REPORT

Evaluation of CSIRO's collaboration with CBG Systems

Prepared for
Commonwealth Scientific and Industrial Research Organisation (CSIRO)

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Contents

BOXES, CHARTS AND TABLES

Summary

CSIROs HIPS2 technology delivers a positive net benefit and represents a major success in CSIROs collaboration with industry

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) has created a game-changing patented polymer technology called HIPS2 (the 2nd version of its Hybrid Inorganic Polymer System). The technology was employed as part of a collaboration with CBG Systems (CBG), a Hobart based manufacturer, which allowed CBG to create its next generation fire-retardant panel Rapid Access Composite (RAC) Plus, appropriate for conventional steel ships (SOLAS Ships) and aluminium high speed crafts (HSC vessels). This offers CBG significant scale up opportunities for the business, which had previously been limited to a niche part of the market. The RAC Plus panels, underpinned by CSIRO's HIPS2 technology, are suitable for ships in the largest segment of the shipping market and offer improved ship performance, and more cost effective compliance with mandatory fire safety standards.

Prior to its association with the CSIRO, CBG's fire-retardant panel (the original RAC) expanded when subjected to fire due to an intumescent layer that expands as part of its fire retardancy mechanism. This expansion means it cannot be used on conventional steel ships and is not desirable on Navy ships. RAC panels also do not pass the pre-requisite standard for IMO FTP 2010 Part 3, the sub-standard: ISO 1182, due to the expansion of the intumescent layer in a fire.

CBGs original RAC product was therefore limited to selling into non-steel ship markets, where its panels are used by around 90 per cent of high-speed aluminium ferries.

Prior to the CSIRO-CBG collaboration, CSIRO had a legacy technology called Hybrid Inorganic Polymer System (HIPS), that had achieved no commercial applications. This HIPS technology was a fire-retardant polymer coating that was mostly inorganic, with a small amount of organic material. CSIRO had previously attempted to improve HIPS and develop applications by changing the organic component of the substance, including by adding polyimide and phenolic organics, but with no success. At the start of this project, CSIRO was seeking to improve HIPS by adding an organic epoxy.

CBG discovered the work of the CSIRO research team (using a Google search), and following a period of engagement and exploration, commissioned the team to improve its HIPS material and develop a prototype for a new fire-retardant panel suitable for the steel ships market.

Impact pathway shows success in meeting project goals

The objectives of the HIPS2 project were to deliver three key outcomes for CBG:

- developing HIPS2, which was to be an improvement on HIPS1 such that the corrosive properties of HIPS1 were significantly reduced
- incorporating HIPS2 and other inputs provided by CBG into a prototype for a new fire-retardant panel that is demonstrated to be superior to CBG's existing RAC panel in terms of:
  – retaining the fire-retardancy properties of the RAC panel (or improving on this)
  – not expanding when heated (making it potentially desirable for navy vessels),
  – able to be rated A60 under standard IMO FTP 2010 Part 3 (making it suitable for conventional steel ships), and
- demonstrating that CBG would be able to practically implement CSIROs solutions and manufacture and market the new panel on a commercial basis.

CSIRO is estimated to have invested $356 000 in the HIPS2 project, measured in net present value (NPV) terms.[1]

CSIRO activities on the HIPS2 project included those that involved the application of science skills, and those that related to collaboration with CBG. Activities relating to science skills include those undertaken to develop unique and novel products (HIPS2 and then a prototype for a new fire-retardant panel), based on a deep understanding of the scientific principles of inorganic and organic polymers and fire-retardancy. Collaboration-based activities are those involving the tailoring of outputs to meeting the needs of CBG.

CSIRO researchers were able to demonstrate that HIPS2 retains the fire-retardancy properties of the original HIPS1 coating and, after curing, forms a structure that contributes to the structural integrity of the fire-retardant panels that it forms a part of.

In early demonstrations, the prototype fire-retardant panels made with HIPS2 technology were found to *not* expand when subject to fire. CSIRO also successfully conducted a 'pilot manufacturing run' at CBG facilities. In this pilot, existing equipment at CBG was used to make the panels, and no special steps were required on account of corrosive material. This meant that while HIPS2 retained some (lower) amount of corrosiveness, this was not significantly problematic (in contrast to HIPS1 and other similar materials). While the research failed to pass the second 'furnace test', it was sufficiently advanced for CBG to use the HIPS2 technology to underpin the very strong performance of the final panels it developed for market (RAC Plus), which achieved the standard CBG required. CBG note that if HIPS2 is removed from the RAC Plus panels, the overall performance drops by around half, and the panel would not be fit for purpose.

The final impact of the RAC Plus fire-retardant panels is an improvement in the performance and profitability of the ships where these panels are installed, relative to using the existing, heavy blanket based passive fire-retarding systems. The panels boost

1 'Net present value terms' is standard technique in economic evaluations. It means we use an interest rate (here: 7 per cent, consistent with recommendations from the Office of Best Practice Regulation in Canberra) to discount streams of benefits and costs that are incurred after the first year of the project (in this case 2017).

ship profitability because they are relatively inexpensive to install and lightweight, which means the ship performs better.

The total revenue that ship owners provide to CBG when they purchase RAC Plus panels is a data point that allows us to measure the size of this total financial impact, as it is an indicator of the value that ship owners place on it. The share of this value that can be attributed to CSIRO's inputs is measured as the revenue share that is allocated to CSIRO by CBG under the terms of the licence agreement: that being 2 per cent.

Economic impact of CSIROs contribution

CSIRO has enabled CBG systems to bring a unique product to market that improves the efficiency of ships, and the cost effectiveness of complying with shipping regulations to manage fire safety.

Very conservatively estimated, the value of final outcomes that can be attributed to CSIRO are valued at $724 000 in NPV terms. This is based on the NPV of forecast licence fee payments from CBG to CSIRO up to 2026.

CSIRO contributed costs of $356 000 in NPV terms for the HIPS2 project.

Hence, the net benefit or impact created by CSIRO researchers is $368 000 in NPV terms, with an implied benefit-cost ratio of 2.0.

The project is considered to be particularly successful due to the agility shown by the CSIRO team in deploying scientific knowledge to a new problem, and the effort undertaken to collaborate with industry and ensure its outputs solved problems that faced CBG, generating outcomes that were valued by its customers.

1 Net benefit created by or net impact attributable to CSIRO (NPV terms)

	$ 000
Incremental costs	-356
Incremental benefits	724
Net benefit or net impact	368
Benefit cost ratio	*2*

Note: 7 per cent discount rate, 10 year horizon

Source: The CIE

1 Introduction

Demand for fire retardant panels

Ship fires are an infrequent phenomenon, but are costly when they occur. In 2017, fires caused the loss of six international merchant ships (0.012 per cent of the stock of 50 000 international merchant ships). While relatively small in number, of the ten largest ships lost in 2017, three were caused by fire. In one case, the fire caused the ship to be lost with at least five fatalities. In the other two, the fire was extinguished but both ships were towed and needed to be sold for break-up.

The phenomenon of ship fires mean that shipping regulations require ships to have active fire protection systems (such as sprinklers) and passive fire protection systems (such as profile-wrap blankets, panels, etc.). The purpose of passive protection systems is to contain fires for a certain period of time so that evacuations can occur and allow time for the active fire system to extinguish and/or control the fire.

The traditional system for passive fire protection is to install profile-wrap blankets within the walls of ships, which wrap around areas where a fire may need to be contained (engine rooms, vehicle decks on ferries, etc.) These blankets are relatively heavy (around 3.5 square metres of blanket is required to wrap and protect 1 square metre of wall), reducing the performance of the ship. They are also costly to install because coordination is required with other trades during construction to fit them properly within walls.

In recent decades, manufacturers, including CBG (a Hobart based manufacturer of passive fire protection systems and other shipping equipment) have developed fire-retardant panels that can be installed as the passive fire protection system.

These panels are much easier and cheaper to install, as they can be fitted on the surfaces of walls in ships. Innovation in fire retardant panels has seen their weight drop substantially, improving the performance and profitability of the ship for the owner. For example, over 25 years, the weight per square metre of CBG's panels has halved, from around 12 kg per square metre to between 5-6 kg per square metre. Where they can be installed, fire-retardant panels are now the most efficient, profitable solution for ship-owners.

Substantial opportunity for innovation and development

Conventional steel ships have relatively heavy passive fire systems

Most new ships being constructed are steel ships (the largest part of the market). To be appropriate for steel ships, a passive fire protection system must be rated A60 under the standard IMO FTP 2010 Part 3, which means that when it is used to encase a furnace (in testing), and the furnace is set at 1000^{o}C, the outside must remain under 140^{o}C for 60 minutes. This means that in a fire, the structural integrity of the steel ship will remain intact for 60 minutes allowing an evacuation to occur over at least this time period.

Because IMO FTP 2010 Part 3 is an onerous standard (which manufacturers of panels have struggled to meet) and because steel ships are very heavy, all steel ships to date have been fitted with the heavy blanket passive fire protection systems within their walls.

However, increasing commercial pressure has prompted owners of conventional steel ships to become interested in alternatives to the heavy, costly-to-install, blanket fire-protection systems.

CBG's original product was unable to service the steel ships market

Prior to its association with the CSIRO, CBG's fire-retardant panel — Rapid Access Composite (RAC) — expanded when subjected to fire due to a intumescent layer that expands as part of its fire retardancy mechanism. This expansion means it cannot be used on conventional steel ships and is not desirable on Navy ships.

In fact, RAC panels do not pass the pre-requisite standard for IMO FTP 2010 Part 3, the sub-standard: ISO 1182, due to the expansion of the intumescent layer in a fire, making them unsuitable for conventional steel ships.[2] Also, Navies generally do not purchase fire retardant panels that contain intumescence because their tendency to expand marks them a frail or an inelegant solution.

CBGs original RAC product was therefore limited to selling into small non-steel ship markets, where it has been internationally successful. Its RAC panel is used by around 90 per cent of high-speed aluminium ferries worldwide due to its competitive advantages. Compared to other products it is lightweight, easy and quick to install, and can be uninstalled, flipped around and reinstalled on the other side to prolong service life. The ability to uninstall and reinstall, with two usable sides, is a feature of CBG products.

Despite its niche market success, high-speed ferries represent less than 1 per cent of the total market for new ship construction each year.

CBG's pre-CSIRO attempt to innovate for the broader shipping market

To expand into the larger ship market, CBG needed to innovate and conceived a new panel with three essential layers:

2 To pass ISO 1182:2010, RAC (and any other product) must be determined to be non-combustible, using a specified test methodology. This test methodology must be performed under specified conditions, and applies to homogeneous products and substantial components of non-homogeneous products. The instrumentation required for this test methodology does not accommodate the expansion of intumescent material in RAC. As the intumescent material expands during the test, it actually breaks the instrumentation, which means the test delivers invalid results, which in turn means it is unable to demonstrate whether RAC panels satisfy the non-combustibility criteria. As the standard is 'black and white', the RAC panel fails.

1 an outer layer, manufactured by 3M, that has aesthetic and water-proofing properties
2 a middle layer, made from a new product or substance, to add to the fire-retardancy and insulation properties, and
3 an inner layer, made from board supplied by a company in the United States, which provides insulation.

CBG launched a global search for the right product for the middle layer.[3]

CBG initially believed that using a purely inorganic polymer coating with fire-retardant properties could be the right material for the middle layer of its new panel. These products aim to protect materials from ignition in a fire, but do not improve the structure of the material or create benefits in other ways. These polymer coating products are reasonably standard, well understood products.[4] Therefore, CBG engaged a French company to develop a version of this type of coating for its panel.

Despite investing significant funds in the project with the French company, CBG rejected the solution of an inorganic polymer coating because inorganic polymers are highly alkaline and therefore corrosive. Had a highly corrosive material been used, CBG would have needed to take expensive measures during the manufacturing process to limit negative impacts on employee health and the degradation of equipment. The final panel would also have been less saleable, because the corrosive middle layer would have degraded the other layers, meaning the panel would need to be replaced more frequently.

CSIROs initial Hybrid Inorganic Polymer System

Prior to the CSIRO-CBG collaboration, CSIRO had a legacy technology called Hybrid Inorganic Polymer System (HIPS). HIPS was a fire-retardant polymer coating, similar to the French product initially tried by CBG, made up of Aluminium (Al), Oxygen (O) and Silicon (Si) atoms. Its structure can be described as 'barbed wire' – long strings of material, where Al, O and Si form the 'barbs'. Similar to the French product, it was corrosive. It was a mostly an inorganic product, with a small amount of organic material.

At the time, HIPS had achieved no prior commercial applications.[5]

A mooted area for future development of HIPS was polymer products that, in addition to providing fire-retardancy properties, also provided additional structural properties to the material it is incorporated into (that is, polymer products that go beyond coatings).[6]

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3 For example, in the final product CBG developed: RAC Plus, which includes a CSIRO's technology for the middle layer, CBG note the fire-retardancy properties of the new panel drops by halve if CSIRO's middle layer is removed.

4 Morgan 2018, *The Future of Flame Retardant Polymers – Unmet Needs and Likely New Approaches,* Polymer Reviews, 14 May 2018

5 Around a decade ago, CSIRO and partners tried HIPS as a coating in two applications: for electrical wiring in the Brisbane airport and for weatherboard applications, but these efforts did not result in a commercial product being developed.

6 Morgan 2018, op. cit.

CSIRO scientists were trying to improve the performance of the mostly inorganic HIPS material by adding an alternate organic material (specifically: an epoxy), and develop new commercial applications. Partially, this was driven by internal restructuring which resulted in staff moving from a section focusing on organic material into the section containing the inorganic HIPS technology.

CSIRO-CBG collaboration on HIPS2

Following the failure of the French product, CBG contacted CSIRO after they discovered a publication (using a Google search) that confirmed that CSIRO were trying to improve their inorganic HIPS technology.

CBG commissioned CSIRO to improve its HIPS material and develop a prototype for a new fire-retardant panel, using other inputs provided by CBG. Referred to as HIPS2, this is the project that is evaluated in this report.[7]

Data sources for this evaluation

The key data sources for this evaluation are multiple consultations with the CEO of CBG, CSIRO scientists and CSIRO business development staff, as well as reports and other documents prepared by CSIRO. The CIE sincerely thanks these stakeholders for their time.

[7] For the purposes of this impact evaluation, the original HIPS technology is referred to as HIPS1 from hereon.

2 Impact pathway for HIPS2

The objectives of the HIPS2 project were to deliver three key outcomes for CBG:

- developing HIPS2, which was to be an improvement on HIPS1 such that the corrosive properties of HIPS1 were significantly reduced
- incorporating HIPS2 and other inputs provided by CBG into a prototype for a new fire-retardant panel that is demonstrated to be superior to CBG's existing RAC panel in terms of:
  - at least retaining the fire-retardancy properties of the RAC panel,
  - not expanding when heated (making it potentially desirable for navy vessels),
  - able to be rated A60 under standard IMO FTP 2010 Part 3 (making it suitable for conventional steel ships),
  - not exceeding 5.5kg per m2
  - should be hydrophobic
  - should have same structural strength as CBG's RAC panel
  - not to exceed thickness of 20mm
  - should be a maximum size of 2400mm x 1200mm, and
- demonstrating that CBG would be able to practically implement CSIROs solutions and manufacture and market the new panel on a commercial basis.

CSIRO project stages

CSIRO's project involved 4 stages (table 2.1).

2.1 Steps taken by CSIRO in this project

Stages of project	Steps taken by CSIRO
Stage 1: initial testing, demonstration and consultation	Initial development and testing of improvements to HIPS1 to create HIPS2 and early demonstration to CBG
Stage 2: experimentation to refine HIPS2 and demonstrate practicality	Use experimentation to develop a preferred specification of HIPS2 Make prototype fire-retardant panels with HIPS2 and demonstrate durability, performance in a furnace test and superiority to existing RAC panel Pilot manufacturing run at CBG to demonstrate that using HIPS2 to make new fire-retardant panels is a feasible, potentially commercial solution
Stage 3: specific improvements to HIPS2 for CBG	Further development of formula for HIPS2 to increase future expected returns to CBG (lower costs, extend potential life, protect CBG's IP, etc.)
Stage 4: help develop a new manufacturing facility	CSIRO staff member is seconded to CBG to help establish new manufacturing facility

Source: The CIE

Inputs

CSIRO is estimated to have invested $356 000 in the HIPS2 project, measured in net present value (NPV) terms.[8] These costs were incurred by CSIRO between 2017 and 2019.

Labour inputs

CSIRO provides its staff to the project, and provided access to the use of materials and equipment to conduct research and experiments.

To develop HIPS2 prototype fire-retardant panels and other outputs, CSIRO staff conducted research and experiments, analysed and developed results, consulted with CBG, produced reports that documented their work, and performed administrative tasks (including required supervision of researchers). These are the incremental costs incurred as a result of the decision to undertake this project. Living expenses were also incurred for one staff member during the secondment phase of the project.

Cost of labour inputs

CSIRO note the total cost it incurred for this project is the time of CSIRO researchers, multiplied by the rate $15 000 per month, which it quoted to CBG for the project.[9] This rate covers the labour costs of the researchers, plus additional costs required to facilitate

8 'Net present value terms' is standard technique in economic evaluations. It means we use an interest rate (here: 7 per cent, consistent with recommendations from the Office of Best Practice Regulation in Canberra) to discount streams of benefits and costs that are incurred after the first year of the project (in this case 2017).

9 The secondment agreement between CSIRO and CBG quotes a rate for CSIRO services of $60 000 (total cost) for 4 months work, or $15 000 per month

research, including costs associated with laboratory inputs and equipment, development and experimentation, reporting and administrative/supervision fees.

Quantity and value of inputs

CSIRO has estimated the labour costs of its research staff for each stage of the project, which have been multiplied by the noted cost rate to estimate total input costs (table 2.2). These input costs are estimated at $349 000 in NPV terms.

2.2 Costs CSIRO incurs as a result of its decision to collaborate with CBG

Project stage	Effective number of CSIRO research staff at work	Time-period of work	Quantity of labour inputs	Cost of input [a]	Year costs incurred
	Number	*Months*	*Months*	*$ 000*	
Stage 1	1	3.5	3.5	53	2017
Stage 2	1.5	6	9	135	2017
Stage 3	1	6.5	6.5	98	2018
Stage 4	1	4	4	60	2019
Stage 4 living expenses				20	2019
Total costs				365	2017-2019
Total costs, NPV terms	-	-	-	349	-

[a] Cost of input is quantity of research labour inputs multiplied by the rate of $15 000 per month; as noted this includes labour costs and other associated costs (experiments and materials, administration, etc.)

Source: The CIE estimates from CSIRO supplied data

Patent costs

We estimate CSIRO incurred total costs of around $7 000 in NPV terms to maintain patents on HIPS2 in USA, Australia and New Zealand in 2017 and 2018.[10]

Summary of costs for included inputs

Total costs sum to $356 000 in NPV terms.

10 The annual cost is around $3 700, estimated from rates noted in the licence agreement with CBG. Also see: https://patents.google.com/patent/US7771686B2/en. From 2019 these costs are transferred to CBG, under the terms of the licence agreement.

2.3 Total costs incurred by CSIRO for this project, NPV terms

Costs	Cost ($ 000)
Research project costs (labour, materials, equipment, etc., plus living expenses for secondee)	349
Patent costs	7
Sum, NPV terms (7 per cent discount rate)	356

Note: In this report we use discount rate of 7 per cent to estimate NPV values. These NPV calculations effectively place everything back in 2017 dollars

Source: The CIE

Other inputs that are not included

We have excluded the opportunity cost of the CSIRO laboratories (the physical capital of the laboratories, and the land they are on). These physical assets would have been retained by CSIRO regardless of the decision to participate in this collaboration.

Activities undertaken

CSIRO activities on the HIPS2 project included those that involved the application of science skills, and those that related to collaboration with CBG. Activities relating to science skills include those undertaken to develop unique and novel products (HIPS2 and then a prototype for a new fire-retardant panel), based on a deep understanding of the scientific principles of inorganic and organic polymers and fire-retardancy. Collaboration-based activities are those involving the tailoring of outputs to meeting the needs of CBG. These activity-types were applied at different stages of the project (table 2.4).

2.4 CSIRO activities by project stage

Project stage	Skills	Specific activities undertaken
Stage 1	Science	CSIRO puts organic epoxy material into mostly inorganic HIPS1 to try to improve its properties, and create HIPS2
	Collaboration	Early demonstration to CBG, which allows for crucial early feedback and development ideas, on the basis of CBG's business acumen and lessons learnt from the failed French project
Stage 2	Science	▪ CSIRO creates two alternative formulations of HIPS2, and uses these to make prototype fire-retardant panels ▪ Experimentation is used to demonstrate its prototype fire retardant panels that use HIPS2 are durable, high performing, and superior to existing RAC panels; the 2nd alternative formulation for HIPS2 is selected
	Collaboration	CSIRO performs a 'pilot manufacturing run' at CBG where it demonstrates HIPS2 is not corrosive and existing CBG equipment can be used to make HIPS2 and the new prototype fire retardant panels from scratch
Stage 3	Collaboration	▪ CSIRO get better quotes for HIPS2 inputs and ensure all are commercially available ▪ CSIRO makes changes to HIPS2 to increase its pot life, making the future manufacturing process easier, and adds masking agents to protect CBG's future IP
Stage 4	Collaboration	A CSIRO staff member, working as a secondee at CBG, helps CBG to set up its new manufacturing facilities

Source: The CIE, summarised from CSIRO project documents and discussions with CSIRO

Creation of HIPS2 (by improving HIPS1)

The key innovation made by CSIRO to create HIPS2 is the addition of a small amount of an organic, epoxy substance to the mostly inorganic structure of HIPS1. HIPS1 was designed to act as a fire-retardant coating that had properties broadly consistent with other existing commercial products. To the mostly inorganic polymer structure of HIPS1, the addition of the organic epoxy adds 'cross-pieces' to the 'barbed-wire strings' of HIPS1, which creates HIPS2. These cross pieces give HIPS2 a unique structure and characteristics.

CSIRO outputs

A unique product HIPS2 and panels that partially achieve CBG's goals

HIPS2 retains the fire-retardancy properties of the original HIPS1 coating and, after curing, forms a structure that contributes to the structural integrity of the fire-retardant panels that it forms a part of. These new structural properties of HIPS2 are delivered by the 'cross-pieces' created by the epoxy that was added to the original HIPS1 material, as a replacement for the existing organic material in the product, and were demonstrated by the results of experiments for stage 2 of this project. These results showed that the measured impact strength and flexural strength of the prototype fire-retardant panels change as different formulations of HIPS2 are used, which means the HIPS2 component is contributing to the strength of the panels. In early demonstrations, the prototype fire-retardant panels made with HIPS2 technology were found to *not* expand when subject to fire, solving a key problem for CBG.

CSIRO also delivered on other required objectives for the project by successfully conducting a 'pilot manufacturing run' at CBG facilities in stage 2. In this pilot, CSIRO demonstrated the HIPS2 substance was substantially not corrosive, as existing equipment at CBG could be used to make the panels and no special steps were required on account of corrosive material.[11]

This reduction in corrosive properties was a result of the addition of the epoxy (the organic component). Further, by using equipment at CBG to manufacture HIPS2 and then prototype panels from scratch, CSIRO demonstrated its solution is an implementable, potentially commercial proposition.

CSIRO partially delivered on CBG's ultimate goal of new fire-retardant panels that are appropriate for steel ships. The second 'furnace test' conducted by CSIRO in stage 2 shows the outside of prototype panels made with HIPS2 reach around 250°C when the furnace they enclose reaches 900°C after one hour.[12] While encouraging, this was inferior to what CBG required and subsequently achieved.

CBG used the HIPS2 technology to underpin the very strong performance of the final panels it developed for market (RAC Plus, which achieved the standard CBG required). CBG note that if HIPS2 is removed from the RAC Plus panels, the overall performance drops by around half, and the panel would not be fit for purpose.

CBG further note that it is not aware of any substance that is similar to HIPS2 or any other substance that could deliver what HIPS2 delivers for the fire-retardant panels it has developed in this project. It also notes that it could not have obtained the HIPS2 technology by recruiting the relevant CSIRO staff members and paying them to develop this technology 'in-house', making the CSIRO collaboration a necessary condition for project success.

Other benefits/strengths of CSIRO's prototype panels

In stage 2, CSIRO demonstrated that prototype fire-retardant panels made with HIPS2 are likely to be durable by demonstrating their performance under exaggerated conditions, including: a flexural strength test after boiling and appearance/inspection tests after fog room exposure, high temperature/humidity exposure, environmental chamber, salt solution immersion, outdoor weather exposure, salt spray chamber and UV exposure.[13] CSIRO conclude from these tests that there are no detrimental signs of laminate deterioration for both [HIPS2] candidate formulations 1 and 2 when subject to harsh accelerated conditions such as high temperature, high humidity, UV exposure and

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11 While some corrosive elements of the underlying inorganic polymer remained, these were demonstrated to be not problematic in the way they were for a purely inorganic polymer

12 CSIRO 2018, Dell'Olio M., Sago-Crenstil K., Shapio G., Yan S., *Structural Fire Protection Composite System for Marine Platforms,* Report for CBG Systems, January 2018, p. 67.

13 CSIRO 2018, Dell'Olio M., Sago-Crenstil K., Shapio G., Yan S., op. cit.

saline saturated environments. It also notes that formulation 2 tends to display better resistance to efflorescence than formulation 1 under high humidity environments[14]. Formulation 2 was selected for HIPS.

These test results are another important output of the project, as they indicate the durability of the new panels. Indeed, these results are used by CBG in promotional material for the RAC Plus panel it developed.[15]

In stage 2, CSIRO demonstrated that prototype panels made with HIPS2 are superior to CBG's original RAC panel.[16] In particular, that prototype panels made with HIPS2:

- suffer less impact damage from a dart than RAC panels. Meaning they should suffer less wear and tear when installed on ships, and appear more 'ship-shape' for longer
- have superior (that is, lower) heat transfer properties than RAC panels — in the furnace test, the reverse side of the HIPS2 panel becomes far less hot than the reverse side of a RAC panel, and
- suffer little damage in the salt spray durability test — the existing RAC panel begins to corrode (degrade) in this test.

It is not clear whether CSIRO delivered on CBG's goals to ensure the panel did not exceed 5.5kg per m2, was hydrophobic, did not to exceed total 20mm thickness, and had a maximum size of 2400mm x 1200mm. Any comparison in terms of flexural strength between the prototype fire-retardant panels and the existing RAC panel was not documented, and it is assumed that these goals would likely have been achieved by CBG in its refinements after CSIRO's involvement.

Additional support for future commercialisation

CSIRO have provided CBG with exclusive use, under a licence agreement, of the HIPS2 technology to manufacture fire retardant panels. This exclusive use is an important underpinning of the commercial returns that CBG can expect to earn from its new RAC Plus panels which use the HIPS2 technology, making it an important output of the project.

To protect CBG's commercial returns, CSIRO have also:

1. limited the ability of third parties to uncover CBG's intellectual property with 'reverse engineering' (by adding a masking agent to the HIPS2 formula)
2. acted to lower CBG's mixing costs for HIPS2 (and/or created more flexibility for CBG during manufacturing shifts) by extending its pot life from a short time to around 6 hours. This means CBG does not have to continuously remix batches throughout a manufacturing shift. This was achieved with a small adjustment to the formula for HIPS2, and

14 Ibid, p. 60.

15 CBG Systems, see: https://www.cbgsystems.com/wp-content/uploads/2019/07/RAC-Plus-Rev.-G.pdf, accessed May 2020

16 CSIRO 2018, Dell'Olio M., Sago-Crenstil K., Shapio G., Yan S., op. cit.

3 reduced the expected cost of ingredients for HIPS2 (by sourcing bulk suppliers, or by getting a better quote from existing suppliers). It also ensured that one ingredient, Metakaolin, could be sourced by CBG (previously, it had just used existing laboratory samples (table 2.5).

2.5 Selected ingredients for HIPS2

Ingredient	Inventory notes for stage 2		Inventory notes for stage 3	
	Source	Cost	Source	Cost
Metakaolin	Calix Ltd	*Lab sample used*	Filchem Australia	$4000/t
Epoxy F2 A	Ironbark composites	$53/kg	Ironbark composites	$37/kg
Epoxy F2 B	Ironbark composites	$63/kg	Ironbark composites	$49/kg
Silane	Sigma Aldrich	$356/kg	IMCD Australia	$18-$19/kg
	Gelest	$63/kg	Gelest	$20.5/kg

Source: Developed from the 'inventory of materials used' for the reports for stage 2 and stage 3; we assume 0.6 USD = 1 AUD

CSIRO also helped to ensure the process of CBG establishing a new manufacturing facility for RAC Plus went as smoothly as possible by providing its senior researcher on the project as a secondee employee at CBG.

CBG outputs (partially from CSIRO outputs)

CBG has created its 'next generation' fire-retardant panel: RAC Plus, which is suitable for steel ships because it is rated as A60 under the IMO FTP 2010 Part 3 standard.[17] CBG has already sold these new panels to two ships in 2020.

CBG created RAC Plus panels by improving the prototype panels created in the CSIRO project. For this, CBG refined the insulation board at the centre of the prototype panels, in consultation with the US manufacturer, and refined HIPS2 in consultation with CSIRO.

The HIPS2 formula used by CBG is not corrosive in a way that creates problems for CBG or its customers. Further, RAC Plus panels do not expand when they are subject to fire, which means they should be suitable for Navy customers.

CBG notes the RAC Plus fire-retardant panels are a truly unique product. Recently there was one other fire-retardant panel that was rated as A60 under the IMO FTP 2010 Part 3 standard. This panel was at least twice the weight of RAC Plus (per square metre), which is significantly worse for the performance of the ship it is installed on. It is also understood that this product has lost its accreditation under the relevant standard and is no longer available.

[17] This means that the outside of RAC Plus panels do not exceed 140°C for 60 minutes when the panels encase a furnace set to 1000°C. CBG achieved this final certification in February 2020.

It is possible that CBG will identify other new markets for its RAC Plus panels or similar products. The initial licence agreement between CBG and CSIRO (12 October 2018) allows CBG to use HIPS2 to develop fire retardant panels for the fields of marine vessels and offshore structures. This licence agreement has been adjusted (10 July 2019) so that CBG can also develop fire retardant panels for domestic/commercial buildings, rail and aerospace industries.

CSIRO note that future opportunities to increase the applications of HIPS2 may result in additional collaboration projects between CSIRO and CBG, as the HIPS2 formulation may have to be adjusted.

The key CSIRO staff member involved notes that this project has seen him improve his ability to collaborate. He expects any future collaboration projects would take significantly less time (assuming a similar level of complexity). The benefit of this should be more opportunities to collaborate, and more potentially lucrative applications of CSIRO technology, as more efficiency on the part of CSIRO staff lowers the cost to external parties of collaborating with CSIRO.

Outcomes

Improved ship performance and cost effectiveness

The final impact of the RAC Plus fire-retardant panels is an improvement in the performance and profitability of the ships where these panels are installed, relative to the using the existing, heavy blanket based passive fire-retarding systems. The panels boost ship profitability because they are relatively inexpensive to install and are lightweight, which means the ship performs better.

Because RAC Plus panels are a replacement for existing passive fire protection systems, and both the new and the old systems meet applicable standards, there should be no substantial reduction in the impact of fires when they occur – the ships should be approximately as well protected from fires with RAC Plus panels as with the systems they replace. The impact of the RAC Plus panels is mostly a financial one: they allow ships to meet fire reduction standards in a way that is more cost effective.

The total revenue that ship owners provide to CBG when they purchase RAC Plus panels is a data point that allows us to measure the size of this total financial impact, as it is an indicator of the value that ship owners place on it. The share of this value that can be attributed to CSIRO's inputs could be measured as the revenue share that is allocated to CSIRO by CBG under the terms of the licence agreement: that being 2 per cent.

Income to CSIRO

CBG have agreed to pay CSIRO 2 per cent of revenue earned from the RAC Plus fire-retardant panels (set by the terms of the licence arrangement, which gives CBG exclusive use of the HIPS2 technology).

Expected sales of RAC Plus panels and implied adoption curve

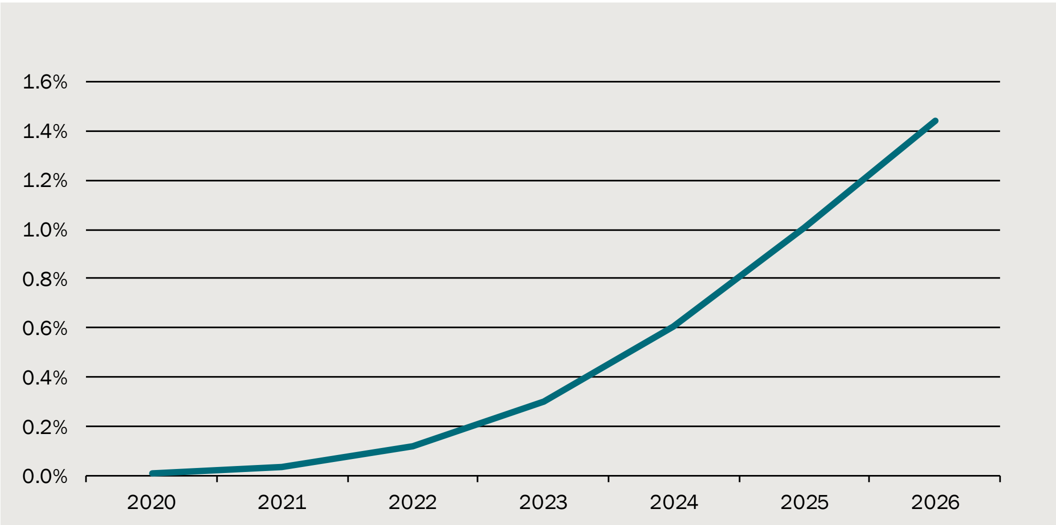
RAC Plus panels are a new and unique product, and demand for them is uncertain.[18]

However, CBG confirm that, from initial sales of 2 new ships in the first year (2020) it is reasonable – as a very conservative assumption – to expect sales to grow by 1 ship per year as CBG adopt an organic growth strategy (without heavy marketing).

This implies that sales of RAC Plus panels reach just under 1.5 per cent of the global market for new ship construction out to 2026.

Assuming a 10 year time horizon for the whole project (hence, six years of future potential revenue for CSIRO), the expected adoption curve for RAC Plus panels is depicted in chart 2.6.

2.6 Adoption curve for RAC Plus panels (share of market for new ship construction)



Data source: The CIE assumptions, confirmed with CBG

These assumptions for future sales are conservative because:

1 given the unique, desirable properties of RAC Plus panels, the implied adoption curve is low

2 sales of RAC Plus panels to retrofit ships are not included even though it will be possible to retrofit ships, especially upgrades to ships using existing RAC panels, and

3 it ignores potential applications for RAC Plus panels other than ships.

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18 The CSIRO Impact Evaluation Framework notes the appropriate way to deal with uncertainty is with scenarios. However, we do not have enough information to develop credible scenario analysis. Therefore, we develop assumptions that CBG agree are reasonable and conservative, so as not to overstate potential benefits.

Expected income for CSIRO

We expect licence fee payments from CBG to CSIRO to grow from around $65 000 in 2020 (the first year of sales) to $260 000 in 2026 (the last year of sales under our assumed timeframe).[19] In NPV terms, this equates to a total of $724 000.

Revenue that we have not included

During the project, CBG paid CSIRO project fees for particular, intermediate milestones (two project reports and a secondment). These fees were partially covered by the Australian government (through direct grants and an in-kind allowance by CSIRO). We have not included these payments as income for CSIRO because they merely cover costs incurred by CSIRO, and they do not represent the creation of additional value.[20] Within this economic evaluation, it does not matter who bears the financial burden of particular costs or inputs – what matters is the incremental value that is created from deploying them. In this project, the incremental value that is created from CSIRO deploying its inputs is the value that CBG places on the new outputs that CSIRO created. This value is the income that CBG pays to CSIRO, under the terms of the licence agreement, estimated above.

19 These figures are derived from our assumptions for ship sales, and the CSIRO-CBG expectation that 2 per cent of revenue from RAC Plus corresponds to around $32 500 per ship (between $25 000 and $40 000 per ship).

20 These project fees were set with or consistent with the rate we use to estimate costs for CSIRO ($15 000 per month)

3 Modelling outcomes

Conservative estimate of net benefit

CSIRO has enabled CBG systems to bring a unique product to market that improves the efficiency of ships, and the cost effectiveness of complying with shipping regulations to manage fire safety.

Very conservatively estimated, the value of final outcomes that can be attributed to CSIRO are valued at $724 000 in NPV terms.

CSIRO contributed costs of $356 000 in NPV terms for the HIPS2 project.

Hence, the net benefit or impact created by CSIRO researchers is $368 000 in NPV terms, with an implied benefit-cost ratio of 2.0.

The project is considered to be particularly successful due to the agility shown by the CSIRO team in deploying scientific knowledge to a new problem, and the effort undertaken to collaborate with industry and ensure its outputs solved problems that faced CBG, generating outcomes that were valued by its customers.

3.1 Net benefit created by or net impact attributable to CSIRO (NPV terms)

	$ 000
Incremental costs	-356
Incremental benefits	724
Net benefit or net impact	368
Benefit cost ratio	*2.0*

Note: 7 per cent discount rate, 10 year horizon
Source: The CIE

Key assumptions affecting results

This impact study has addressed crucial points in CSIRO's impact evaluation framework.

In dealing with 'adoption', we do not believe it was necessary to cater for uncertainty of CBG adoption of CSIRO's outputs, because the HIPS2 innovation proved to successfully underpin the RAC Plus panels created by CBG.

What is uncertain is the final, total impact of these outputs, in combination with other outputs (mostly provided by CBG) in the form of sales of new RAC Plus panels.

We have taken a very conservative approach to estimating consumer uptake based on consultation with CBG, instead of undertaking scenario analysis. Scenario analysis was not considered to be viable due to a lack of information and certainty upon which to devise alternative scenarios.

In dealing with attribution of impacts back to CSIRO, we do not believe that scenario analysis was necessary, and have based attribution on the terms of the licence agreement (2 per cent), which acts as a suitable proxy for the extent to which CSIRO contributed to final consumer sales.

The logic of the impact pathway for this evaluation is considered to be sound, as the deployment of CSIRO inputs (labour/'know-how', associated laboratory, material and administration costs, patent costs) *caused* the creation of the outputs and outcomes identified and measured. This causality underpins our calculation of net benefits and the benefit-cost ratio.

An important aspect of this causation is that stakeholders and the literature confirm there were no real alternatives to the HIPS2 technology created by CSIRO, and there are no like-for-like alternatives to the fire-retardant panels that were created using this technology.

For instance:

- HIPS2 is a genuinely novel polymer technology. CBG is not aware of alternative products that deliver the same features, nor is it aware of other passive fire-retardant systems (including panels and other products) that deliver features equivalent to those delivered by RAC Plus panels made from HIPS2. This means CBG would not have been able to access the valuable outputs created by CSIRO if not for the efforts of CSIRO, and ship owners would not be able to access the value created by the RAC Plus product, if not for the creation of this product, and
- CBG note that it could not have developed HIPS2 technology as an 'in-house' solution by recruiting relevant CSIRO staff, making the collaboration with CSIRO a necessary condition for the innovation.

Overall, the HIPS2 project delivers a positive net benefit, and represents a success in CSIROs collaboration with industry.

One of the key success factors was an early demonstration by CSIRO to CBG of an initial version of HIPS2, incorporated into a basic prototype fire retardant panel. Getting early-stage feedback, based on CBG's business acumen and the lessons learnt from its French project, was one factor that drove the positive final outcomes.

It is also an example of success in the opportunities from cross pollination within CSIRO. A significant contributor to the development of HIPS1 (a mostly inorganic product) into HIPS2 (the inorganic product, with an organic epoxy added), was the transfer of a CSIRO staff member from an organic focused team into the inorganic team. This proved to be a very valuable combination of knowledge.

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