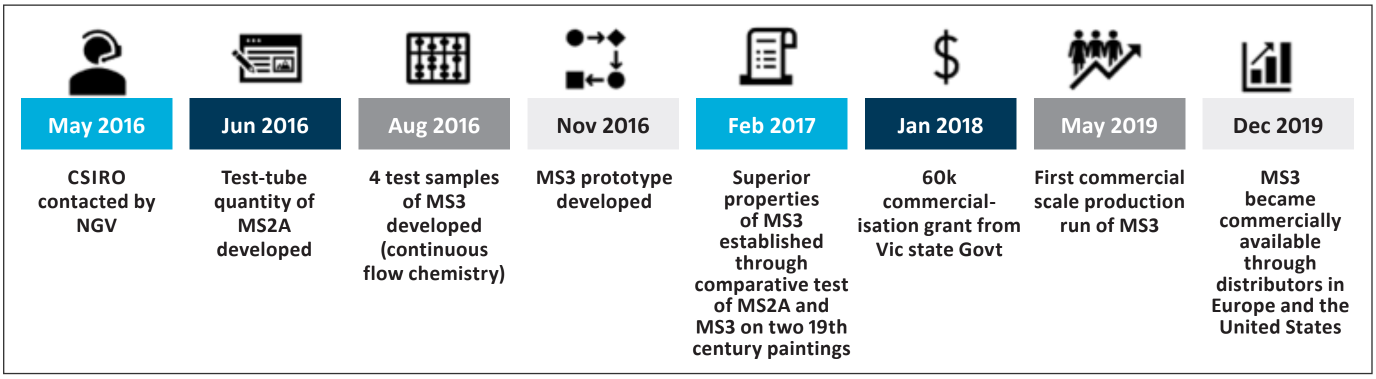


Figure 4: CSIRO's MS3 project journey

Funding

- $60,000 grant from the Victorian state government designed to encourage initiatives in local industrial research production that provided support to mobilise the technology translation from lab scale at CSIRO, to commercial production at Boron. This funding was granted to Boron and matched by them with cash and in-kind contribution.

MS3 validation

- Post-trial validation of the effectiveness of MS3 for its intended purposes and its superior properties
- Commercial feasibility analysis for the uptake of MS3 in alternative markets.

Commercialisation

- Business plan for commercialisation
- Market delivery of MS3 within 3 years from initial proof of concept to delivery, while bringing together the expertise of different cross-functional teams
- Establishment of the sales distribution network of MS3 through distributors

  St.Luke – Australia

  Talas – USA

  Deffner & Johann – EU and Russia

- Understanding of market segments for MS3 (See Appendix B for more details).

Publications, Patents and Awards

- Recipient of Knowledge Commercialization Australasia 2020 award for Best Research Contract/Collaboration

Media Articles

- https://research.csiro.au/floworks/tag/ms3/
- Lau, D., Saubern, S., Alexander, D., Hutt, O., & Villis, C. (in press). The Next Generation of MS2A Resin: MS3. Journal of the American Institute for Conservation.
- https://www.theage.com.au/culture/art-and-design/the-invisible-australian-goo-on-some-of-the-world-s-most-famous-art-20200902-p55rnq.html
- https://particle.scitech.org.au/people/the-varnishing-point-where-science-meets-art/
- https://www.manmonthly.com.au/Resin+developed+for+masterpiece+restoration
- https://www.csiro.au/en/News/News-releases/2019/Australian-innovation-adds-new-sheen-to-old-masters
- https://www.theage.com.au/culture/art-and-design/in-the-cold-dark-of-the-shuttered-ngv-a-conservator-worries-over-dust-20200501-p54p1g.html

Outcomes

The section covers the short- to medium-term outcomes from the successful delivery of MS3 produced using cutting-edge flow chemistry technology. The outcomes are a result of the collective effort of CSIRO and partners NGV and Boron, as well as art conservators across the world.

TBL Impacts to Australia

- Uptake of superior MS3 resin as the new varnish of choice by conservators in several of the world's major art institutions for the preservation and conservation of invaluable artworks
- Application of continuous flow chemistry process imparts improved production flexibility and operational control, while requiring much lower facility footprint. This leads to improved consistency and reduced wastage, thereby lowering the environmental impact associated with fine art preservation and restoration niche market. Any measurable benefits are achieved at higher scales of operation.
- Improved health and safety of professionals in the industry enabled by the reduction in the usage of carcinogenic solvents associated with the application of varnish solutions
- Preservation of artwork and cultural heritage
- Building confidence within the art conservator community through unrestricted access to a desirable resin.

Lift Australia's science capacity and capability

- New opportunities for collaboration and commercialisation with an Australian small business (Boron) thereby generating more benefits for Australia
- Commercially competitive edge for Boron to broaden the scope of their business and upscale their innovative products in the global marketplace, through the implementation of cutting-edge flow chemistry technology
- Evidence of shortened path to market routes through successful application of flow chemistry for domestic and export purposes
- Engagement of specialists from around the world from the diverse fields of painting conservation and polymer chemistry to address an important need in the painting conservation profession and effectively achieve better business outcomes
- Enabling art conservators to create and protect their best work long into the future through the uptake of MS3

- Accessible world-class facilities to underpin research and innovation
- Demonstration of capabilities of CSIRO's world class FloWorks lab to develop a niche product.

Sustainable operations, cultural health, safety and wellbeing

- Market interest in the utilisation of continuous flow chemistry to carry out manufacturing operations in fine chemicals, pharmaceuticals, and polymer sectors
- Uptake of a resin that does not require conservators to use dangerous aromatic solvents, as required by other commercially available solutions
- A revolutionary manufacturing process that is deemed safer, cleaner, and more efficient than traditional batch manufacturing for high-volume operations while imparting more control and producing a higher quality product
- Demonstration of highly successful collaboration among conservators, scientists, and industry, with support from the Victorian state government, to solve a glaring problem for art conservators.

Revenue

- Licence to Boron for the manufacture of MS3
- A new revenue stream for Boron through the sale of MS3
- Building new relationships with key customer influencers to develop trust and drive adoption in an extremely niche and cautious market.

CSIRO

- MS3 project was conceived, developed, and produced in Melbourne. The work highlights CSIRO's ability to deliver against its purpose while demonstrating that there are no inherent barriers to Australian conservators and scientists taking on ambitious projects with high global impact
- A positive lesson for CSIRO/the broader research community regarding delivering a product to market in a short span time when customers are kept at the heart of innovation and involved in the project from the outset
- A successful example of effective internal collaboration through the uptake of CSIRO's SWITCH program[2] to dedicate resources to build quality customer experience
- Uptake of specific customer feedback to drive market adoption
- Saving of CSIRO's time and resources through proactive market investigation that ruled out commercial viability of MS3 in alternate markets
- Recognition of CSIRO's competitiveness in niche art conservators' domestic and global markets.

Testimonial

"The NGV is extremely pleased with the outcome of our highly successful collaboration with CSIRO to develop MS3 resin. Together, we have joined forces to create a product that was much needed by the global conservation profession. It is even more pleasing that CSIRO was able to utilise its expertise in polymer chemistry to develop a superior product than MS2A, the varnish it has replaced. Here in the NGV paintings conservation department we are very happy with the product and have already used it on several important conservation treatments. I can further report that I have received nothing but highly positive feedback from colleagues here in Australia and around the world, including some of the world's most important art museums. Without exception, everyone is thrilled to have such a high-quality and versatile material available to enable us to work to the highest standard. The only reservations I have heard have been in relation to the cost of the resin, which may prevent it from reaching a broader market in both the painting conservation field and with artists who wish to use a premium product. My sincere thanks go out to Deborah Lau and John Tsanaktsidis, whose hard work and project delivery know-how have enabled us to bring this important project to a successful conclusion. We look forward to using MS3 for a long time to come."

Carl Villis
Senior Conservator of Paintings
National Gallery of Victoria

2 https://alumni.csiro.au/get-involved/switch/

Impacts

Table 2: Summary of project impacts using CSIRO triple bottom line (TBL) benefit classification approach

TYPE	CATEGORY	INDICATOR	DESCRIPTION
Economic	New products for niche markets	- ↑ MS3 Customer base - ↑ MS3 sales	MS3 represents a new product for a highly risk-averse conservator market. A high retail price generates benefits in the form of consumer surplus.
	Productivity and efficiency	MS2A/ alternate varnish vs MS3 - ↓ Production cost - ↓ Application frequency - ↓ Labour cost	Application of flow chemistry has provided an improved process for the production of varnish. Application of MS3 lowers the frequency of re-application compared with other commercially available varnish solutions.
	Australia's competitiveness	- ↑ MS3 global customer base - ↑ MS3 exports - ↑ Higher MS3 global customer confidence	Development of MS3 demonstrates Australia's technical competitiveness in the development of a speciality product for a niche market.
Environmental	Energy saved	MS2A/ alternate varnish vs MS3 - ↓ Environmental footprint of production	A shift from traditional batch to continuous flow chemistry production imparts improved control over the operation. This optimises the production operation. Measurable benefits realised at a high scale of operation.
Social	Management of risk and uncertainty	- ↑ MS3 customer "access to superior varnish" confidence	Established chemistry and production process provides confidence to the consumers about unrestricted access to the product.
	Culture and heritage	- Improved maintenance of artwork - ↑ quality years added to the age of artwork - ↑ gallery visitors	Improved maintenance imparted by the application of superior varnish on the artwork leads to improved 'quality life years' of the art assets.
	Health and wellbeing	- Improved health and safety	Application of MS3 does not require carcinogenic solvents, unlike other other commercially available varnish solutions. This is a significant health and safety benefit to the art conservator industry.
	Innovation and human capital (creativity and invention)	- ↑ Uptake of MS3 in alternate industries	There is a potential for the application of MS3 in other industries to improve operations.

5 Clarifying the impacts

The impact evaluation focuses on incremental impacts that result from the uptake of CSIRO's technology in the form of MS3 varnish. The net impact is estimated by comparing the observed or expected benefits with the base reference point (i.e., a hypothetical scenario in the absence of CSIRO's intervention). See *Counterfactual* section below for further details.

Counterfactual

As mentioned, CSIRO – in collaboration with partners the NGV and Boron – delivered a superior MS3 varnish in short time span of <3 years. CSIRO played a key role in driving the project from the initial engagement (which was just targeted at examining the feasibility of replicating chemistry of MS2A) to successfully delivering a refined version of varnish - MS3, based on a revolutionary technology. The project partners recognise CSIRO's pivotal role in the project.

Had CSIRO not undertaken both fundamental and applied research to support the commercial opportunities for this work, may have led to one of the following scenarios:

1. **Use of other research providers by the NGV**
   - Understandably, development and commercialisation of a speciality product like MS3 is highly dependent upon a portfolio of skills. Similarly, commercial uptake of a new varnish in an extremely niche and cautious market is significantly contingent upon brand confidence and customer connections. There are limited national research organisations within Australia that could offer these capabilities to the NGV for the targeted work.
   - In addition to the above, although the chemical manufacture of industrial chemicals is an established industry in Australia, the production of materials for fine art preservation is an unfamiliar and niche space. As it is not actively undertaken by any research organisations globally, there is no existing commercialisation pathway from which experience can be drawn. This would have been a key deterrent in the pathway of uptake of this project by other research organisations.
   - During an interview, the NGV shared that CSIRO was their preferred partner of choice due to factors listed above; and that it would not have been possible to drive the conceived project to a successful conclusion without their participation. In the absence of CSIRO's intervention, the NGV's limited options would have been to contact someone outside Australia to conduct underpinning scientific work, or to wait for a solution to be developed by another nation.
2. **The utilisation of alternate varnishes for protection of art assets**
   - There is general unavailability of commercially produced bespoke resins for the conservation of high-end art assets. Interviews of world-leading art conservators highlighted that even after two years of experimentation with interleaving layers of available resins (post-MS2A ceasing production in 2014), inconsistent results continued to be observed. This also kept catalysing the health, safety and environment (HSE) concerns associated with usage of carcinogenic chemicals during the application process and irreversible damage to valuable artworks across the globe.
3. **Importing specialised varnish from other countries**
   - Any development of a suitable speciality varnish for artwork would have required Australia to import the specialised product, thereby losing all of the potential benefits and sovereign capabilities from this work (see point 1 above).

On the basis of the above scenarios - and after consultation with the NGV, Boron, and CSIRO's research team - a lag time of at least ten years is assumed for conservators to benefit from access to a suitable varnish for protection of their art assets if CSIRO had not been not involved in this work.

This is a conservative assumption, supported by the following facts:

- CSIRO, with its talented team of multi-disciplinary research and extension professionals in both chemical synthesis and continuous flow chemistry, positioned the organisation well to do this work.

  This is further supported by the fact that the translation and commercialisation support for the niche product was provided by CSIRO's start-up Boron – a bespoke and trusted partner. The low-volume and high-value nature of the product would normally restrict the interest of industry partners in prioritising process scale up and product development within their existing busy manufacturing schedules.

- CSIRO's brand recognition as Australia's innovation catalyst and its global footprint, together with the NGV's network provided the confidence to critical influencers in this space to conduct trials for prototype validation.

  Hence, prevailing trends suggest that in the absence of CSIRO doing this work, progress would have occurred, albeit on a longer time scale, at greater cost, or resulting in outputs producing lower efficiency or productivity.

- Typically, similar products take 10 years to develop and commercialise**.
- The art conservation market between 1959 and 2014 has been heavily dominated by MS2A, a period of >50 years. This represents a long period of >50 years. Being a niche and high-risk market, work in this space is not readily undertaken by research organisations.
- Since the varnish is applied on invaluable assets, any successful uptake is contingent upon trust and acceptance of key customers from an extremely niche and cautious market. In general, the target customers belong to a highly risk-averse market and would not prefer to make any frequent changes.

** MS3 team interacted with [title] Xiaoning Qi, Research Scientist, Department of Coatings and Polymeric Material, North Dakota State University (NDSU) during a conference. NDSU is a typical university department that researches industrial coatings but has a few research projects with cultural heritage applications.

They commercialised protective coating for bronze artworks, Bronzeshield -https://elinorcoatings.com/about-2/. The unique urethane clear coating claims long-term durability based on accelerated weathering and other tests. Development took over a decade, coming to maturity at NDSU polymer research centre. Eventually, it was licensed to Dr Battochi who founded the company Elinor Specialty Coatings to drive its further refinements and commercial production. The case presents an interesting comparative case study for commercialisation of a conservation coating technology.

Attribution

The economic assessment was conducted to estimate the net Australian and global social benefits from the MS3 work conducted by CSIRO in collaboration with the NGV and Boron, and to estimate the portion of the net benefits attributable specifically to CSIRO. A snapshot of the key roles played by the collaborators to drive the project to its successful conclusion are provided below (see Fig. 5 for an illustration of the role of the partners):

1. The NGV conceptualised this project. As co-partner, they played a significant role for trial and validation of MS3 prototypes during the course of its development. The NGV's network helped to connect the research team with art conservators across the world to mobilise the uptake of the specialised resin.
2. CSIRO science drove the development of the resin. The superior resin was developed through bringing together expert scientists in the domains of chemical synthesis and flow chemistry. The NGV states that without CSIRO's involvement, there is a slim chance that this project would have been successfully completed in Australia. In addition, CSIRO also offered the capability of tapping into additional funding needed for the project.
3. Boron Molecular was the bespoke industry partner which commercialised the manufacturing process for MS3, thereby enabling its reach to art conservators globally. Boron also provided the necessary funding support that was critical to carry out commercialisation.

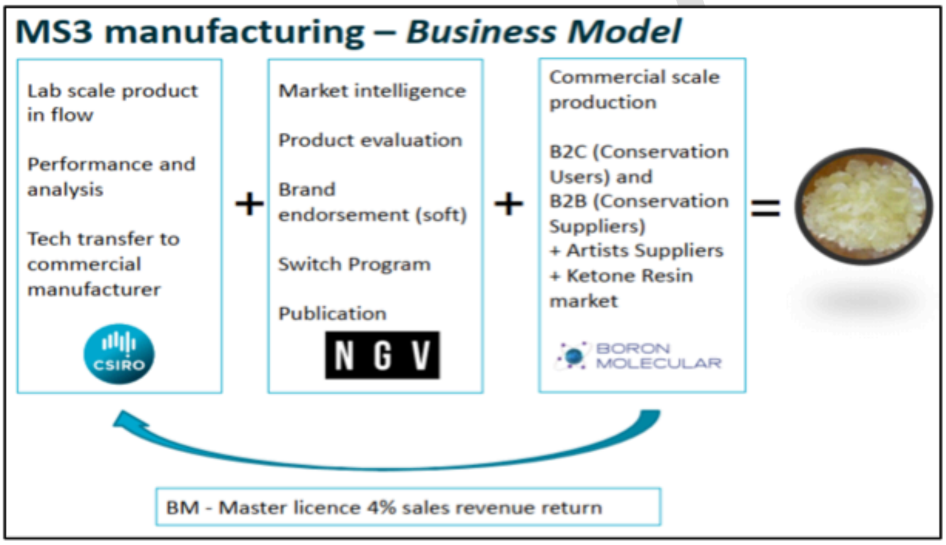


Figure 5: MS3 manufacturing business model and role of co-partners

Each partner contributed in a unique way to underpin the benefits stemming from this work. Cost share is not truly reflective of the actual attribution of each organisation towards delivering estimated benefits. To conduct a fair evaluation, NGV and Boron were contacted to gain their assessment of CSIRO's attribution:

Table 3: Co-partner assessment of CSIRO's attribution

CO-PARTNER	ASSESSMENT OF CSIRO'S ATTRIBUTION
NGV	40%
Boron	40%

The CBA in this study is conducted assuming CSIRO's attribution of 40%.

6 Evaluating the impacts

Investment objectives

- The original investment objective was to revive the chemistry of MS2A and regain access to its unique set of properties for the benefit of art conservators globally
- Post development of MS3, the investment objective was its translation and commercialisation.

Modelling approach

Quality enhancing research has become increasingly important. However, economic assessments of different kinds of research that aim to improve the desirable characteristics of a product are limited. Cost-reducing research has generally been the main focus for assessors thus far. In addition, acceptable ways to model research-induced quality improvements are not always straight-forward.

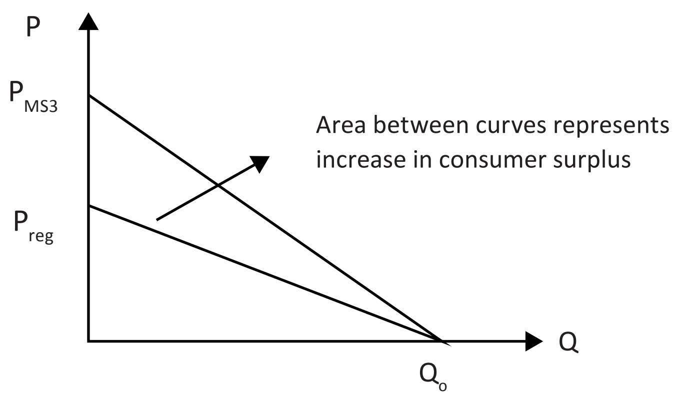
A demand curve that indicates a willingness to pay for a product or service will automatically reflect the matters that people value, such as pride, heritage value, etc. However, they are difficult to estimate separately in the absence of reliable information and data.

Potential approaches for quantifying the economic benefits from the improved quality of the MS3 varnish, compared with varnishes being used since the discontinuation of MS2A, are outlined below:

METHOD 1

One approach is to assume that cheap and low-quality commercially available varnishes will be completely replaced by MS3 because of its much-improved quality. This will cause the demand curve for varnish to pivot outwards to the right, thereby increasing the consumer surplus – the measure of economic benefit – attributable to the research and production undertaken to produce MS3. The outwards pivot of the demand curve represents an increase in quality, rather than an increase in demand.

In the current case shown in Fig. 6, the MS3 demand curve shows a higher reservation price (P_{MS3}), than the inferior options currently available in the market (P_{reg}). However, the quantity demanded (Q_o) is assumed to be the same. The indicated quantity demanded is for Australia only. Any profit – but not consumer surplus gained by foreigners – from Australian sales of MS3 overseas would be added to the overall estimated benefits.



P	Price
P_{MS3}	Reservation Price MS3
P_{reg}	Regular varnish reservation price
Q	Quantity
Q_o	Quantity Demanded (Australia only)

Fig. 6: Additional consumer surplus generated by uptake of MS3 for all commercial art conservator varnish demand (i.e., complete replacement of current varnish options)

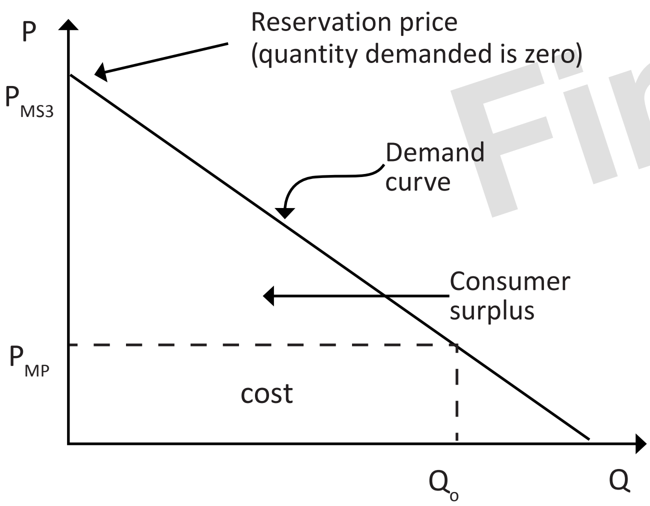
Limitations

Reservation prices and the quantity demanded by Australian conservators are needed to conduct an assessment with this approach. This information is currently unavailable.

METHOD 2

This method considers an alternative assumption that only MS2A and MS3 are suitable for <u>high-end conservation work</u>. The corollary is that the currently available commercial varnishes are inferior and would not be used at all if one of the superior varnishes (MS2A/ MS3) were available. Consequently, MS3 – a new product – will be used for conservation of all high-end work. P_{MP} represents the (constant) marginal production cost of MS3 and Q_0 - demand from Australian galleries. The area within the triangle presents consumer surplus – that is, the economic benefit to Australian conservators from having access to MS3.

The economic benefit to society beyond Australia would not be considered in the same way; but any profit from sales of MS3 overseas would be counted, as it represents benefits to Australian producers of MS3 (i.e., a producer surplus). Fig. 7 illustrates the gain in consumer surplus to Australian conservators: the triangular area below the demand curve but above the horizontal price line.



P	Price
P_{MS3}	Reservation Price MS3
P_{MP}	MS3 production cost
Q	Quantity Demanded
Q_o	Quantity Demanded (Australia only)

Figure 7: Consumer surplus generated by uptake of MS3 for all high-end artwork i.e., complete replacement of current varnish options used for high-end artwork

Limitations

- A reservation price is needed to conduct this assessment. This information is unavailable.
- MS3 production cost estimates are commercial-in-confidence and unavailable, so it is not possible to determine P_{MP}.

METHOD 3

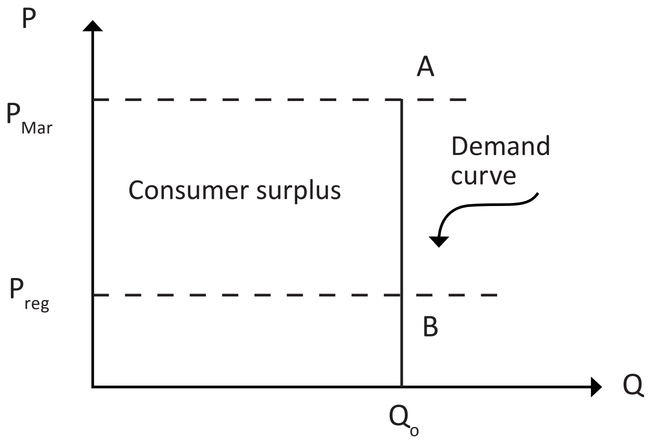
This approach assumes consumer surplus (i.e., the benefits of developing and producing MS3) created by the difference in market prices for the current inferior varnish (P_{reg}) and MS3 (P_{Mar}) which is of higher quality. It has been assumed that the quantity of varnish demand for each type is approximately the same (Q_0). Fig. 8 indicates that if the superior varnish MS3 were to become unavailable, the conservators would be forced to revert to inferior varnish products, and the loss of consumer surplus would be equal to the rectangle PMarABPreg.

A vertical demand curve is unlikely to occur in practice, but it has been assumed that demand for MS3 is highly inelastic, given the unavailability of competing varnish of similar quality and the risk-averse nature of the conservator industry. Therefore, the assumption is not entirely unrealistic.

Due to the high retail price of MS3 and low market penetration of the newly launched product, the uptake will be low in the initial years. The analysis estimates consumer surplus on the basis of the forecasted adoption rate of MS3 over the chosen time period of impact assessment (See Tables 5 and 6 below).

Limitations

- The demand curve shown in Figure 8 is an approximation. It is likely to be highly inelastic, but not vertical.
- The estimate of consumer surplus from developing and producing MS3 is an overestimate, because it includes consumer surplus that would be gained by overseas users. The consumer surplus gain to society beyond Australia is irrelevant to Australia's welfare. Only the profit made by the manufacturer Boron should be included, together with the consumer surplus gained by Australian residents.
- An implicit assumption is that MS3 and inferior varnishes will be applied with the same frequency, despite their difference in quality; that is, inferior varnishes will last as long as MS3. It has therefore been assumed that the quantity demanded per period (Q_0) of both varnishes is equal.



P	Price
P_{Mar}	Market Price MS3
P_{reg}	Regular varnish price
Q	Quantity
Q_o	Quantity Demanded

Figure 8: Consumer surplus created by difference in market prices for the current inferior varnish, and MS3 driven by better quality of the new product

METHOD 4

This method adopts a "**producer surplus**" approach that estimates the additional profit reaped by the manufacturer from the demand for, and sale of, MS3. Considering the current business environment, a profit margin of at least 10% could be assumed for Boron from the sale of MS3. Based on the sales forecast of MS3 for the assessment period, potential benefits can be estimated.

Limitations

- The approach is based upon profit margins for Boron. This information is commercial-in-confidence and unavailable.
- Due to COVID-19 there is significant uncertainty around the assumption of profit margin of 10%.

In practice, it is rare for a cost-benefit analysis to be favoured by the availability of data and information that matches a preferred analytical approach. That is the case here. Method 1 and Method 2 would have been the preferred analytical approaches, but the information available lacked critical data such as reservation prices and Boron's profit levels for overseas sales.

This current analysis adopts Method 3 as its basis for assessment. This method measures benefits in the form of the price premium that conservators across the world are willing to pay to have MS3 as the preferred varnish for their artwork. In other words, if conservators were to switch from a superior varnish like MS3 to an inferior, cheaper varnish there would be a loss of rectangular amount $P_{Mar}ABP_{reg}$ of consumer surplus. However, the area $P_{Mar}ABP_{reg}$ is an overestimate of the benefits accruing to Australian residents because it includes consumer surplus gained by foreigners. The extent of the overestimate cannot be determined on the basis of the information available.

This case study therefore highlights the importance of researchers collecting relevant information that can be used to provide a useful assessment of the benefits of their research.

Perspective and stakeholders

CSIRO is a national institution that is funded by the Commonwealth government and its work affects Australian society as a whole. A cost-benefit analysis, therefore, needs to be conducted from a national perspective. Some of the key stakeholders include art conservators, retailers, and other key players in the supply chain. However, there was insufficient information to permit a distributional analysis of the welfare gains from the research and development of MS3 to the Australian community.

Costs and Time Period

CSIRO's MS3 project started in FY2016. As the technology was commercialised in Dec 2019, the uptake of the work remains an ongoing activity. For any R&D work, there are lags between the delivery of the technology and the realisation of benefits post-adoption.

Establishing the development costs involved throughout the entire pathway from inputs to impact is an important part of any cost-benefit analysis. This includes estimating the input costs incurred by both CSIRO and its collaborators, as well as any usage and adoption costs borne by clients, external stakeholders, intermediaries, and end-users. For the MS3 project, these include costs associated with R&D, trials, and scale-up (capital and operating costs). It is estimated that CSIRO and its research partners would have contributed approximately AUD $740,000 (in FY2021 $) in real terms discounted at 7% per annum (see Table 1).

To the extent that CSIRO research was funded by the government out of increased taxation, the project would have had an adverse effect on economic activity in Australia. This deadweight loss would be a cost attributable to the MS3 project and has been included in the cost-benefit calculations.

The impact investigation covers the costs of this project for a period of FY2016 (year of inception) to FY2020. The assessment of benefits is carried out for the period of FY2020 (year of commercialisation) to FY2029.

A conservative approach is adopted where it is assumed that benefits are measured to FY2029, as conservators are a highly risk-averse cohort and are expected to use the new varnish for a much longer period. This claim is supported by use of MS2A for >50 years. This assumption is consistent with our prior assumption in the counterfactual scenario, that the development and adoption of the technology would be delayed by at least 10 years had CSIRO had not been involved in this work.

Thus the analysis involves a small ex-post component (relating to the costs and benefits in the period FY2016-FY2020), but also a large component of ex-ante analysis forecasting the benefits flowing from this work over the period FY2020 to FY2029.

Table 4: CSIRO - With and without scenarios for economic assessment

1) Scenario representing no CSIRO involvement	BENEFITS: 2) Scenario representing CSIRO's involvement
Without CSIRO	**With CSIRO**
Status-quo • Experimentation with interleaving layers of different industry resins available commercially in the absence of MS2A/other suitable varnish • Increased risk of irreversible damage to valuable artwork • Health and safety risks	**Potential benefits to 2029** • Increase in consumers' willingness to pay for the MS3 as reflected by price premiums paid for the product, due to following attributes: - superior quality and consistency of MS3. - Environmental benefits due to application of efficient flow chemistry manufacturing process (vs traditional batch operation) - ↓ health and safety risks of the varnish application process. - ↓ frequency of the asset maintenance cycle requiring reapplication of varnish - ↓ labour costs (due to lowered frequency of application) • MS3 demand • Distribution of benefits which are then passed to other players in the supply-chain.

Defining the 'with' and 'without' scenarios

This analysis is based on a mixed method approach and examines benefits from this work using both qualitative and quantitative data as discussed in the sections below.

Economic Impacts

Economic impacts usually can be expressed in dollar values, such as an increase in retail prices and sales. For the current assessment, the superior quality of MS3 has led to net benefits from the program, in the form of a higher retail price and increased demand. The two 'with and without' scenarios that form the basis of economic analysis are given in Table 4 above.

Quantification of Benefits

ASSUMPTIONS

- Of all the museums in the world, 5% are rated as the most high-profile. These museums will represent key 'high-demand customers' for MS3, due to the high value of their art assets.
- Adoption of MS3 by these high-profile museums would vary from 1%-25% for the period of 2020-2029. This provides a demand rate for the varnish and presents a conservative assumption. Based on the interviews conducted, the adoption of MS3 by high end art galleries is estimated to be likely in the vicinity of 80-85%.
- Estimates of consumer surplus from the demand of MS3 are based on 4 different demand scenarios for the selected high-profile art galleries:

  A - 0.25 kg MS3 per annum

  B - 0.50 kg MS3 per annum

  C - 0.75 kg MS3 per annum

  D - 1.0 kg MS3 per annum.

These scenarios present a conservative estimate, as based on the interviews conducted for this study, the MS3 demand rate is projected to be 2 kg/annum for the high-profile art galleries.

- In practice, MS3 would lower the required frequency of reapplication of varnish compared with other commercially available inferior options. This would result in the lowering of overall required quantities for MS3 per conservator/asset. However, for the CBA an equal demand scenario is assumed (for MS3 vs other options), due to lack of available information. Since MS3 is a new product, the magnitude of decrease in frequency is not clear at this stage.
- All costs and benefits are discounted at real discount rates of 7% per annum.
- As shown below in Table 5 and 6, the assessment considers the customer base in Australia as well as globally. Hence, the stated consumer surplus is an overestimate. However, the forecasted adoption rates as well as the annual demand have been significantly underestimated compared with estimates shared during stakeholder interviews; accordingly, there will also be some underestimation of net benefits.

Method 3 (See above for details)

The net benefits from this project in the form of additional value of MS3 is calculated as:

Project Case:

Indicative retail value1 = Market demand of MS3*(Retail Price of MS3)

Counterfactual:

Indicative retail value2 = Market demand of available conservation varnish*(Average retail price of commercially available industrial varnishes)

Net Benefits$_{MS3}$ = Indicative retail value$_{1}$ - Indicative retail value$_{2}$ = Difference in price X Quantity demanded

Consumer benefits are reflected in the form of lower asset management costs and improved confidence. The application of MS3 incurs reduced labour costs when painting treatment is undertaken. Due to slower ageing of MS3 compared with other commercial varnishes used by conservators, the overall frequency of reapplication of varnish is reduced. This saves the labour cost associated with the operation. The economic effects of all these benefits are reflected in willingness to pay higher retail price for MS3.

Table 5: Background data and approach for assessment of economic impact of MS3 program

PARAMETER	ESTIMATES	REFERENCE
Total number of museums in the world (#)	55000	World museum stats
Estimated high-profile museums in the world (%)	5	Arbitrary estimate based on NGV conservator's interview
Estimated total number of high-profile museums in the world (#)	2750	5% of (Total number of museums in the world (#))
Estimated varnish demand per high profile museum (Dn, kg/annum)	0.25 - 1	4 Scenarios assessed assuming demand of 0.25/0.5/0.75/1 kg/annum, See Table 6 Conservative estimate. Informational interviews suggest demand of 1 -2 kg/annum for high profile art galleries
MS3 Market Price (P_{Mar}, USD/kg)	2800	https://www.talasonline.com/MS3-Museum-Varnish-Resin?quantity=1&size=884
Other commercially available varnish price (P_{reg}, USD/ kg)	35	Avg of Damar and Laropal A81 price
Estimated MS3 adoption rate by high-profile museums in the world (An, %)	1-25	See Table 6 for forecasted adoption profile 1-25%: Conservative estimate Boron/ CSIRO estimate: 25% NGV estimate: - 85% adoption by high-profile art galleries globally - 40% adoption by small-mid size galleries and private conservators globally
Project case benefits (B_1, in $$)	$\sum_{n=FY2020}^{FY2029}$	P_{Mar}*Total High-Profile Museums*An*Dn
Counterfactual case benefits (B_2, in $$)	$\sum_{n=FY2020}^{FY2029}$	P_{reg}*Total High-Profile Museums*An*Dn
NET PROGRAM BENEFITS	B_1-B_2	
CSIRO's Attribution (%)	40	See Section 5
NET BENEFITS ATTRIBUTABLE TO CSIRO	(B_1-B_2)*40%	

Table 5 provides background data for the CBA. It also lists the source of information in the form of references/assumptions for the data used for CBA calculations. The forecasted adoption profile, demand, and estimated benefits for the 4 chosen scenarios are given in Table 6.

Table 6: Estimated economic benefits from MS3 work (See Table 5 above)

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
ADOPTION RATE (AN, %)	1.0%	5%	10%	15%	20%	25%	25%	25%	25%	25%
REAL DISCOUNT RATE (%)	1.07									
CSIRO'S ATTRIBUTION (%)	40									
PROJECT CASE BENEFITS (B1)	$\sum_{n=FY2020}^{FY2029}$	P_{Mar}*Total High-Profile Museums *An*Dn								
COUNTERFACTUAL CASE BENEFITS (B2)	$\sum_{n=FY2020}^{FY2029}$	P_{reg}*Total High-Profile Museums *An*Dn								

SCENARIOS	Estimated Demand (Dn, kg/annum)	Project Case B_1 (in nominal USD$)	Project Case B_1 (in FY2021 USD$)	Counterfactual Case B_2 (in nominal USD$)	Counterfactual Case B_2 (in FY2021 USD$)	Net Benefits (in FY2021 USD$)	Net Benefits (in FY2021 AUD$)[1]	BCR (without dead weight loss)[2]	BCR (with dead weight loss)[2]	Net Benefits attributable to CSIRO (in FY2021 mil AUD $)[2]	CSIRO BCR (WODWL)[2]	CSIRO BCR (WDWL)[2]
A	0.25	3388000	2473969	42350	30925	2.44	3.59	4.9	4.0	1.44	2.43	2.02
B	0.50	6776000	4947939	84700	61849	4.89	7.19	9.7	8.1	2.87	4.85	4.04
C	0.75	10164000	7421908	127050	92774	7.33	10.78	14.6	12.1	4.31	7.28	6.07
D	1.00	13552000	9895878	169400	123698	9.77	14.37	19.4	16.2	5.75	9.71	8.09

Notes

[1] AUD/USD calculated at 0.68

[2] For Costs, See Table 1 (WODWL and WDWL)

Secondary effects

1. Benefits accrue to Boron in the form of new revenue streams through the sale of MS3, and by gaining a commercially competitive edge through the implementation of cutting-edge flow chemistry technology for production of speciality chemicals. This has the potential to broaden the scope of the business and shorten the path to market.
2. Demonstration of Australia's sovereign manufacturing competitiveness in the speciality chemical industry and capability building in these new markets.
3. Other benefits to the niche art conservator community (e.g., high-profile museums) could include earnings generated by attractive artwork in the form of artists fees and sales of work, and visitor expenditure on food, accommodation, services, and retail purchases.
4. There is insufficient data to determine outcomes such as direct and indirect employment.
   It should be noted that any additional employment (typically stated as 'jobs created') is not an economic benefit. Just as for any other resource, use of additional labour resources imposes an opportunity cost on Australian society, because those workers cannot be used elsewhere to produce goods or services. In addition, some workers will simply transfer from other jobs (potentially including from CSIRO positions), so the net creation of jobs will be zero. Those workers who are employed in new positions will obtain a wage, but the cost of the wage is borne by employers, so the net benefit to society is zero, except for any additional profit (producer surplus) that is generated.
   Nevertheless, estimates of job creation opportunities are generally of interest to decision-makers, especially in cases of high unemployment rates involving skilled professionals. Normally these can be reported separately from the cost-benefit analysis to provide a comprehensive outline of expected impacts (for more details see Appendix D).

Social Impacts

As stated, MS3 development was undertaken with an intent to resolve a glaring issue for art conservators across the world created by the disappearance of MS2A.The social benefits of a high-quality/low-scale product for a niche market automatically valued in benefit cost analysis through willingness to pay should not be counted again. Nonetheless, it can be useful to identify them separately. These are listed separately to provide better clarity.

Potential social impacts from MS3 project include:

1. **Management of risk and uncertainty**: MS3 development is recognised as the revival of a significant tool of which the art conservator community had been deprived. Available access and ease of using a superior varnish that brings together all the desired properties has generated a renewed level of confidence within the community. Management of risk and uncertainty is an impact of utmost importance from this work. The varnish has received highly positive feedback from art conservators across the world.
   The NGV highlights MS3's potential uptake of >85% by high-profile art galleries across the world despite its current pricing.
2. **Culture and heritage**: Preservation of cultural heritage in the form of historical resources for technical and art historical studies owned by private and public collections across the world fosters community pride. The intrinsic impact is derived through the rejuvenation of artwork as a means of feeling social integration, aesthetic development, encouraging a strong community identity, and creative and cognitive stimulation.
3. **Health and Wellbeing**
   - Most of the current commercially available varnishes need to be mixed with carcinogenic solvents for application. Due to faster ageing, the frequency of application is relatively higher. MS3 does not require the usage of toxic solvents, which greatly improves the safety of the process
   - Social and cultural benefits that are accrued to the users, staff, volunteers, and funders of the local museums. Individual and community social benefits include networking, quality of life, interaction, etc.
   - With museums being an important part of social capital, the adoption of MS3 helps the institutions achieve social benefits in the form of mental health and social well being
   - Museums develop an appreciation of place and culture, and community pride, as well as preserving heritage, and providing opportunities for learning across all age levels.
4. **Innovation and human capital**: Benefits from the lower economic and environmental footprint of continuous flow chemistry production operation, which also offers potential opportunities for uptake of the technology for other speciality chemicals and industries.

7 Sensitivity analysis

The CBA is necessarily based on a series of assumptions which imparts a degree of uncertainty around the results. Sensitivity testing has been conducted to clarify which assumptions can materially change the results. The assessment has been undertaken on the following key parameters:

- Discount rate: Analysis in Section 6 is based on the real discount rate of 7%. Sensitivity test results are provided for real discount rates of 4% (lower) and 10% (higher)
- Changes in adoption rate: The forecasted base adoption profile is given in Table 6. To perform sensitivity analysis, two cases have been tested – estimating benefits at adoption rates (i) (-)5%; and (ii) (+)5% for every year vs the base profile. For cases where the adoption rate becomes negative (e.g., FY2020), it has been assumed as 0%
- Changes in CSIRO's attribution: Base CBA calculations have been conducted with CSIRO's attribution as 40%. To conduct sensitivity analysis, two cases with 20% (lower) and 60% (higher) attribution have been tested.

The results of the sensitivity analysis are provided in Table 7.

It is important to note that overall benefits from any research work depend crucially on the achievement of the forecasted adoption profile. The current assessment lacks benchmark data and there is currently no organisation measuring the adoption profile of MS3 for the ex-post or ex-ante period. This data is critical to measure, monitor, and project the overall impacts generated by the work. Consequently, there is considerable variability in the reported results for the BCRs due to the wide range of assumed inputs employed in the model, as well as the lack of reliable benchmark data.

Table 7: Sensitivity Test results (Overall). All values are given as range for Scenario A-D as defined in Table 6

	Overall BCR		
Variable	**Without deadweight loss**	**With deadweight loss**	**Overall NPV** (in mil AUD FY2021$)
REAL DISCOUNT RATE			
No change (7%)	4.9-19.4	4.0-16.2	3.6-14.4
4%	5.9-23.6	4.9-19.6	4.1-16.4
10%	4.0-16.2	3.4-13.5	3.2-12.7
ADOPTION RATE (EX-POST)			
No Change (See adoption rate assumed in Table 6)	4.9-19.4	4.0-16.2	3.6-14.4
Decrease of 5% / year wrt base Adoption rate assumed in Table 6	3.5-14.0	2.9-11.7	2.6-10.4
Increase of 5% / year wrt base Adoption rate assumed in Table 6	6.4-25.5	5.3-21.2	4.7-18.9

Table 8: Sensitivity Test results (CSIRO). All values given as range for Scenario A-D as defined in Table 6

	CSIRO BCR		
Variable	**Without deadweight loss**	**With deadweight loss**	**CSIRO NPV** (in mil AUD FY2021$)
CSIRO'S ATTRIBUTION			
No change (40%)	2.4-9.7	2.0-8.1	1.44-5.75
20%	1.2-4.9	1.01-4.04	0.7-2.9
60%	3.6-14.6	3.03-12.13	2.2-8.6

8 Confidence rating in impact assessment

The MS3 project is aspirational with the potential to address a significant gap in the art conservator industry. As discussed earlier in the report, due to inherent unpredictability of the future, combined with the longer-term time frames of the suggested transition – and the unique challenges posed by COVID-19 – result in the confidence rating in the benefits reported for this impact assessment being rated as medium – low. As CSIRO's research progresses, the current study should be revisited and refined, drawing on more detailed evidence to provide greater insights to enable improved decision-making.

Appendix A: **Alternative commercial industry grade varnishes**

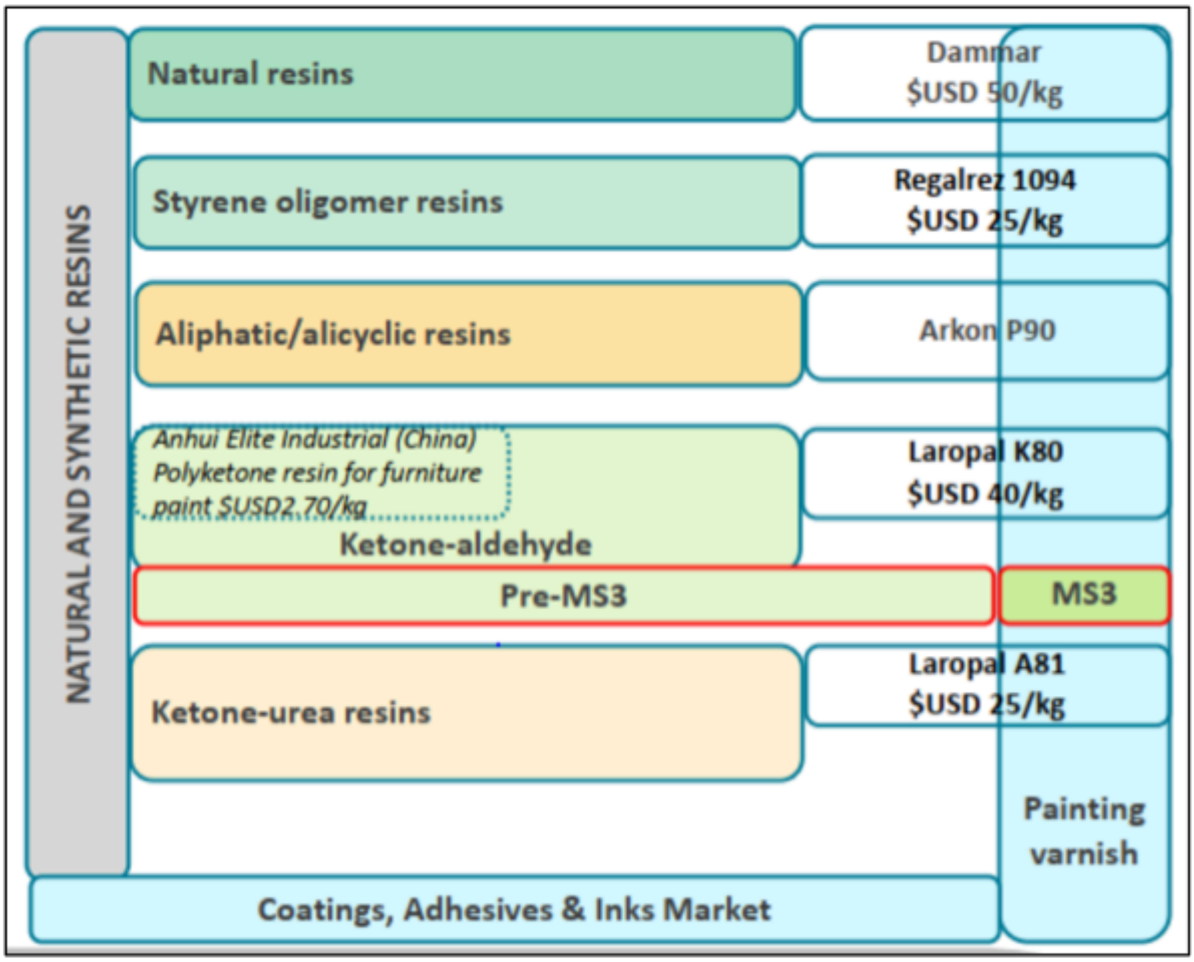


Figure 9: Alternative commercially available varnishes

Appendix B: **MS3 market segments**

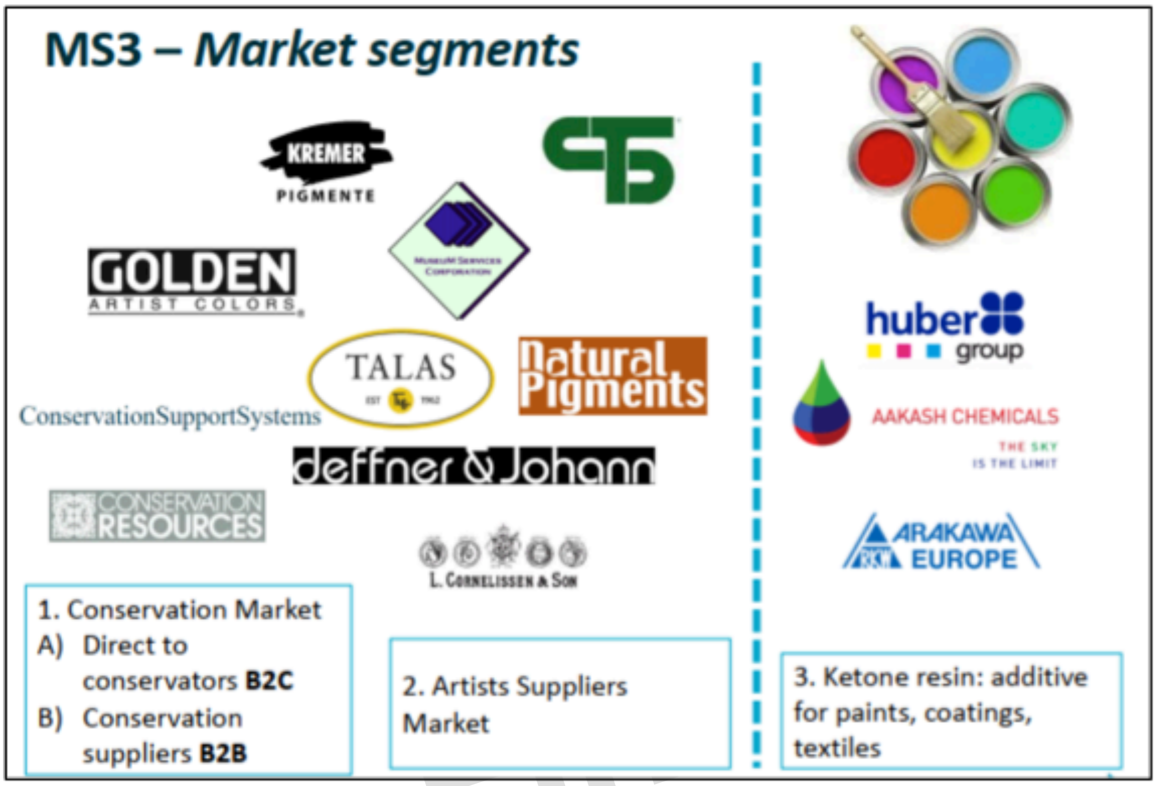


Figure 10: MS3 Market Segments

Appendix C: **References**

1. Radosław Chocha: Recollections of a career in conservation – an interview with tutor and mentor Mary Kempski; The Picture Restorer, No. 55 Autumn 2019, p.17.
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5. Australia Museums: Statistical overview
6. https://crawford.anu.edu.au/people/visitors/leo-dobes
7. https://www.talasonline.com/MS3-Museum-Varnish-Resin?quantity=1&size=884
8. https://issuu.com/norma29/docs/talascatalog/140

Appendix D: **Employment contributions**[3]

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

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

Taxes have a depressive effect on the economy by reducing aggregate demand and/or output. They, therefore, reduce job opportunities and profits. To the extent that the MS3 project is funded by CSIRO and other funding sources through government taxation, there will be some potential loss of jobs in the economy. In other words, it cannot be claimed without qualification that there will be a straightforward increase in employment levels attributable to the project.

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