Inland Revenue
Te Tari Taake

IR1238
AUGUST | 2024

Research & Development Tax Incentive (RDTI)

R&D activity eligibility

Examples 1-4 included

Digital technology sector

Digital technology sector guidelines

The purpose of this document is to provide businesses in the digital technology sector with some further guidelines to help them when accessing funding under the RDTI. It will provide businesses with the following outcomes.

- An understanding of the type of R&D that qualifies for funding in this sector.
- An insight into the type of technical information that we would expect to be included within any application.
- Practical examples of completed general approval applications.

These sector specific guidelines build on the general principles of RDTI eligible activities. Further detail can be found in the following locations.

Go to www.ird.govt.nz/
Enter keywords: 'r&d eligible activities' in search box

Go to www.rdti.govt.nz/
Click on the the RDTI quick quizzes to determine the eligibility of your business and its RDTI.

We recommend you review this content before continuing further.

At a glance

General principles of RDTI eligible activities

Core R&D activities must meet the following criteria.

Occur in New Zealand	Seek to resolve scientific or technological uncertainty	Follow a systematic approach	Seek to create new knowledge, or new or improved processes, services or goods

See definitions of Science and Technology at the following link: Go to **rdti.govt.nz** and select the quick quiz 'Is my R&D eligible?', click on the '+' sign next to 'Test 1', then click on the link in the last paragraph for 'scientific or technological uncertainty'.

What information is needed in the application

After a review of the general principles of the RDTI, you may believe that you are doing R&D that could be eligible for funding. If this is the case, it is important you provide us with the correct type of information to help process your application efficiently.

A business will naturally describe its R&D in commercial terms. However, for us to determine whether it meets the requirements of RDTI funding, the focus of the narrative must be at a scientific or technological level.

We have developed a tool to help you provide this information. The tool is similar in nature to a dart-board. The information required to process your claim must hit the **dark teal** bullseye. Information from the outer **ruby** and **burnt orange** sections of the dart board can provide useful context for the R&D, but you cannot solely rely on that information.

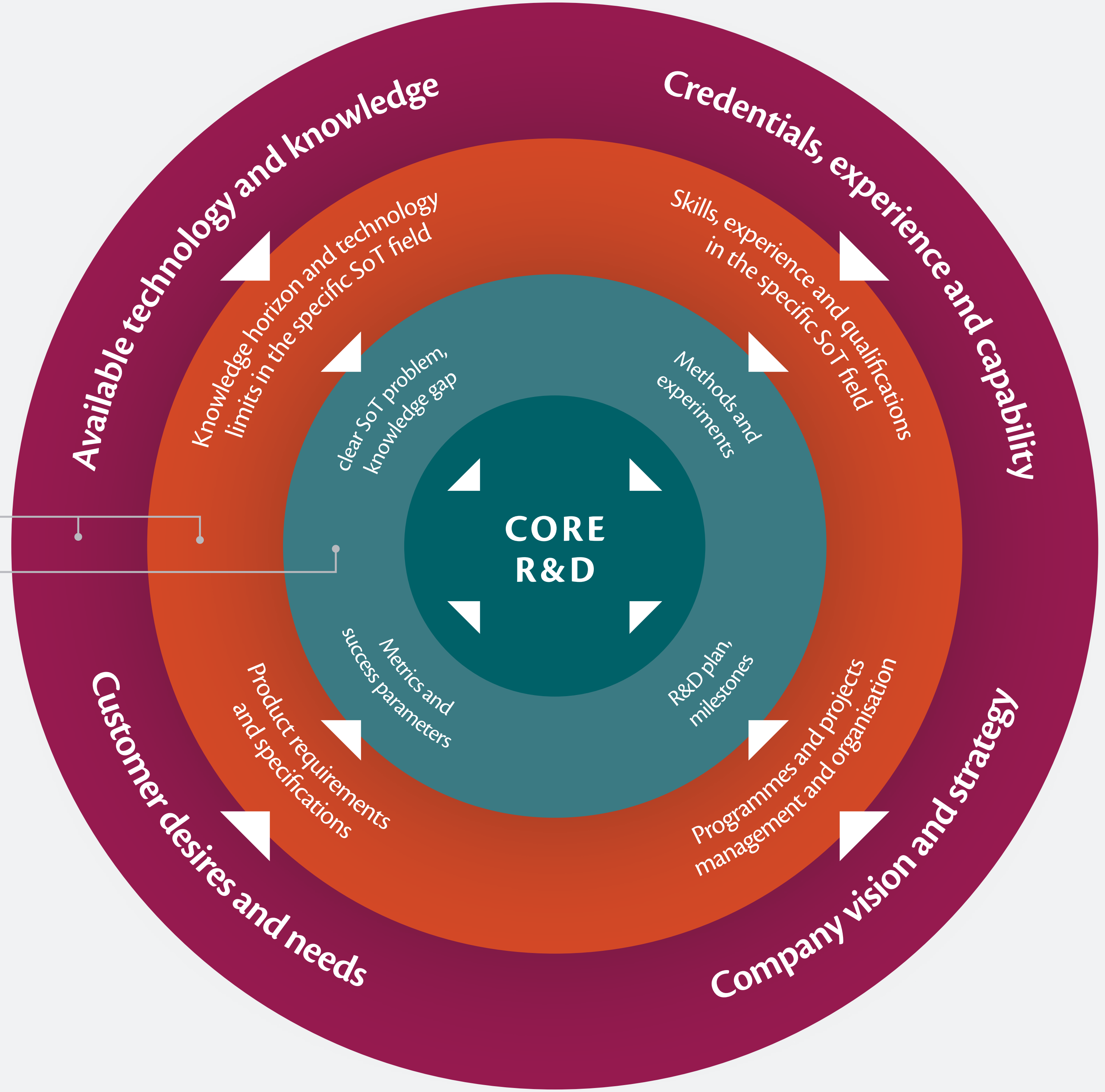
Examples of questions you should be seeking to answer when completing your general approval are from the **dark teal** bullseye and may include (but are not limited to):

- What is the scientific or technological problem you are trying to overcome?
- What is the gap in knowledge that you have (in a scientific, engineering or technological context)?
- What methods or experiments do you plan to undertake to solve the problem?
- What is your R&D plan and milestones?
- What are your metrics and success parameters?

Information from the outer **ruby** and **burnt orange** sections can provide useful context for the R&D – but you cannot solely rely on that information.

The information required to process your claim must hit the **dark teal** bullseye. All features in the **lighter teal** circle must be present to be R&D.

Key: SoT – scientific or technological



How does the RDTI work for the digital technologies sector?

Many digital technologies businesses doing R&D will be eligible for funding, but not all software development or innovation will be. It is important to understand what gets funded and what does not.

Preliminary step: Identify technology(ies) used for R&D

To understand how the RDTI framework applies to this sector, it is useful to first consider the underlying technology that underpins the R&D within your business. Examples may include:

	Demonstrated in page 7 examples
Machine learning	2
Application software	1, 2, 3
Embedded software	4
Digital hardware	4
Image processing	3
Cloud	1
Drones	3

The focus is purposely drawn to the technology used in the R&D, rather than the commercial product developed. In many cases, businesses may be using a combination of technologies to undertake their R&D.

Once you have considered what technologies the business uses to undertake its R&D, you now need to consider whether the R&D meets the general principles of RDTI eligible activities. Refer to the 'Refresher' on page 8.

We have developed a number of examples focusing on different aspects of technology development to bring the tax legislation to life for the digital technologies sector. These examples are detailed below, with a guide to show you which focus area of the RDTI rules are demonstrated*.

*Note: each example has a different focus, the examples are not intended to cover all aspects of the RDTI rules

Example	Technology	Demonstrating						Page
		General principles of RDTI eligibility	Benchmarking technological uncertainties	Core vs supporting R&D	R&D start & finish	Systematic approach	Overseas activities	
1. A security system for a building site	Cloud based facial recognition engine	✓	✓	✓	✓			10 & 65
2. A legal search platform for the building code	Machine learning-based natural language processing (NLP) and rule-based models	✓		✓	✓			30 & 74
3. A drone based computer vision (CV) platform for wheat growing	Computer vision model development and image resolution	✓	✓	✓		✓	✓	30 & 78
4. A low-cost, satellite-based location tracker	Digital hardware and embedded software	✓	✓	✓	✓	✓	✓	46 & 82

At a glance

General principles of RDTI eligible activities

Core R&D activities must meet the following criteria.

Seek to resolve scientific or technological uncertainty

Follow a systematic approach

Seek to create new knowledge, or new or improved processes, services or goods

Eligibility tests	Questions
What is the technological uncertainty?	What is the problem within the technological field that you are trying to overcome? Where is the knowledge gap?
What is the systematic approach?	How are you planning to solve the above problem? What is the R&D plan? What technical metrics and success parameters demonstrate success (or failure)?
What is the new knowledge or improved processes, services or goods?	Why are you undertaking R&D? What is the expected outcome?

How do I demonstrate that scientific or technological uncertainty exists?

Is the knowledge required to resolve the uncertainty either publicly available, or deducible by a competent professional in the relevant field?	Has someone done this before, and you have access to that knowledge? Do you have to investigate and experiment in a systematic way?

Additional information:
www.ird.govt.nz: 'R&D eligible activities'
www.rdti.govt.nz: take the quick quiz 'Is my R&D eligible?'(click on Tests 1 to 5.)

Example 1

A security system for a building site

The business applied for 1 year of funding using the general approval method. We recommend reading the applications in examples 1a and 1b in the Appendix before continuing.

The highlights

The commercial project

The commercial project was to develop a solution to ensure security of personnel on building sites in different locations with a minimum impact on workers.

The technical problem

To develop a security solution that uses artificial intelligence (AI) facial recognition, a cloud-based server and cameras to identify personnel.

The project had technical constraints of accuracy, speed and hardware cost.

How the technical problem became a technological uncertainty

Interconnected technological uncertainties resulted from the technical constraints of speed, accuracy and hardware costs and related to:

- image compression
- acutance
- resolution
- facial recognition engine selection.

Further details are provided in example 1a of the general approval application in the Appendix.

Remember – the colour coding represents the different levels of the dart board tool. The **dark teal** layer (being the bullseye) is the critical information required to efficiently process the funding application.

The following diagram demonstrates the progress of the project from its commercial objectives, to its technological uncertainties.

The commercial project

Commercial objective

Develop a solution to ensure security of personnel on building sites in different locations with minimum impact on workers

The practical idea

- Use camera with a full http stack
- Capture 'facial images'
- Upload to a 'cloud-based server'
- Perform the 'facial recognition'
- Send approve/decline for entry

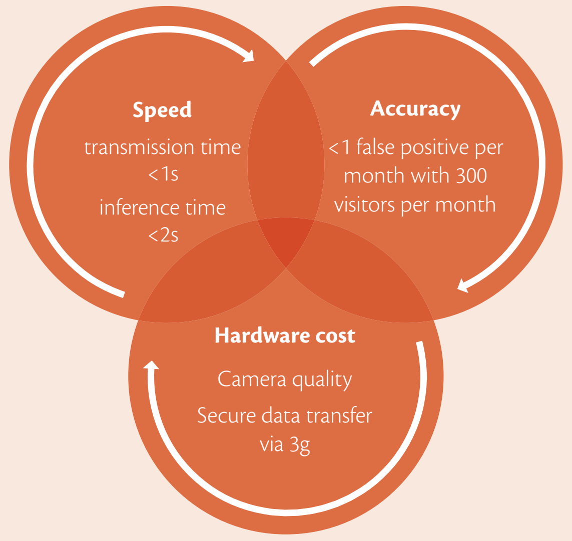
The technical problem

Problem Statement

To develop a security solution that uses 'AI facial recognition, a cloud-based server' and 'cameras' to identify personnel

'Technical constraints' of accuracy, speed and hardware cost

Performance parameters



The technological uncertainties

Activity 1

What level of 'image compression' was required to resolve the trade-off between transmission speed vs inference speed and accuracy

Activity 2

What 'acutance' (constrained by cost of hardware) and 'resolution' (constrained by cost of hardware and total identification time) would meet the required recognition performance metrics while still meeting the time and cost constraints

Activity 3

Which 'facial recognition engines/models' were suitable for use with the images we were capturing, and which facial recognition models worked best in changing and challenging environments (including, what was most efficient for speed of throughput - edge based facial recognition vs cloud engines)

Points to note

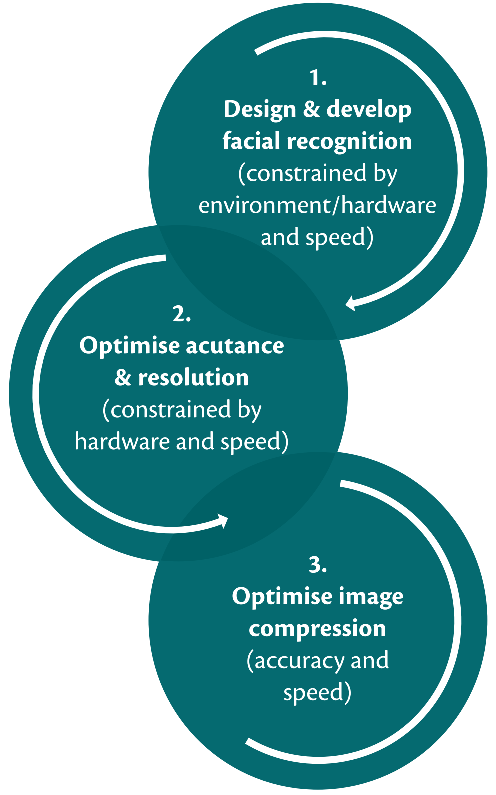
The general principles of RDTI eligibility

The general principles of RDTI eligible activities require all 3 aspects of the eligibility requirements to be met. The following table and diagram demonstrate the relationship between them using the approach of Problem > Plan > Investigate > Outcome.

The technological uncertainties	The technological uncertainties in this example are interrelated demonstrating the 'problem'. This problem has technological principles underpinning it.
The systematic approach	The 'plan' and 'investigate' phase are directly related to the relevant technological uncertainties. Stepped through the R&D plan with investigative steps to work towards resolving the specific technological uncertainties.
The new or improved...	The resulting outcome is clearly stated. The 'why' the R&D was undertaken.

Core activity

The technological uncertainties



Problem

Systematic approach*

R & D plan	Investigate
Facial recognition engines/models	
• Literature review • Edge-based vs cloud-based • Iterative development of a novel facial recognition engine using DCNN	Testing, modifying and retesting: • Matching faces to known faces in a prepared database • Testing edge-based vs cloud-based for speed • Training the recognition models and optimising hyper-parameters through seven steps of machine learning
Acutance and resolution	

• Review available camera technology
• Identify 3 cameras to test (different acutance levels)
• Iterative development when unsatisfactory result to find alternative technology choices if not satisfactory
	Testing for the following outcomes:
	• The minimum acutance for recognition in lab conditions
	• Impact on acutance under differing:
	  • Environmental conditions
	  • Resolutions

Image compression	
• Development of novel compression algorithms for facial images • Iterative development when unsatisfactory result to find alternative technology choices if not satisfactory	• Tests of speed for compression algorithms – must retain accuracy • Develop matrix - accuracies vs compressions vs speeds, in various environmental conditions • Evaluation of results • Modifying and retesting

Plan   Investigate

New or improved

Outcome

*refer to example 1a of the general approval application in the Appendix for additional detail.

Points to note

Benchmarking the technological uncertainties

Remember, a key matter to consider is how to demonstrate that the knowledge required to resolve the technological uncertainties are not publicly available, or deducible by a competent professional in the relevant field.

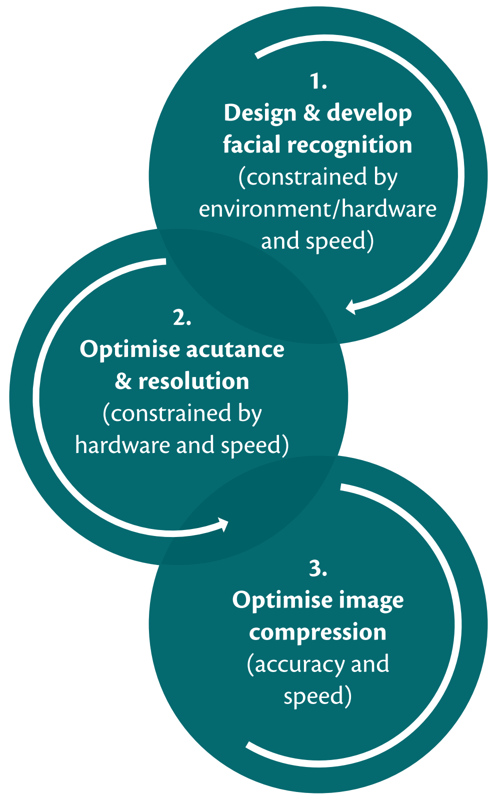
The following table and diagram demonstrate how to benchmark the technological uncertainties.

The publicly available test	There is a known solution for facial recognition and security. For example, e-passport scanning at Customs. Therefore, it is important to explain why this R&D is different.
The competent professional test	This test is demonstrated in the scientific and technological methods required by the business to resolve the uncertainty through the systematic course of investigation and experimentation.
Example demonstrating when these tests are not met	If the competent professional is only undertaking tests to confirm that a common solution to a common problem could be resolved, then the R&D is not eligible for funding under the RDTI. This is demonstrated in example 1b of the general approval application in the Appendix.

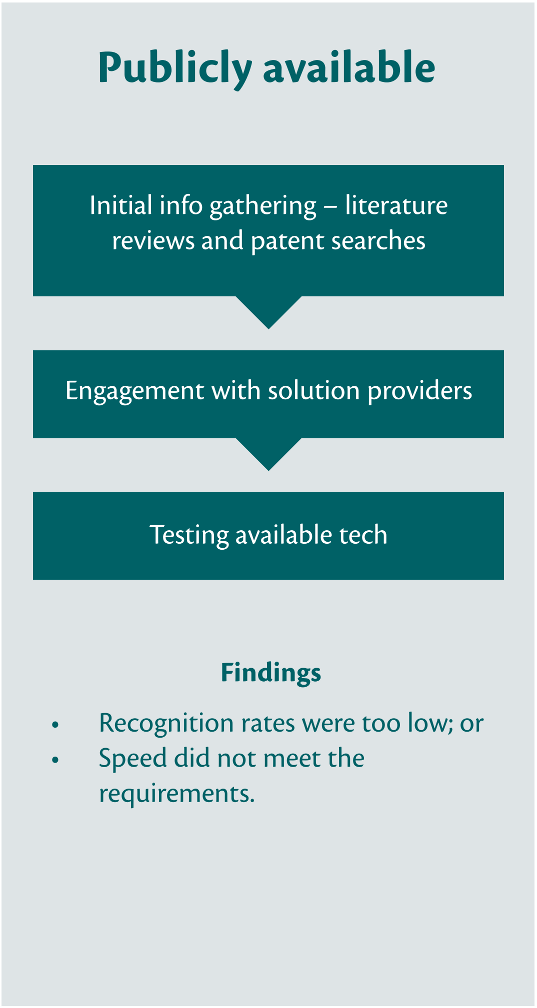
Remember – the General Approval application example provides a full description of the eligible RDTI activities. This is the expected level of detail required by us. You must focus on the bullseye (dart board tool) and be technical in nature.

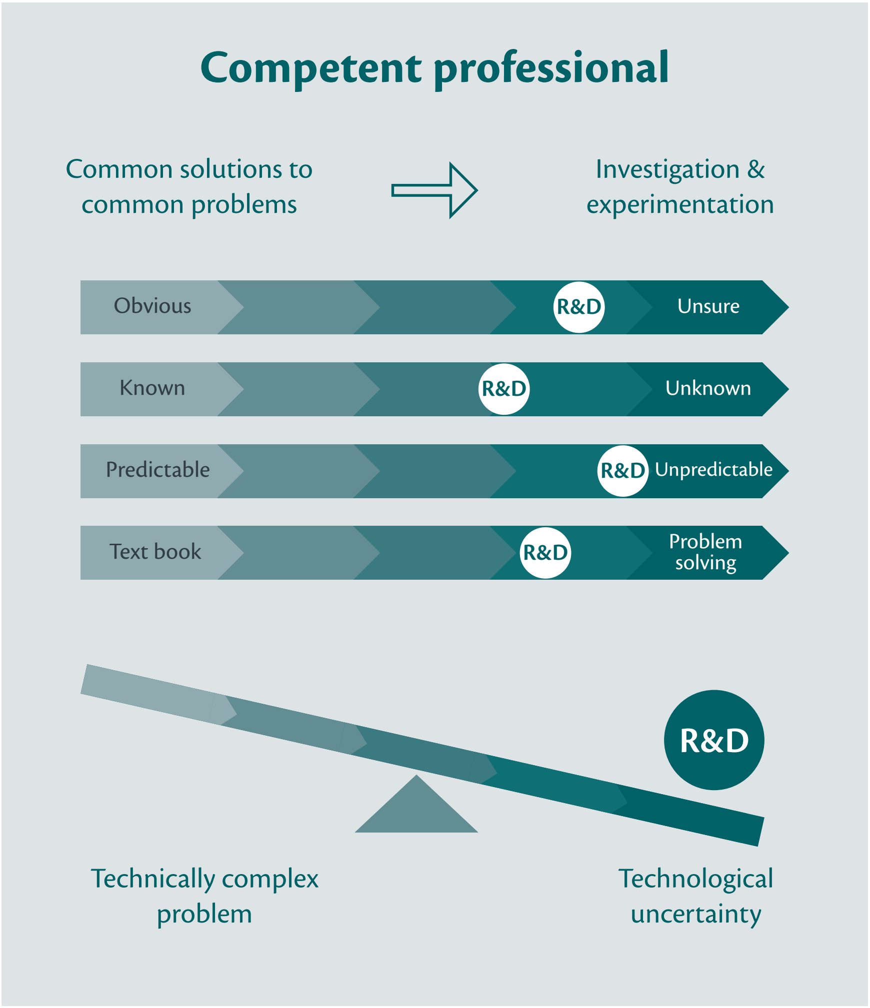
Core activity

The technological uncertainties



Benchmarking the technological uncertainties





Points to note

Core & supporting R&D

Refresher

Core vs supporting R&D

Eligible R&D activities must involve core R&D activity. There may also be supporting activities.

Type of activity	Definition
Core activity	An activity that has the material purpose of creating new knowledge or new or improved processes, services, or goods. It must also attempt to resolve scientific or technological uncertainty using a systematic approach.
Supporting activity	An activity that has the only or main purpose of supporting the core activity.

Excluded activities

Certain activities are ineligible core R&D activities. A smaller number are ineligible supporting R&D activities.

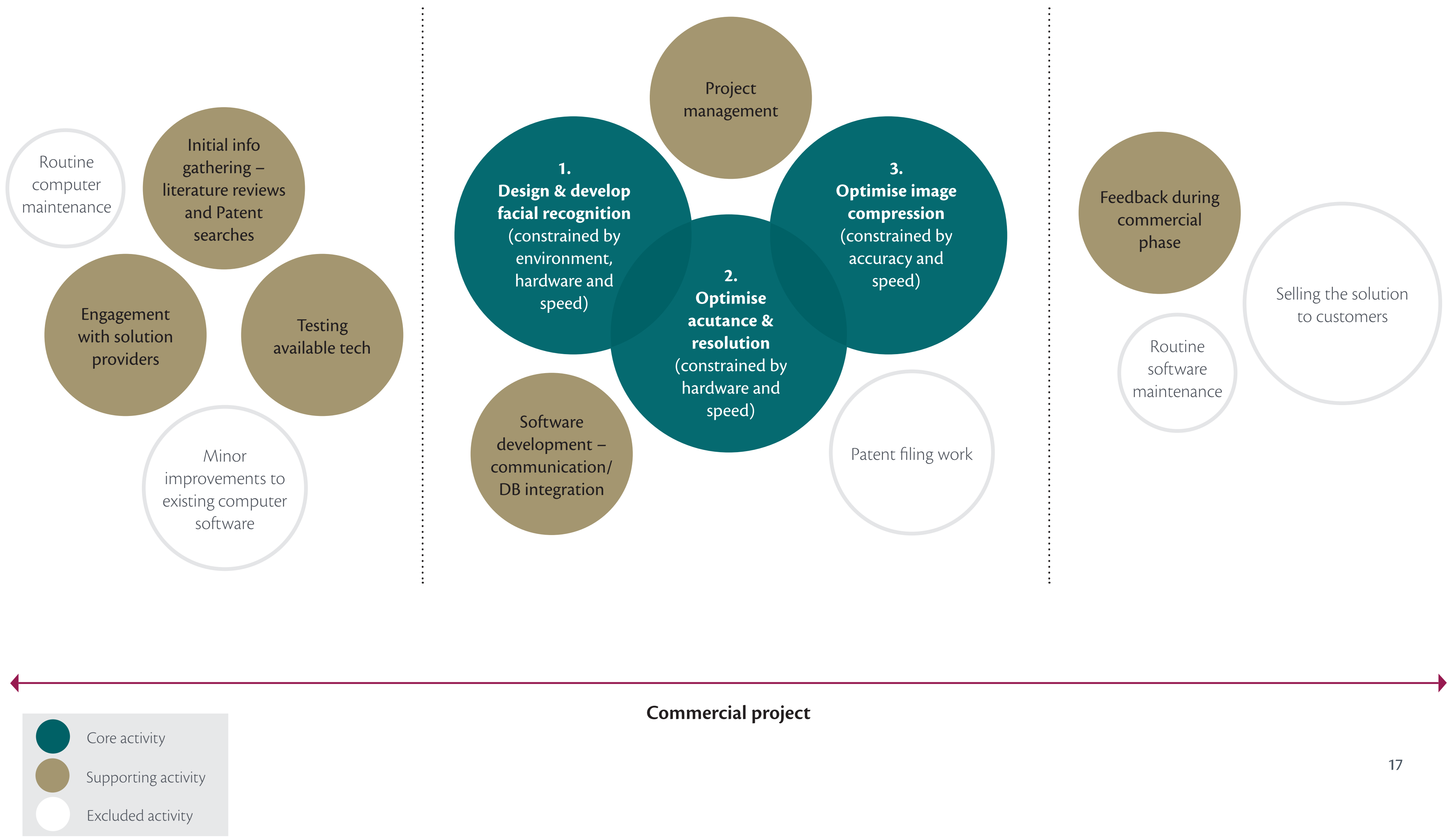
Further information on supporting R&D activities can be found on the IRD website. Go to **www.ird.govt.nz/** Enter keywords: 'r&d eligible activities' or 'r&d ineligible activities' in search box.

To demonstrate the core and supporting R&D activities for the security systems example, and the ineligible excluded activities, we have included the following table and diagram.

Core & supporting activities	Only core and supporting activities are funded under the RDTI.
Excluded activities – do not get funded	Certain activities the business undertook in the security systems example are ineligible for funding.
Commercial project vs RDTI funded activities	The whole commercial project does not get funded, only the core & supporting activities are funded, being a slice of the wider project.

What are core and supporting R&D activities?

What are excluded activities?



Points to note

When does the R&D start and finish?

Refresher

Beginning and end of core activities

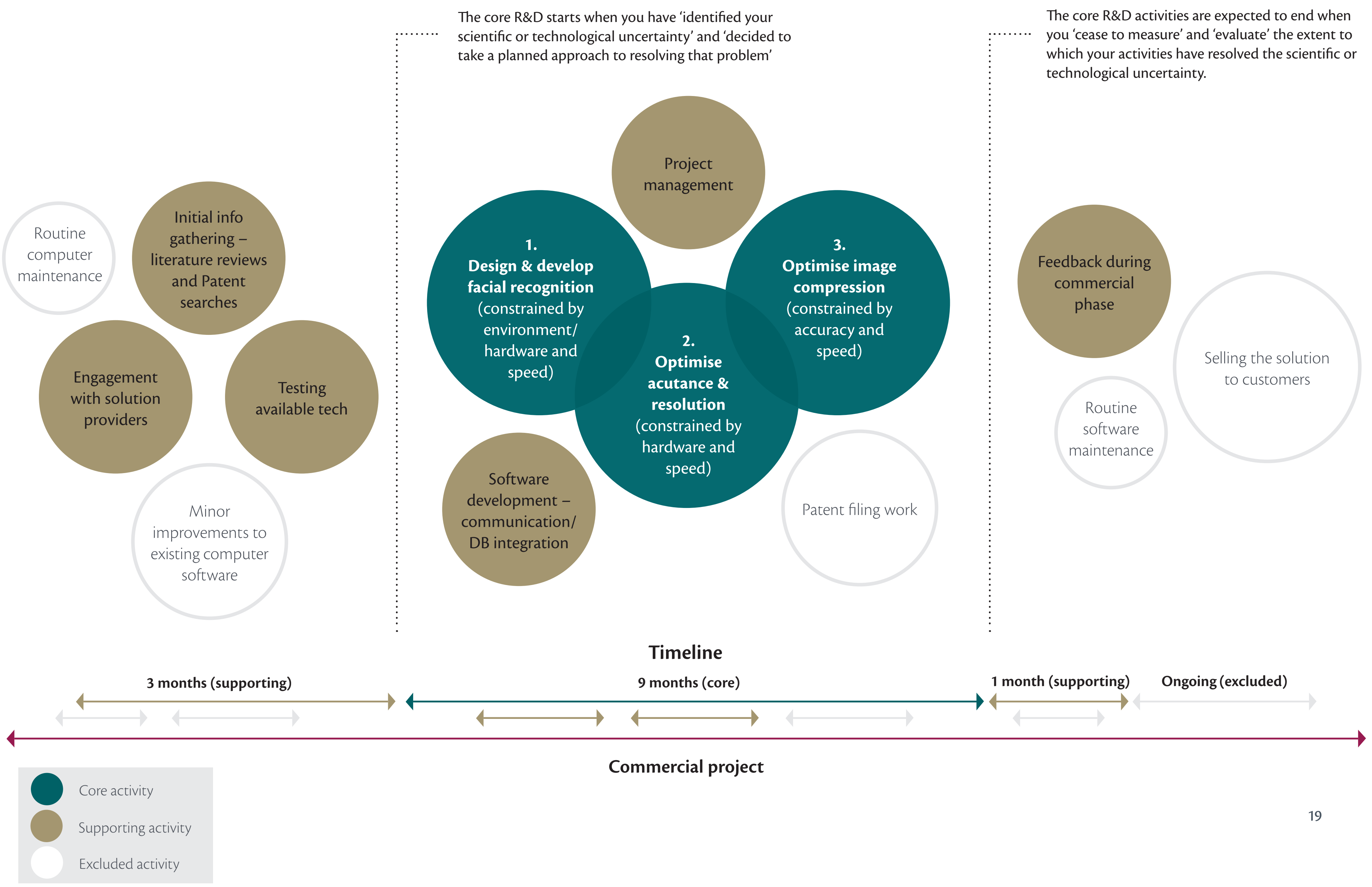
The Core R&D starts when you have identified your scientific or technological uncertainty and decided to take a planned approach to resolving that problem.

The Core R&D activities are expected to end when you cease to measure and evaluate the extent to which your activities have resolved the scientific or technological uncertainty.

Further information on when R&D activities start and finish can be found in the Research and Development Tax Incentive IR1240 Guidance. Go to **www.ird.govt.nz/** Enter keywords: 'r&d eligible activities' in search box.

The following diagram demonstrates at what time the R&D started. Supporting R&D activities can still be claimed before the core R&D starts and after the core R&D finishes. A timeline for the application is included for reference purposes only.

The R&D start & finish



A legal search platform for the building code

The business applied for a 1 year approval of funding using the general approval method. The business had yet to complete its R&D at the point of filing. We recommend reading the eligible application (example 2) in the Appendix before continuing.

The highlights

The commercial project	Development and operation of a smart legal search platform that makes the NZ Building Act accessible to a large variety of users without legal jargon.
The technical problem	Develop a semantic search engine that can identify relevant legal passages using a mixed semantic model (rule based machine learning/natural language processing) significantly better than random. The performance parameters of the project are: • timely (sub 3s) search results • high accuracy • close to 0 false negatives with a minimum of false positives.
How the technical problem became a technological uncertainty	Constraints like a limited corpus, unknown required and achievable semantic depth, and varying legal interpretations render success uncertain.

Remember – the colour coding represents the different levels of the dart board tool. The **dark teal** layer (being the bullseye) is the critical information required to efficiently process the funding application.

The following diagram demonstrates the progress of the project from its commercial objectives, to its technological uncertainties.

The commercial project

Commercial objective: smart platform

Development and operation of a smart legal search platform that makes the NZ Building Act accessible to a large variety of users without legal jargon

The practical idea: semantic search

Development of a semantic search engine that will not only allow search for legal key words, but understand search items and questions by determining their intent and contextual meaning

The technical problem

Problem Statement: high accuracy mixed model

Develop a semantic search engine that can identify relevant passages using a mixed semantic model (rule based & ML NLP based) significantly better than random

Performance parameters

Timely (sub 3s) search results at a high accuracy: close to 0 false negatives with a minimum of false positives

The technological uncertainties

Technological uncertainties resulting from **constraints** like a limited corpus, unknown required and achievable semantic depth, and varying legal interpretations render success uncertain

Points to note

The general principles of RDTI eligibility

The general principles of RDTI eligible activities require all 3 aspects of the eligibility requirements to be met. The following table and diagram demonstrate the relationship between them using the approach of Problem > R&D Plan & Investigate > Outcome.

The technological uncertainties	The technological uncertainties are described using the technical principles of the software engineering used to develop the semantic model.
The systematic approach	The 'R&D plan & investigate' phase is directly related to the technological uncertainties. Stepped through the R&D plan with investigative steps to work towards resolving the specific technological uncertainties. This R&D is yet to happen, so the plan is high-level, but still demonstrates how the business expects to resolve its technical problem and technical knowledge gap that it currently anticipates.
The new or improved...	The resulting outcome is clearly stated. The 'why' the R&D was undertaken. In this case to develop a new service.

Remember – the general approval application example provides a full description of the eligible RDTI activities. This is the expected level of detail required by us. You must focus on the **dark teal** bullseye (dart board tool) and be technical in nature.

Core activity

The technological uncertainties

Technological uncertainties resulting from 'constraints' like a limited corpus, unknown required and achievable semantic depth, and varying legal interpretations render successes uncertain

Problem →

Systematic approach*

Performance parameters

Data preparation and pre-processing

Manual benchmarking

Model development

Run and compare both models against each other and against manual benchmark

R&D Plan & Investigate →

New or improved

The development of a 'new service' using a mixed semantic model (rule based & ML NLP based)

Outcome →

*refer to example 2 of the general approval application in the Appendix for additional detail.

Points to note

Benchmarking the technological uncertainties

Remember, a key matter to consider is how to demonstrate that the knowledge required to resolve the technological uncertainties are not publicly available, or deducible by a competent professional in the relevant field.

The purpose of this example is to mainly demonstrate the application of the general principles of RDTI eligibility through tabular and diagrammatic form. However, further detail of how to benchmark the uncertainty can be found in the general approval application Appendix, example 1a.

The security systems example, also provides further detail regarding benchmarking the technological uncertainty and is demonstrated above (pages 14 & 15) in tabular and diagrammatic form.

Points to note

Core & supporting R&D

Refresher

Core vs supporting R&D

Eligible R&D activities must involve core R&D activity. There may also be supporting activities.

Type of activity	Definition
Core activity	An activity that has the material purpose of creating new knowledge or new or improved services or goods. It must also attempt to resolve scientific or technological uncertainty using a systematic approach.
Supporting activity	An activity that has the only or main purpose of supporting the core activity.

Excluded activities

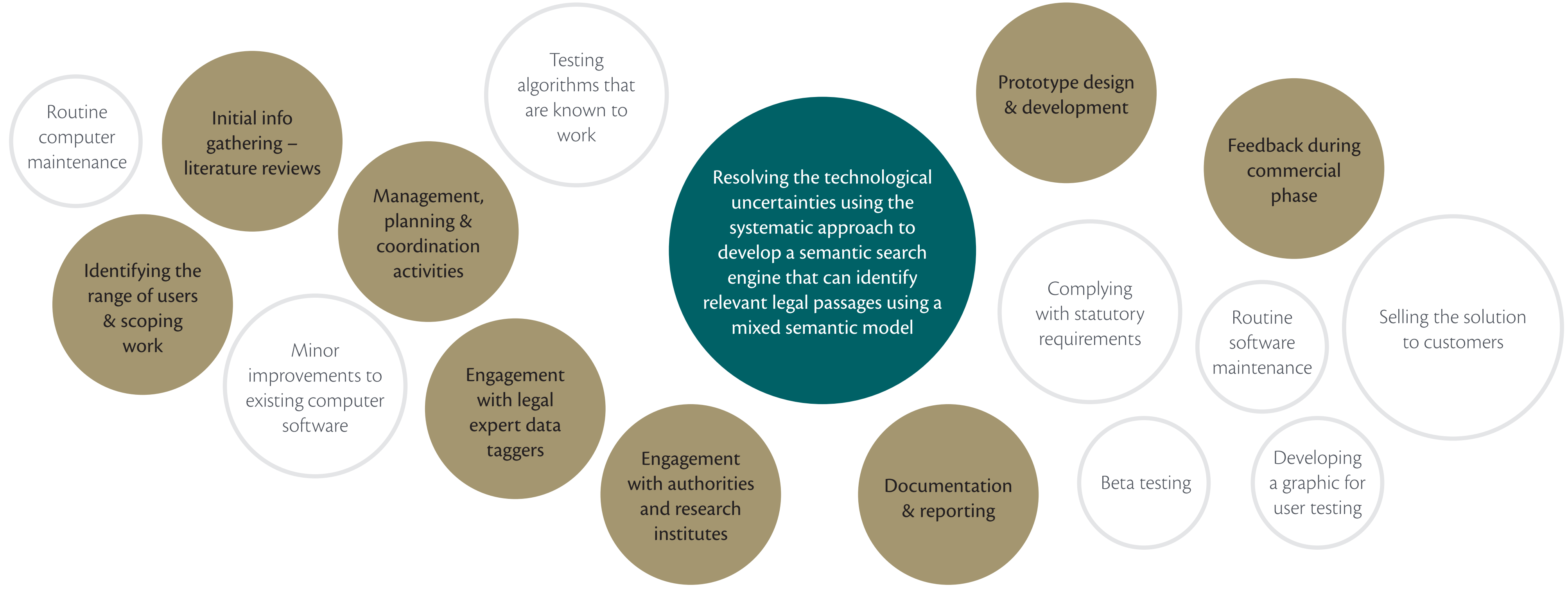
Certain activities are ineligible core R&D activities. A smaller number are ineligible supporting R&D activities.

Further information on supporting R&D activities can be found on the IRD website. Go to **www.ird.govt.nz/** Enter keywords: 'r&d eligible activities'or 'r&d ineligible activities' in search box.

To demonstrate the core and supporting R&D activities for the legal search platform example, and the ineligible excluded activities, we have included the following table and diagram.

Core & supporting activities	Only core and supporting activities are funded under the RDTI. A number of business-as-usual activities can be funded as supporting R&D activities. To get funding the main purpose of these activities MUST be to support the core R&D activity (in other words, the R&D could not go ahead without these activities).
Excluded activities – do not get funded	Certain activities the business undertook in the legal search platform example are ineligible for funding.
Commercial project vs RDTI funded activities	The whole commercial project does not get funded, only the core & supporting activities are funded, being a slice of the wider project.

What are core and supporting R&D activities? What are excluded activities?



Key
- Core activity
- Supporting activity: supporting activities may happen at the same time as the core R&D. For example, integrated documentation and reporting on the uncertainties.
- Excluded activity

The core R&D is a slice of the wider commercial project

*refer to example 2 of the general approval in the Appendix for additional detail – this diagram shows the relationships between activities (not a timeline).

Points to note

When does the R&D start and finish?

Refresher

Beginning and end of core activities

The core R&D starts when you have identified your scientific or technological uncertainty and decided to take a planned approach to resolving that problem.

The core R&D activities are expected to end when you **cease to measure** and evaluate the extent to which your activities have resolved the scientific or technological uncertainty.

Further information on when R&D activities start and finish can be found here Research and Development Tax Incentive (Go to **www.ird.govt.nz/** Enter keywords: 'r&d eligible activities' in search box) in IR1240, page 37.

The following diagram demonstrates at what time the R&D started. Supporting R&D activities can still be claimed before the core R&D starts, after the core R&D finishes or during the core R&D activities (for example, integrated documentation & reporting on the uncertainties is a supporting activity happening alongside the core R&D).

The R&D start & finish

Example 3

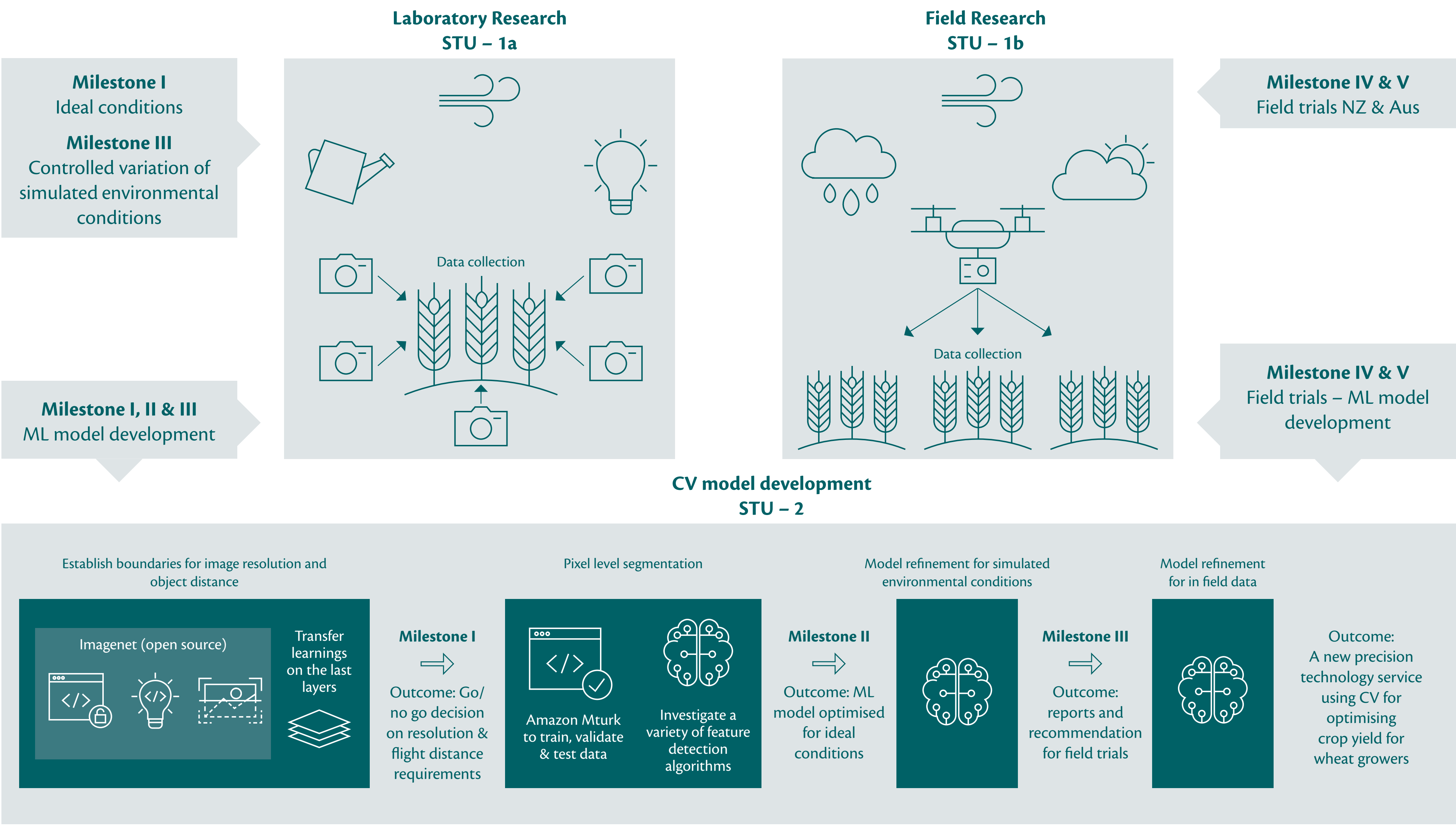
A drone based computer vision (CV) platform for wheat growing

The business applied for a 3-year approval of funding using the general approval method. They had not completed their R&D at the point of applying. We recommend reading the eligible application (example 3) in the Appendix before continuing.

We have also included the following diagram to aid with the understanding of the project.

Please note, it is not a requirement that you provide a visual representation of your project when applying for the RDTI.

Wheat growing | CV model development & image resolution



Key

STU – scientific or technological uncertainty

Aus – Australia

ML – machine learning

The highlights

The commercial project

To develop a precision technology service using CV for optimising wheat yield.

The technical problem

To develop a CV model that automatically identifies the percentage of flowering wheat heads (anthers) well enough to optimally time application of treatment (fungicide) to the plants.

The performance parameters of the project are to identify the time when 75% of the plants have passed from Feekes 10.5.0 (where the wheat head has completely emerged) to Feekes 10.51 (the beginning of flowering) in a narrow time window of up to 7 days.

How the technical problem became a technological uncertainty

Background

- In the early growth stages of wheat and the onset of flowering, the anthers may only take up a few pixels on an image.
- This makes it difficult to distinguish by colour from other parts of the plant.
- In turn, this makes the accuracy of a CV model challenging, particularly under real conditions.

This technical problem becomes technological uncertainties from both the complexities regarding the quality of the data collected (STU 1a & 1b), and how that data can influence the CV model development and its accuracy (STU 2).

Further details are provided in example 3 of the general approval application in the Appendix.

Remember – the colour coding represents the different levels of the dart board tool. The **dark teal** layer (being the bullseye) is the critical information required to efficiently process the funding application.

The following diagram demonstrates the progress of the project from its commercial objectives to its technological uncertainties.

The commercial project

Commercial objective: precision technology

To develop a precision technology service using CV for optimising wheat yield.

The technical problem

Problem Statement: high accuracy CV model

To develop a CV model that automatically identifies the percentage of flowering wheat heads (anthers) well enough to optimally time application of treatment (fungicides) to the plants.

Performance parameters

To identify the time when 75% of the plants have passed from Feekes 10.5.0 (where the wheat head has completely emerged) to Feekes 10.51 (the beginning of flowering) in a narrow time window of up to seven days.

The technological uncertainties

Background

- In the early growth stages of wheat and the onset of flowering, the anthers may only take up a few pixels on an image.
- This makes it difficult to distinguish by colour from other parts of the plant.
- In turn, this makes the accuracy of a CV model challenging, particularly under real conditions.

This technical problem becomes technological uncertainties from both the complexities regarding the quality of the data collected (STU 1a & 1b), and how that data can influence the CV model development and its accuracy (STU 2).

STU 1a: Laboratory research

Collection of data for CV model development in:

- Ideal conditions
- Controlled variation of simulated environmental conditions

to determine the optimal camera specifications regarding height, placement and image resolution.

STU 1b: Field research

Collection of data under real conditions (variable environmental conditions) using drones to consider the trade-off between image resolution and object distance.

STU 2: CV model development

The main technological challenge results from the colour resolution between the object and its background. The goal is the continued improvement of the accuracy of the CV model using increasingly more complex and realistic inputs.

Points to note

The general principles of RDTI eligibility

The general principles of RDTI eligible activities require all 3 aspects of the eligibility requirements to be met. The following table and diagram demonstrate the relationship between them using the approach of Problem > R&D Plan & Investigate > Outcome.

The technological uncertainties	The technological uncertainties in this example are interrelated demonstrating the "problem" is twofold. This problem has technological principles underpinning it for both the quality of the data collected (due to variable environmental conditions) and the flow on effect for CV model development and its accuracy.
The systematic approach	The "plan' and "investigate" phases are directly related to the relevant technological uncertainties. The R&D plan involves undertaking investigative steps to work towards resolving the specific technological uncertainties. Further detail is provided in the "Systematic approach" section of this example.
The new or improved...	The resulting outcome is clearly stated. The "why" the R&D was undertaken. In this case to develop a new service.

Remember – the general approval application example 3 provides a full description of the eligible RDTI activities. This is the expected level of detail required by us. You must focus on the **dark teal** bullseye (dart board tool) and be technical in nature.

Core activity

The technological uncertainties*

The technological uncertainties result from the complexities regarding the quality of the data collected (STU 1a & 1b), and how that data can influence the CV model development and its accuracy (STU 2)

Problem →

Systematic approach*

Performance parameters

Milestone I: Ideal conditions in the laboratory

Milestone II: ML model development

Milestone III: Simulate real environmental conditions in the laboratory

Milestone IV: Field trials New Zealand

Milestone V: Field trials Australia

R&D Plan & Investigate →

New or improved

A new precision technology service using CV for optimising crop yield for wheat growers

Outcome →

*refer to the diagrams on pages 31 or 37 for a demonstration of STU 1a, 1b, and 2.

*refer to example 3 of the general approval application in the Appendix for additional detail.

R & D plan & investigate	Performance parameters
Milestone I: Ideal conditions in the laboratory	
Establish boundaries for parameters: • image resolution • object distance Use off the shelf CNN model (e.g. ImageNet) with transfer learning on the last couple of layers	
Milestone II: ML model development	
Pixel level segmentation: • use Amazon MTurk to prepare training, validation and test data • test feasibility using existing knowledge of model/framework, e.g. Detectron to analyse segmentation results, e.g. ROC chart Investigate a variety of feature detection algorithms for continued improvement in accuracy	70-80% accuracy for lab conditions
Milestone III: Simulate real environmental conditions in the laboratory	
Controlled variation of environmental conditions including: • lighting • rainwater on the lens/plants • effect of plants moving in wind (sudden gusts) • occlusion This stage likely includes further model refinement	90% accuracy for simulated non-ideal conditions
Milestone IV & V: Field trials (NZ & Aus respectively)	
• a test field to be prepared which will be used for the trials • testing potential flight patterns to discover optimal path • testing on larger scale Collect the above real-world data and model refinement for continued improvement in accuracy	90% accuracy for real conditions in NZ, building to >95% accuracy NZ & Aus conditions combined

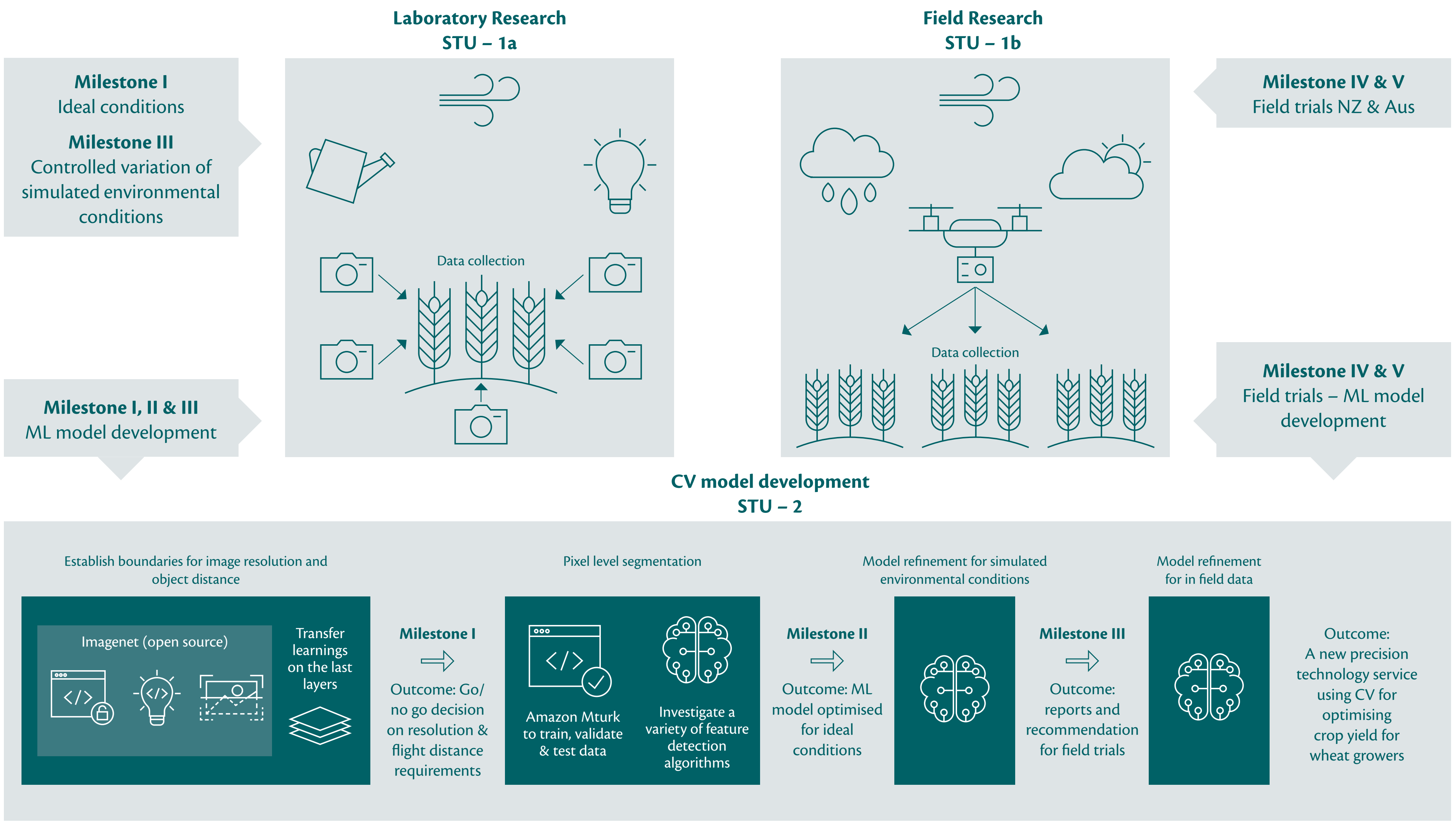
Systematic approach

A systematic approach involves a planned, logical investigation to solve the problem (for example through testing, experimentation, or prototyping). A systematic approach can be flexible and adaptive, changing in response to results, but the approach remains logical and focused on solving the problem.

In this example the R&D is yet to happen. However, the systematic approach still demonstrates how the business expects to resolve its technical problems and the technical knowledge gap it anticipates.

The business has used the systematic approach to help provide further context to the technological uncertainties. It has proposed several solutions to technological problems it plans to undertake. This is not essential but can help provide additional substance to the activities planned when explaining the eligibility of the R&D project.

Wheat growing | CV model development & image resolution



Key

STU – scientific or technological uncertainty
Aus – Australia
ML – machine learning

Points to note

Benchmarking the technological uncertainties

Remember, a key matter to consider is how to demonstrate that the knowledge required to resolve the technological uncertainties are not publicly available, or deducible by a competent professional in the relevant field.

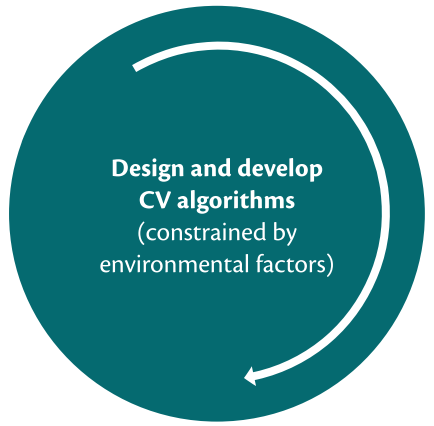
The following table demonstrates how to benchmark the technological uncertainties.

Remember – the general approval application example 3 in the Appendix provides a full description of the eligible RDTI activities. This is the expected level of detail we require. You must focus on the **dark teal** bullseye (dart board tool) and be technical in nature.

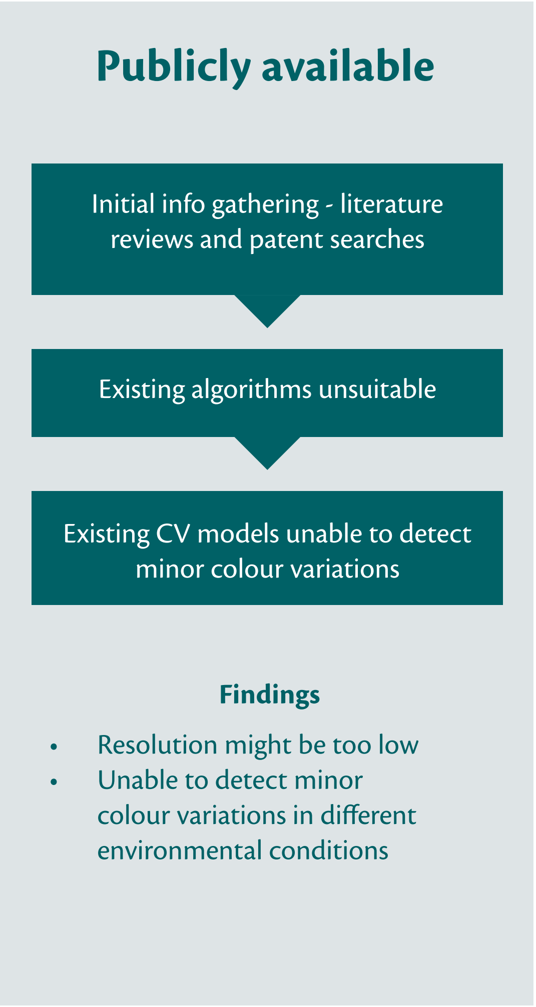
The publicly available test	The competent professional test	Example demonstrating when these tests are not met
There are known solutions for CV models and detection algorithms. For example, ImageNet and Detectron. It is recognized that R&D activity can build on prior knowledge and solutions. So it is important to explain how this R&D builds on these publicly available solutions, what is different and why.	This test is demonstrated in the scientific and technological methods required by the business to resolve the uncertainty through the systematic course of investigation and experimentation. The detail provided in the systematic approach helps support the complexities of the work required, providing an insight into the problem solving required to resolve the technological uncertainties. If the competent professional is only undertaking tests to confirm that a common solution to a common problem could be resolved, then the R&D is not eligible for funding under the RDTI. Note: To help determine where your activities fall, the diagram [below] demonstrates how you might compare a "common solution to a problem" versus "investigate and/or experimentation". You may consider several factors when coming to your conclusion, and on balance demonstrate that sufficient activities are undertaken to "tip the seesaw" towards technological uncertainty. General examples are narrated in the dotted line and then applied to the CV model example (along with the publicly available test).	If the competent professional is only undertaking tests to confirm that a common solution to a common problem could be resolved, then the R&D is not eligible for funding under the RDTI. This is demonstrated in example 1b of the general approval application in the Appendix.

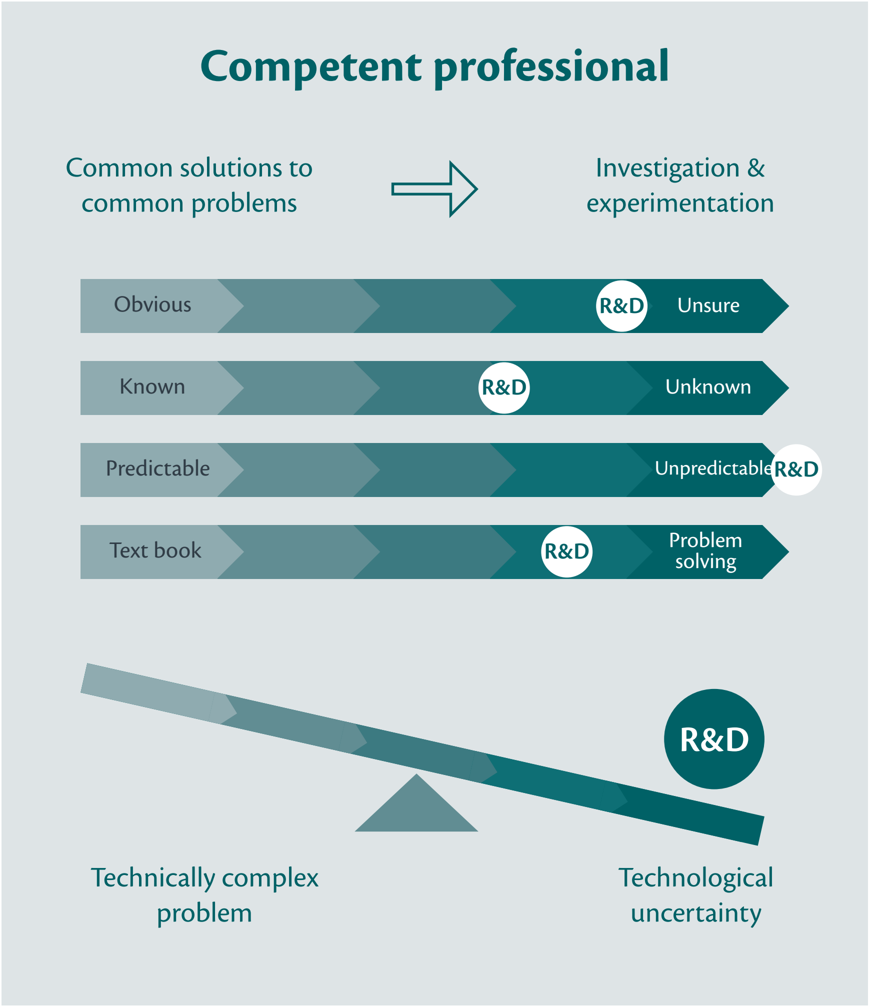
Core activity

The technological uncertainties

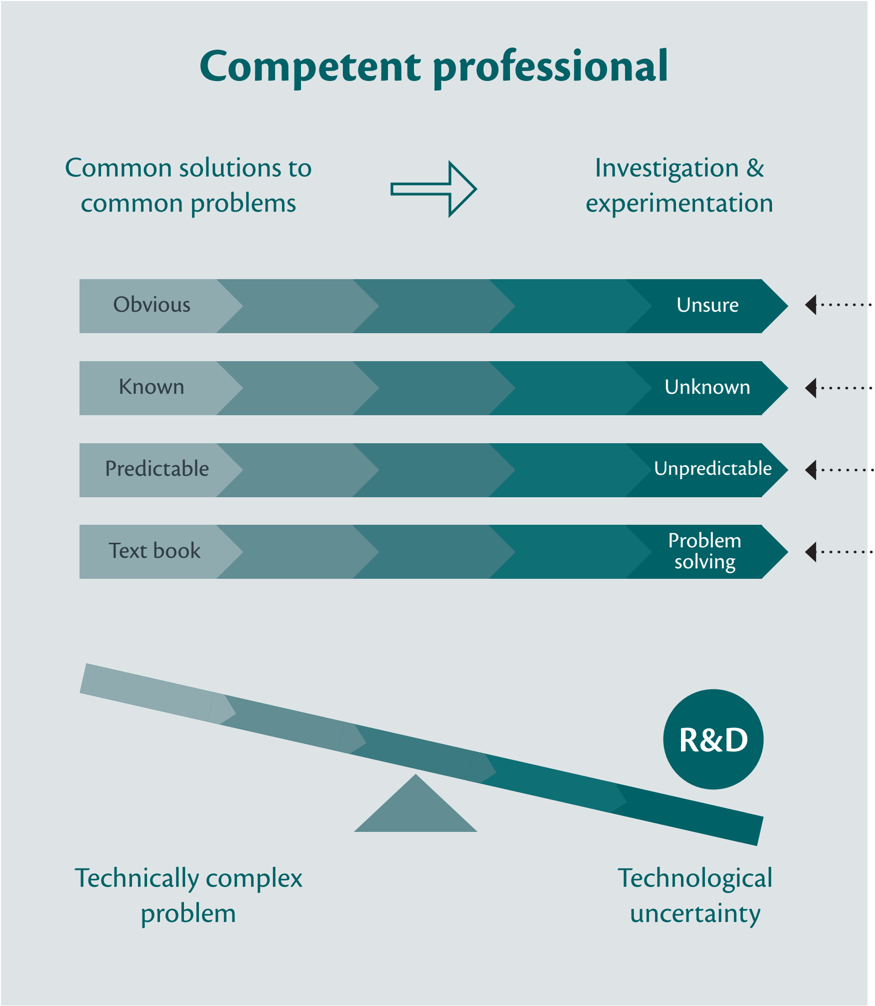


Benchmarking the technological uncertainties





General examples: Competent professional



A competent professional (CP) is aware of the current state of knowledge in the field but is unsure how to solve the scientific or technological problem

A CP may be confident that an objective can be achieved but do not know how to achieve it

There may be unpredictable results creating uncertainty from a scientific or technological perspective as to whether the product specifications can be achieved

A CP would need to undertake a systematic course of investigation to resolve the uncertainty using investigative problem solving

Points to note

Core & supporting R&D

Refresher

Core vs supporting R&D

Eligible R&D activities must involve core R&D activity. There may also be supporting activities.

Type of activity	Definition
Core activity	An activity that has the material purpose of creating new knowledge or new or improved processes, services, or goods. It must also attempt to resolve scientific or technological uncertainty using a systematic approach.
Supporting activity	An activity that has the only or main purpose of supporting the core activity.

Core, supporting and excluded activities

Refresher

Excluded activities

Certain activities are ineligible core R&D activities. A smaller number are ineligible supporting R&D activities.

Further information on supporting R&D activities can be found on the IRD website. Go to **www.ird.govt.nz/** Enter keywords: 'r&d eligible activities' or 'r&d ineligible activities' in search box.

To demonstrate the core and supporting R&D activities for the CV example, and the ineligible excluded activities, we have included the following table and diagram.

What are core and supporting R&D activities?

What are **excluded** activities?

Core, supporting and excluded activities

Core & supporting activities	Only core and supporting activities are funded under the RDTI. Some business-as-usual activities can be funded as supporting R&D activities. To get funding the only or main purpose of these activities MUST be to support the core R&D activity (in other words, the R&D could not go ahead without these activities). **Supporting R&D - outside of New Zealand** The Australian field trials are part of the data collection required to improve the accuracy of the CV model. The outcome is to develop a robust global CV model that will operate in multiple environmental settings. In the CV example, the Australian field trials are funded as a supporting R&D activity. Note: It is important to remember that you do not receive automatic funding for overseas R&D expenditure as they are excluded from being a core activity. To help determine the amount of funding available for overseas activities, follow the "Step plan: overseas R&D activities".
Excluded activities – do not get funded	Certain activities the business undertook in the CV example are ineligible for funding. For example, market research and applying for patents in respect of any new software would not be eligible.
Commercial project vs RDTI funded activities	The whole commercial project does not get funded, only the core & supporting activities are funded. The project narrative included in the general approval (example 3 in the Appendix) focuses on the RDTI funded activities. For example, the company's market research and commercialisation and sales strategy are not included within the General Approval application because these activities are not funded under the RDTI.

Step plan:

Overseas R&D activities

To determine what activities undertaken outside of New Zealand are funded and by how much, you must follow the steps as outlined below.

Step 1: Are the activities undertaken outside New Zealand eligible for funding?

To determine if the activities undertaken outside New Zealand are eligible for funding you must demonstrate the following:

Test	Computer vision example: Australian field trials
The core R&D activity is performed in New Zealand	The core R&D activities performed in New Zealand are demonstrated in the systematic approach (milestones I-IV) and relate to the development of the CV model accuracy through increasingly complex data sets.
The only or main purpose of the activities are to support the core R&D activity	The purpose of the Australian field trials is to collect new data specific to that environment which is integral to the development of the accuracy of the CV model as a global precision technology service.
Step 1 answer:	The activities are eligible for funding under the RDTI as supporting activities.

Step 2: How much of that expenditure gets funded under the RDTI?

Once you have determined whether the overseas activities are eligible for funding as a supporting activity, you must then determine how much of that expenditure can be funded.

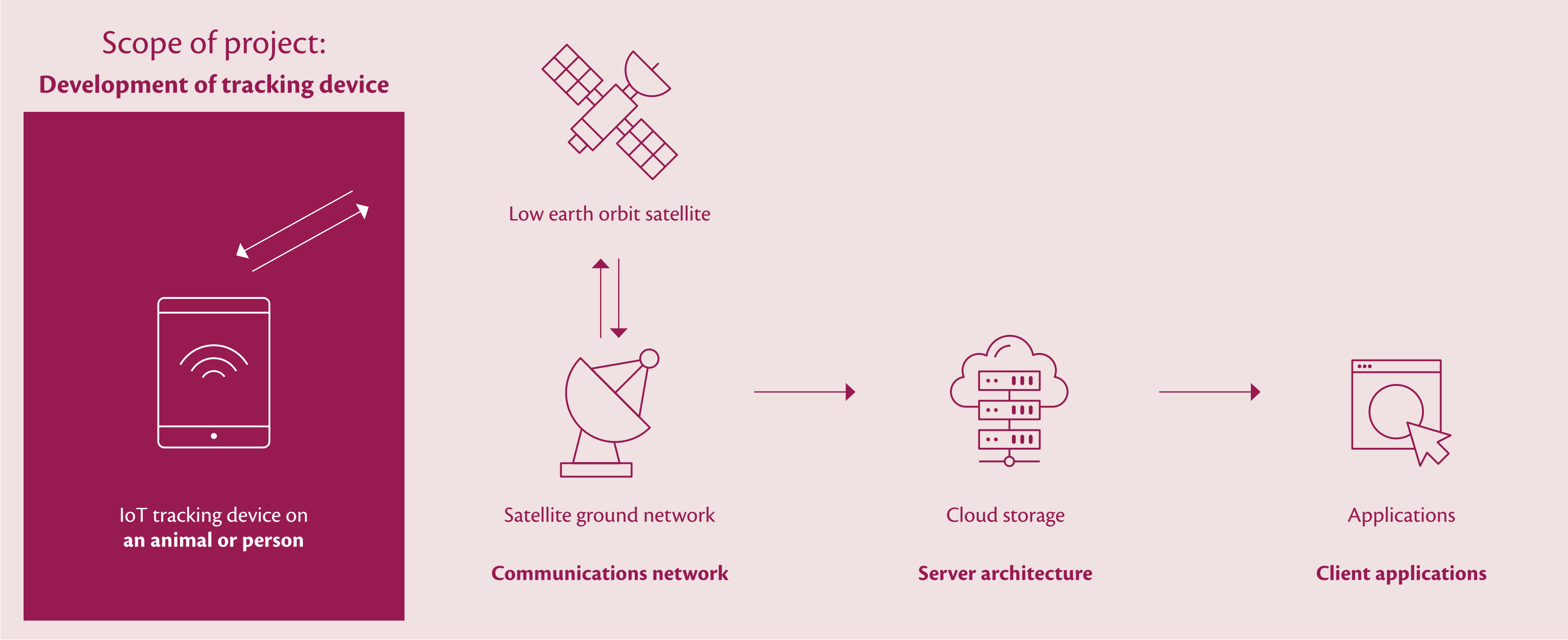
Where you incur expenditure on a supporting R&D activity outside of New Zealand, your eligible expenditure is the lesser of your actual expenditure incurred on the activity overseas, and 10% of your total eligible expenditure.

Step 2 answer: the expenditure funded for the Australian field trials is limited to 10% of the total R&D eligible expenditure (or the actual amount if lower).

A low-cost, satellite-based Internet of Things (IoT) location tracker

This example looks at a hypothetical end-to-end system for an IoT tracking device attached to an animal's collar or people out hunting or tramping, utilising positioning technology to track latitude, longitude, and height. The applications include tracking over long time periods in remote locations with no access to other communication networks.

The RDTI example is focused on the development of an IoT tracking device (including hardware and software) required to create the product and service offering. The scope of this project does not include the cloud storage, or the application used to track the device.



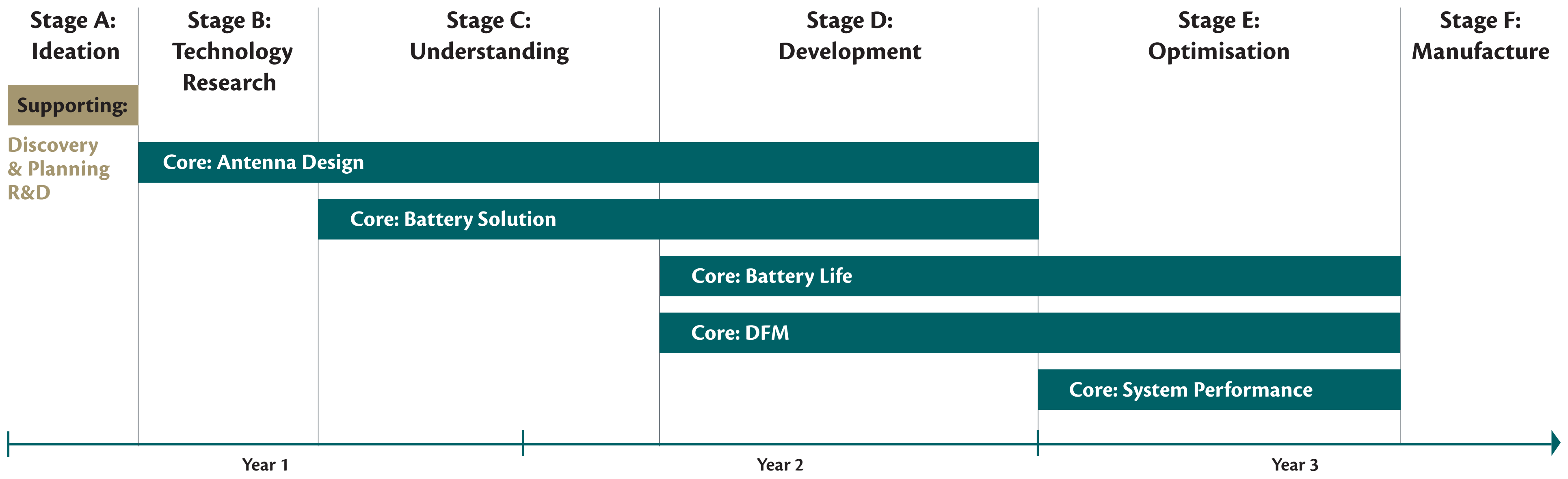
The business is undertaking a 3-year product development phase where the intended product specifications, scientific or technological uncertainties (STU), and core and supporting activities evolve over the course of the project. The business will initially apply for general approval of its activities, and then either apply for a variation of its approval (if materially different to the original application) or apply for a new approval of new activities.

Instead of including several general approval applications with this example, Appendix: A step-by-step guide to the dimensions of the challenge contains a summary of the core research and development, the uncertainties in the core and the systematic approach to the activities undertaken as the project progressed. This tool is intended to guide you through the example and how this would form the respective parts of a general approval application.

Before continuing, to more fully understand the evolving technical issues arising in this example we suggest you read the Example 4 general approval application on page 82 of the Appendix.

Please note, it is not a requirement that you provide a visual representation of your project when applying for the RDTI.

Overview: The core activities



The highlights

The commercial project

To develop a low-cost, satellite based, IoT tracking device for animals or people in remote locations with no access to other communication networks.

The technical problem

Product specifications

Problem statement: to develop an IoT end-user tracking device within the following product specifications:

- device size 4cm x 3cm x 1cm
- device weight <300g
- design for manufacture (DFM) to achieve 30 secs assembly time
- cost of goods to produce <$20 per unit
- internal antenna preferred.

The product specifications create constraints that affect the technological uncertainty. The specific uncertainties identified at the start of the project are below.

Battery life

Problem statement: to develop long-lasting battery life within defined technical constraints.

Performance parameters: the performance parameters of the project are:

- battery size 4 cm3
- battery life > 5 years
- a specified usage pattern - one location report per hour.

Communication link budget

Problem statement: to develop link power within defined technical constraints.

Performance parameters: the performance targets of the project are:

- transmit power 200mW (23dBm)
- device antenna gain is 3dBi at the operational frequency.

How the technical problem became a technological uncertainty

The technical problems created by the product specifications may create scientific or technological uncertainty (STU). This is because the technology needed to meet all product specifications simultaneously is unknown.

The trade-offs between product specifications and the technology needed to achieve these goals is iterative throughout the product development life cycle. This means the STU can evolve and flex based on the results of the investigative steps undertaken.

The development may be affected by the commercial reality that compromises will have to be made due to cost and time constraints. This does not preclude the product from qualifying from RDTI if the product is still of a quality sufficient for sale.

Explaining technological uncertainties in the diagram below

The outer **dark teal** line in the diagram demonstrating the technological uncertainty on page 50 represents the ideal product specifications that the business wants to achieve. It is likely this line will flex and evolve during the stages of product development.

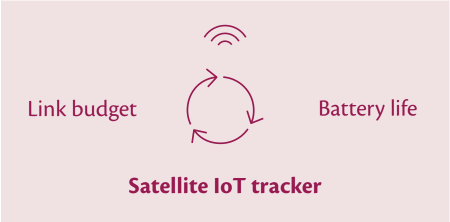
The **dark teal** dotted line and heads of the arrows represent where the current knowledge is for each technology in the product specification.

The product specification within the **dark teal** dotted line is not a STU as it is known to be possible. Instead, the STU arises beyond the dotted line.

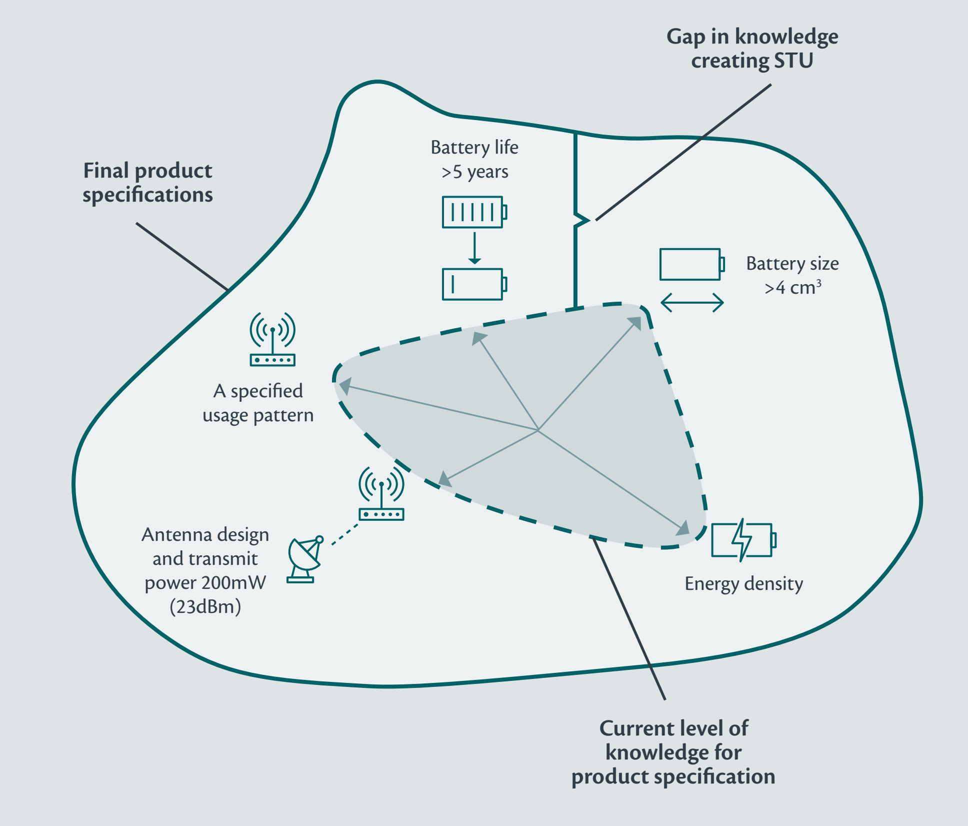
This diagram uses the dartboard colours where the **dark teal** bullseye demonstrates the critical RDTI information.

It tracks the project's progress from the **ruby** commercial objectives to the **dark teal** technological uncertainties.

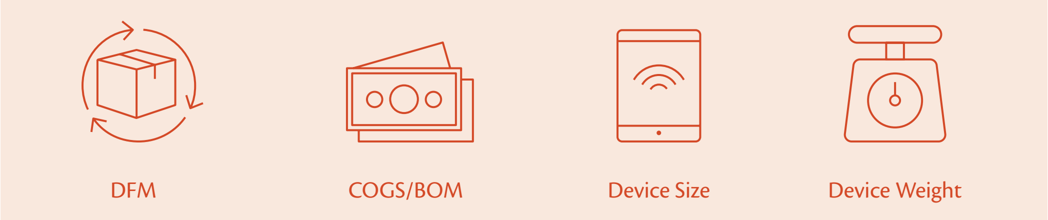
The commercial project

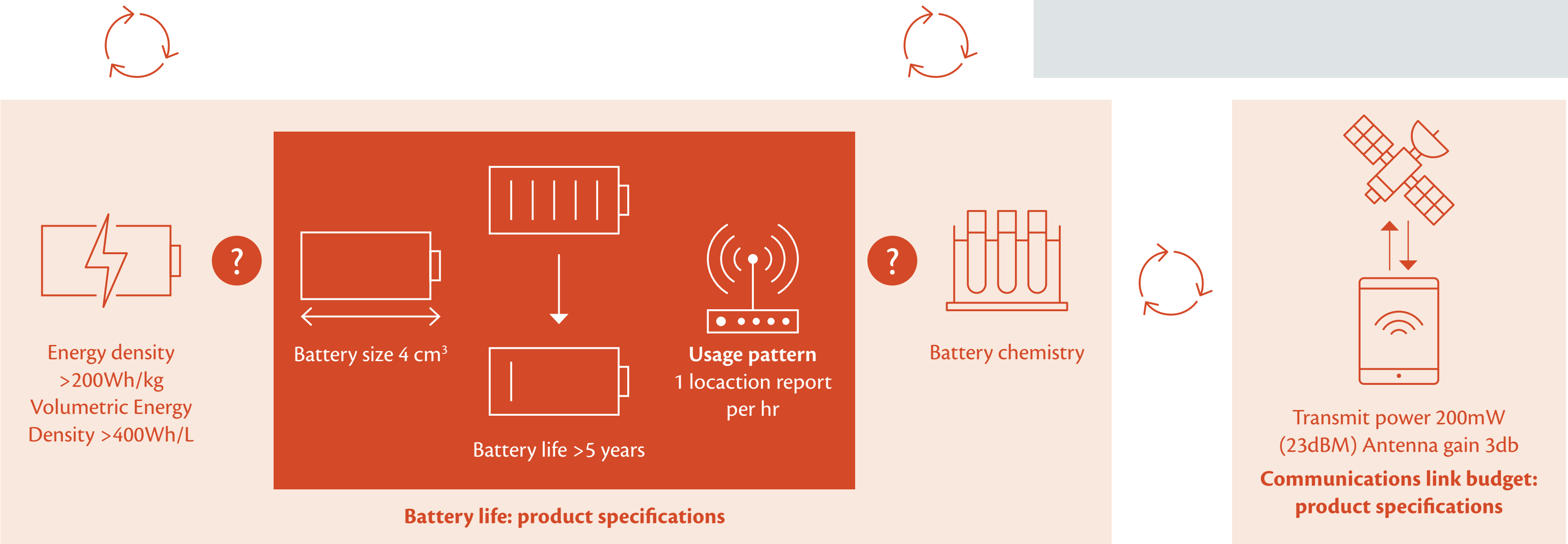


The technological uncertainties



The technical problem





Key

STU – scientific or technological uncertainty
DFM – design for manufacture
COGS – cost of goods sold
BOM – bill of materials

Points to note

The general principles of RDTI eligibility

The general principles of RDTI eligible activities require all 3 aspects of the eligibility requirements to be met. The following table introduces an example of a product development lifecycle and how it could apply to the general principles of RDTI eligibility. This approach steps through the process of the Problem > R&D Plan > Investigate > Outcome.

The technological uncertainties	These are the technological problems with "unknowns". This example shows how uncertainty can exist because of competing product specifications.
The systematic approach	'How' the problems causing the technological uncertainties are addressed. The 'plan' and 'investigate' phases are directly related to the relevant technological uncertainties. The R&D plan involves undertaking investigative steps to work towards resolving the technological uncertainties. We provide further detail in the 'Introduction to a step-by-step guide to the dimensions of the challenge' (and its respective Appendix).
The new or improved...	The resulting outcome is clearly stated. The "why" the R&D was undertaken. In this case, to develop a new product and service.

Remember – the general approval application example provides a full description of the eligible RDTI activities. You must focus on the **dark teal** bullseye (dartboard tool) and be technical in your description.

Overview:

A product development lifecycle

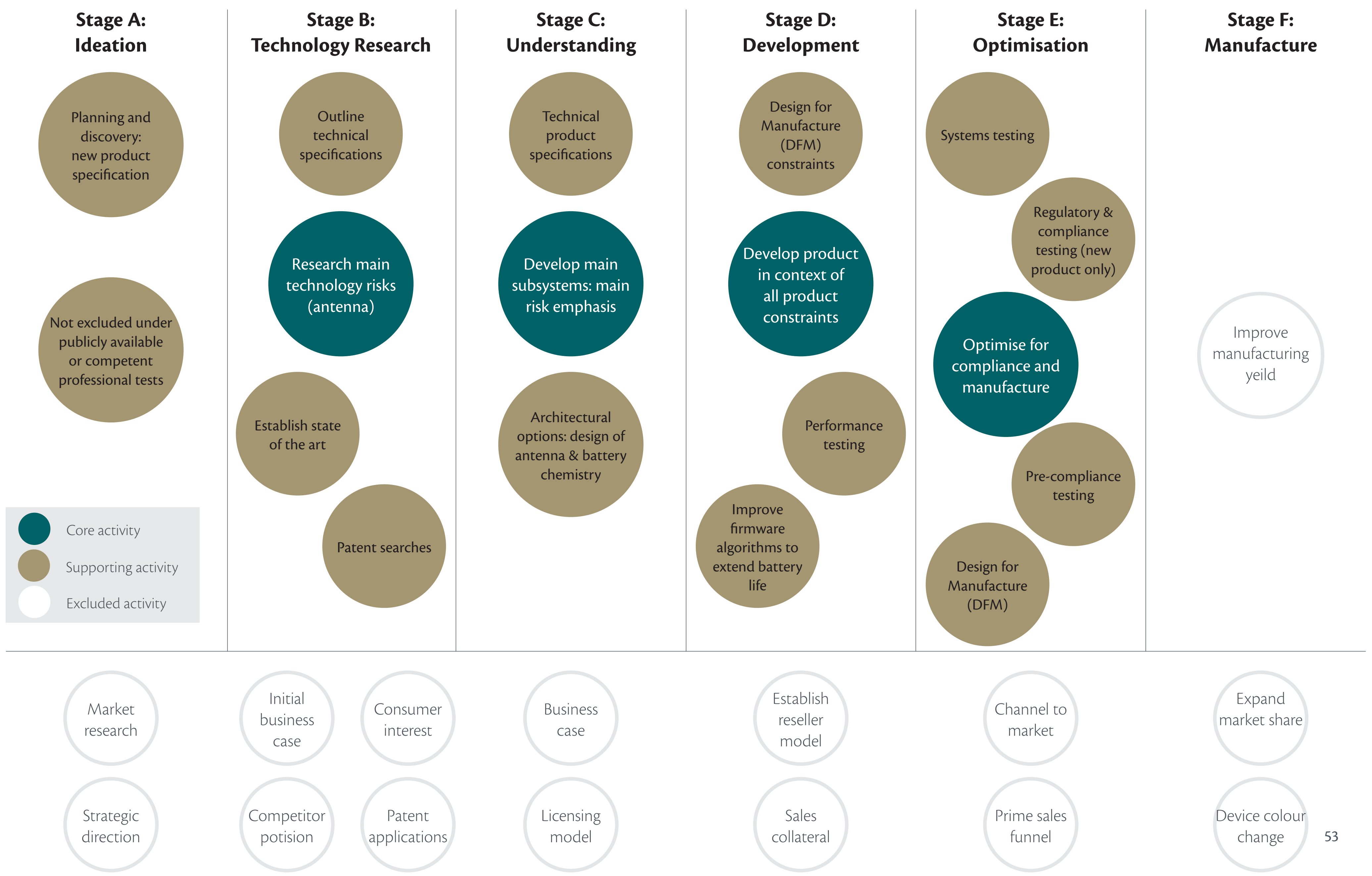
This is a hypothetical example of a product development lifecycle. You may use alternative methods depending on your industry. This example simply demonstrates the practical application of the RDTI in a digital product development environment.

The diagram below demonstrates the different stages of this product development lifecycle. The stages are only used for reference purposes and are not specifically required for the RDTI application.

Stage A	Ideation
Stage B	Technology Research
Stage C	Understanding
Stage D	Development
Stage E	Optimisation
Stage F	Manufacture

Please note: Only core (**dark teal**) R&D and supporting (**brown**) R&D activities are eligible for the RDTI, excluded activities (**grey circles on white**) are not eligible. Core, supporting and excluded R&D activities can arise at any stage of the product development life cycle. Further detail on supporting and excluded R&D activities are detailed in the respective sections of this document.

Stages of product development



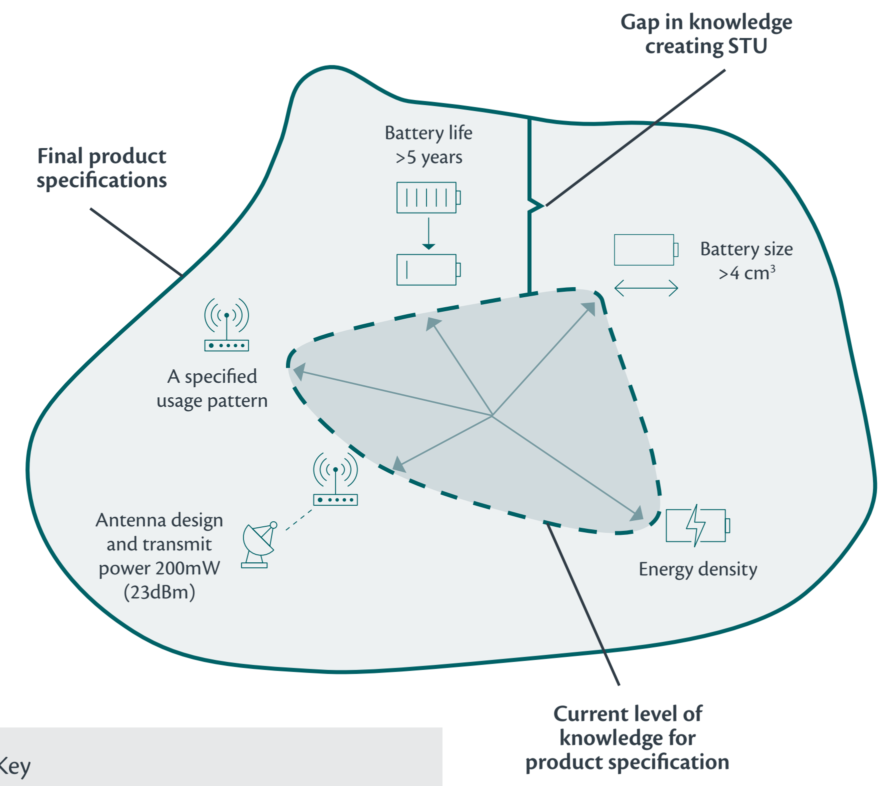
Introduction to a step-by-step guide to the dimensions of the challenge

Describe the core activity

The first diagram to the left shows the desired product specifications at the beginning of stage A: ideation, and the current state of knowledge. The inner **dark teal** dotted line shows where the current knowledge base sits for each product specification, and the outer **dark teal** line shows where the knowledge needs to grow to achieve the product goals. There is a clear knowledge gap.

The Appendix includes a step-by-step guide demonstrating how the dimensions of the challenge can result in an evolving STU throughout the stages of the product development lifecycle from stage A through to stage E. There are several trade-offs and decision points based on the success of the new technology and changes in the ultimate product specification (the outer **dark teal** line of the diagram). Throughout the product development lifecycle both the product specifications change (reflected by the movement in the outer **dark teal** line) and the new knowledge to meet the specification grows (reflected by the movement in the dotted line). The second diagram to the right shows the end result for product release, with more product specifications added and the growth of the knowledge base. The dotted line is what was achieved at the end of the R&D with that final knowledge achieving more or less than the final amended plan.

Current state of knowledge



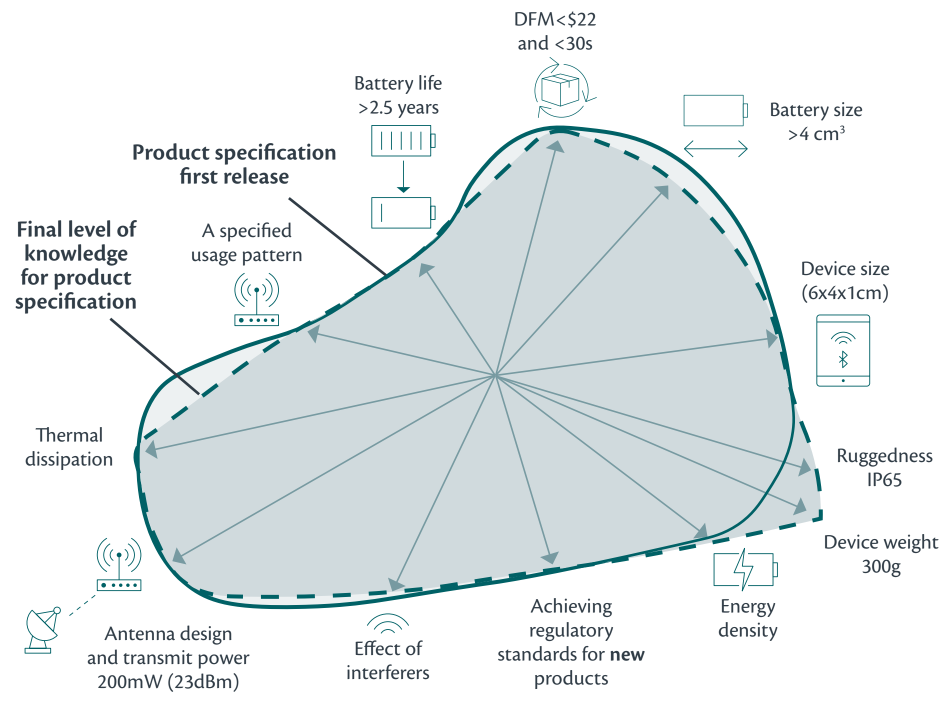
Key

STU – scientific or technological uncertainty
DFM – design for manufacture

Systematic approach

Work is considered systematic if it is sufficiently planned and structured to test possible solution(s) and generate valid results. The systematic approach must relate to the resolution of the uncertainty. This includes possible solutions, the proposed or actual activities and the results of tests or experiments (if known). For a multi-year application, the activities should reflect the plan for the whole period of the application (accepting it will develop and change as the years progress). In this example the R&D is iterative. Regardless, the systematic approach still demonstrates how the business expects to resolve its technical problems and the technical knowledge gap it anticipates as it flexes and evolves.

End result



Points to note

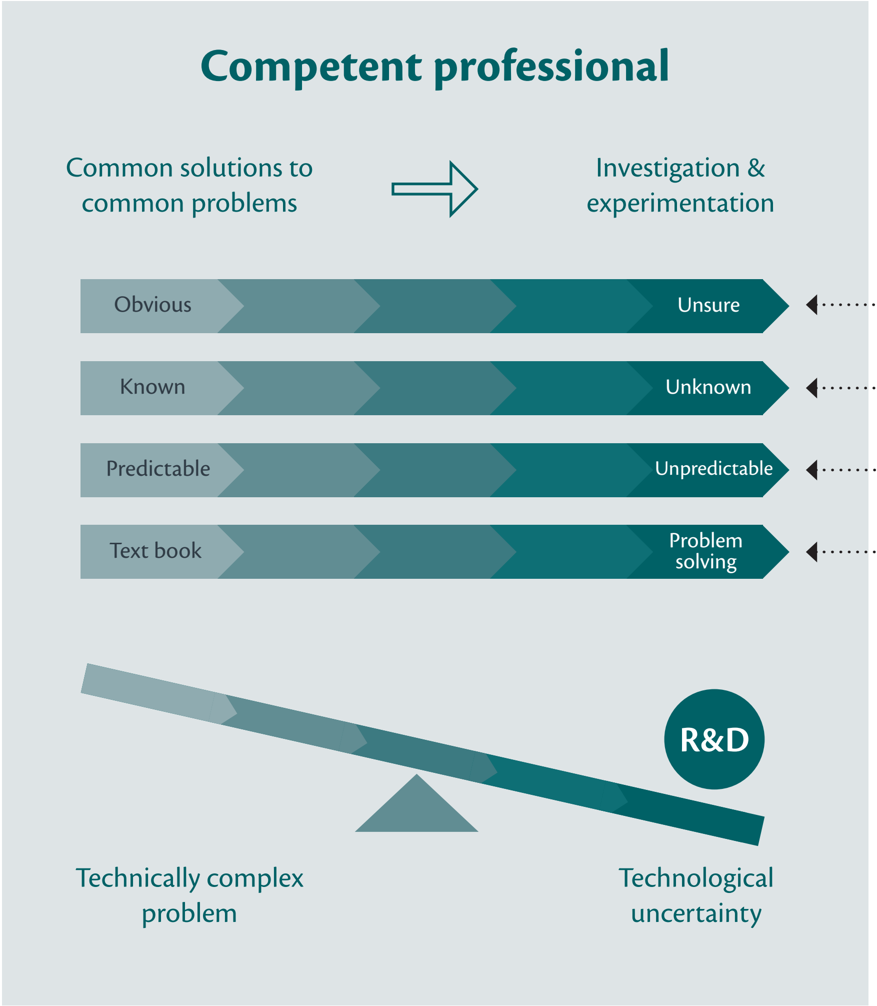
Benchmarking the technological uncertainties

Remember, a key matter to consider is how to demonstrate that the knowledge required to resolve the technological uncertainties is not publicly available, or deducible by a competent professional in the relevant field.

The following table demonstrates how to benchmark the technological uncertainties.

The publicly available test	The competent professional test
There are known solutions to meet product specifications to a lesser standard. It is recognised that R&D activity can build on this prior knowledge and solutions. Therefore, it is important to explain how the R&D builds on these publicly available solutions, what is different and why.	This test is demonstrated in the scientific and technological methods required by the business to resolve the uncertainty through the systematic course of investigation and experimentation. The detail provided in the Appendix "Introduction to the step-by-step guide to the dimensions of the challenge" helps support the complexities of the work required, providing an insight into the problem solving required to resolve the technological uncertainties. Note: To help determine where your activities fall, the diagram to the right demonstrates how you might compare a "common solution to a problem" versus "investigation and/or experimentation." You may consider several factors when coming to your conclusion, and on balance demonstrate that sufficient activities are undertaken to "tip the seesaw" towards technological uncertainty. If the competent professional is only undertaking tests to confirm that a common solution to aecommon problem could be resolved, then the R&D is not eligible for the RDTI credit. General examples are narrated in the dotted line and then applied to the IoT example in the Appendix.

General examples: Competent professional



A group of experienced engineers have compared the product specification to that which is tecnologicallly possible today and were unsure if the specification could be achieved.

The project identifies a number of challenges where it is unknown how to achieve them.

The product specifications identify constraints that collectively compete against one another. This created a situation where the results are unpredictable.

A group of experienced engineers have reviewed the identified uncertainties and concluded they would need to undertake a systematic course of investigation to resolve the uncertainty using investigative problem solving.

Points to note

Core & supporting R&D

Refresher

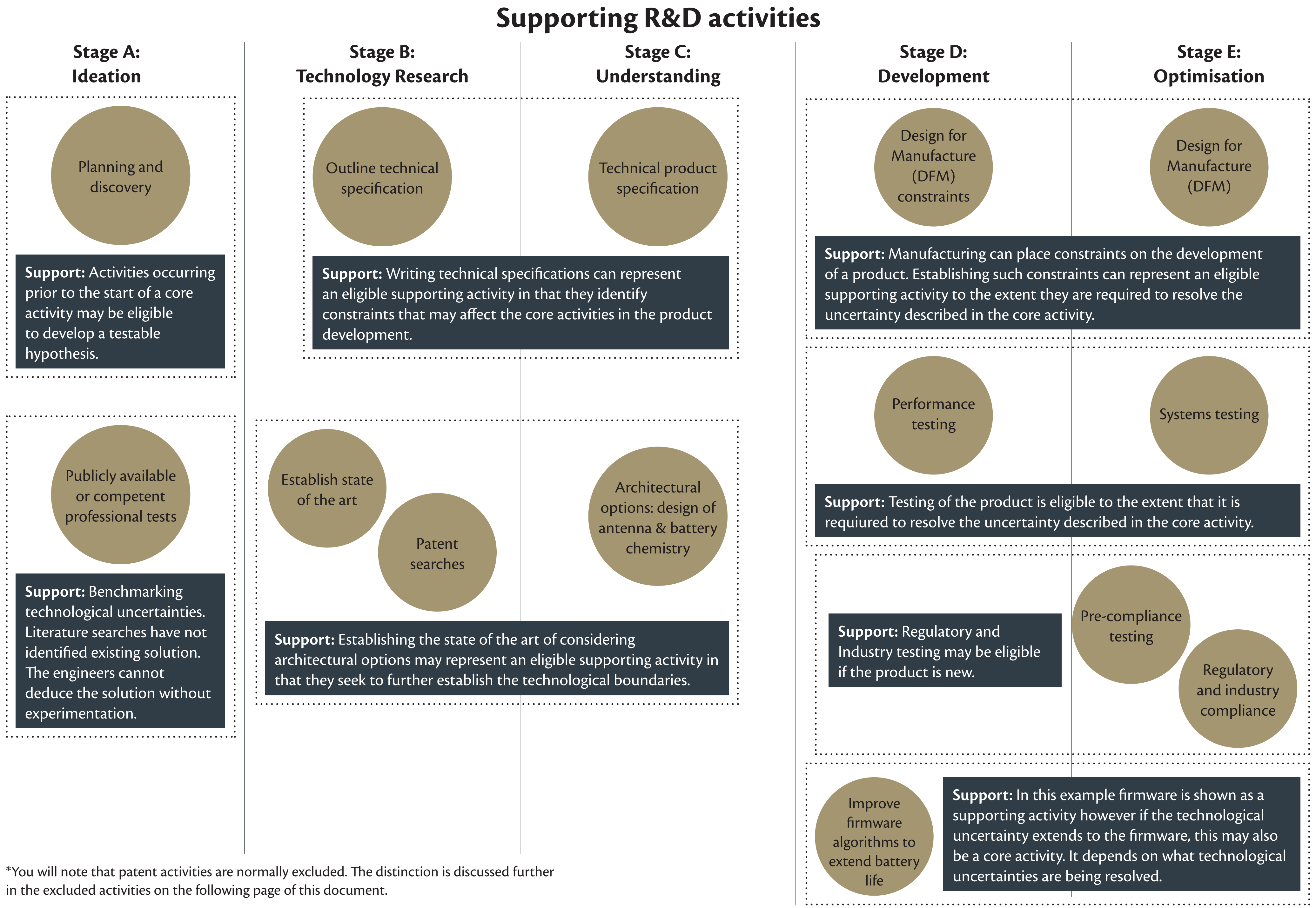
Core vs supporting R&D

Eligible R&D activities must involve core R&D activity. There may also be supporting activities.

Type of activity	Definition
Core activity	An activity that has the material purpose of creating new knowledge or new or improved services or goods. It must also attempt to resolve scientific or technological uncertainty using a systematic approach.
Supporting activity	An activity that has the only or main purpose of supporting the core activity.

Supporting R&D activities

To be a supporting R&D activity, the only or main purpose of these activities MUST be to support the core R&D activity. At the same time, the R&D could not go ahead without these activities. The diagram below shows that supporting activities could happen at any stage of the product development lifecycle. In the IoT example they occur in stages B to E. The diagram also gives a brief description of why the activity supports the core R&D.



*You will note that patent activities are normally excluded. The distinction is discussed further in the excluded activities on the following page of this document.

Refresher

Excluded activities

Certain activities are ineligible core R&D activities. A smaller number are ineligible supporting R&D activities.

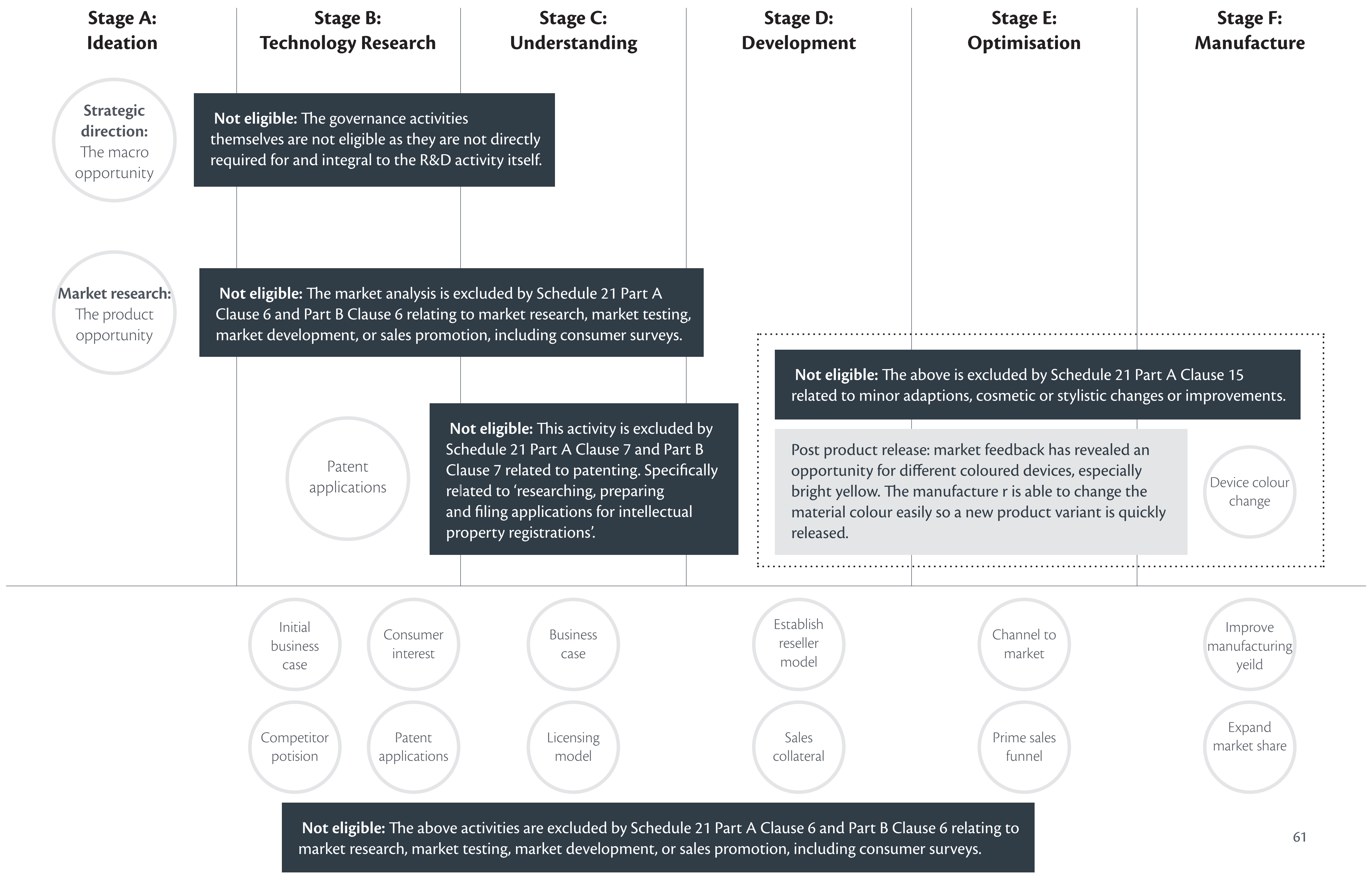
Further information on supporting R&D activities can be found on the IRD website. Go to **www.ird.govt.nz/** Enter keywords: 'r&d eligible activities'or 'r&d ineligible activities' in search box.

Excluded activities are not eligible for the RDTI. The diagram below shows that excluded activities could happen at any stage of the product development lifecycle. In the IoT example, they occur in stages A to F. The diagram also gives a brief description of why the activity is excluded.

Note: patent-related activities are normally excluded. The distinction lies in what the activities in relation to the patents involve.

- Possible eligible (supporting) activities: patent searches which are part of understanding your technology and identifying technological uncertainties.
- Ineligible (excluded) activities: researching, preparing, and filing applications for your own intellectual property registrations. This includes any associated costs.

Activities excluded from R&D



Points to note

When does the R&D start and finish?

Refresher

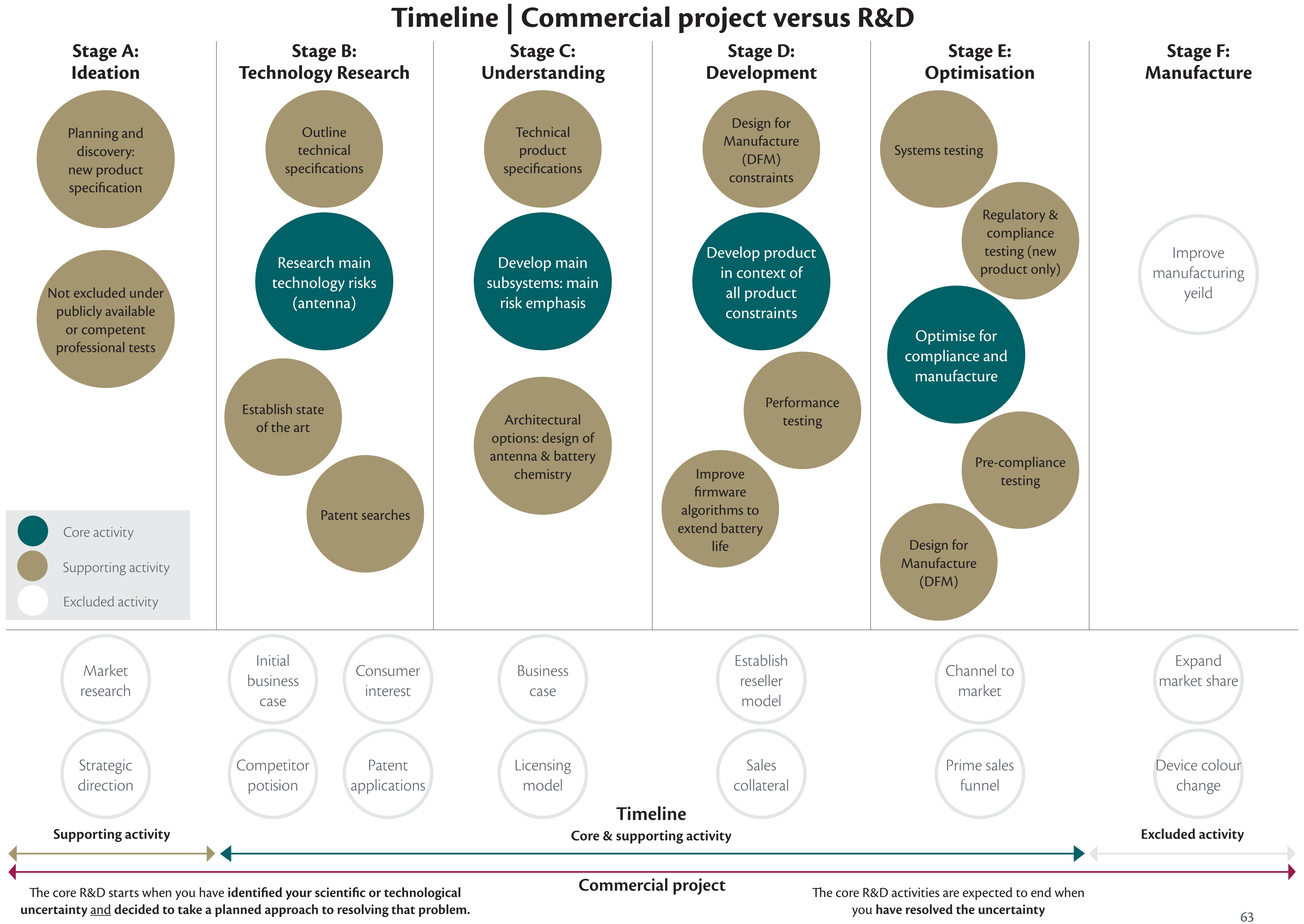
Beginning and end of core activities

The core R&D starts when you have identified your scientific or technological uncertainty and decided to take a planned approach to resolving that problem (Stage B: Technology Research).

The core R&D activities are expected to end when you cease to measure and evaluate the extent to which your activities have resolved the scientific or technological uncertainty.

Further information on when R&D activities start and finish can be found in the Research and Development Tax Incentive IR1240 Guidance. Go to **www.ird.govt.nz/** Enter keywords: 'r&d eligible activities' in search box.

The following diagram demonstrates when the core R&D started. Supporting R&D activities can still be claimed in the Ideation Stage A before the core R&D starts and after the core R&D finishes at the end of the Optimisation Stage E. It cannot be claimed as support activity unless the project goes ahead, and the core activity commences in Stage B. A timeline for the application is included for reference purposes only.



Appendix

Disclaimer

The examples in this guidance are fictitious and are not meant to describe real examples of scientific or technological uncertainty or eligible activities. Rather they are intended to show the types of information needed in an application that will help us assess the eligibility of the activities. The level of information needed will depend on the nature and complexity of the R&D activities you are applying for.

Appendix

A security system for a building site

Projects

An **eligible** & approved application

Project identifier

The real-time staff site identification (RSSI) project

Start date: 1 April 2021	**End date:** 31 March 2022

Project objective

Develop a smart facial recognition security system to identify authorised personnel entering multiple building sites in New Zealand. This requires:

- Security cameras with a full http stack to capture facial images,
- An investigation into existing technology for small businesses using edge processing and security cameras with an http stack. This demonstrated the limitations of the existing technology and a preference for a cloud based matching system. Thus, a new system was approved for development to upload facial images into a cloud-based server to perform the facial recognition matching technology,
- For a successful recognition match send an approve signal to open the automated gate or, if no successful recognition, send a request to the site manager to consider 'validating manually'.

Feasibility studies reveal staff have accepted the privacy implications of their photographs being held in the cloud but are concerned about the possibility of false negative or positive results impacting safety and timeliness of entry. Staff have commented that 'nobody wants to wait outside in the rain and cold for a computer to decide that somebody who's worked for the company for 20 years is okay to get into work'.

Core activity

Related project with a core activity involving 3 interrelated activities

The real-time staff site identification (RSSI) project

The primary objective is to identify personnel on building sites in different locations with a minimum impact on workers. We set a requirement for automatic and secure real-time identification and confirmation of a person visiting a particular site is on an approved list. Secure is defined as '<1 false positive per month with an assumed 300 visitors per month.'

This core activity and the technological uncertainty is to resolve whether it is possible to develop a facial recognition engine to match images taken by an on-site security camera with images stored in a database of images, within the required parameters.

The technical requirements for an automatic and secure real-time facial identification and confirmation security system are:

- Develop compression algorithms that would provide the smallest possible file sizes while maintaining accurate and real time results.
- The camera must take an accurate picture in changeable and challenging weather and light conditions.
- The facial recognition needs to be processed either on the edge or through secure and fast transmission of the image to a facial recognition/ inference engine in the cloud.
- The recognition needs to be in near real-time with the decision to use cloud processing made relatively early in the project. It was necessary to research acutance and resolution performance tests required to establish the standards necessary to meet the required recognition performance metrics.
- We undertook Investigative and experimental activity in facial recognition engines, acutance and image resolution requirements, compression and transmission optimisation using a systematic approach designed to resolve our technological uncertainties.

Benchmarking the technological uncertainties:

1. Is the knowledge to resolve the uncertainty publicly available?

We conducted literature reviews, patent searches, scoured online journals and engaged with providers of solutions. This included reviews of both edge or cloud based facial recognition engines and models, transmission technology, and compression algorithms.

Example 1a

We established through tests with available technologies that there was no solution currently available that would meet the technical requirements – recognition rates were too low, or throughput speed did not meet the business requirements.

2. Is the knowledge to resolve the uncertainty deducible by a competent professional in the relevant scientific or technological field?

We established that a competent professional in the field could not deduce the outcome of the scientific or technological uncertainty without undertaking an investigative and experimental approach to create new knowledge in this field and to develop this new or improved process and service.

Activity 1.

Development of compression algorithms to enable cooperative 1:N matching, capture and pre-processing on the edge, training and inference in the cloud.

Scientific or technological uncertainty

It was unknown what level of image compression was required to resolve the trade-off between transmission speed vs inference speed and accuracy.

We had a requirement to meet the following performance parameters:

- a total identification throughput turnaround of less than 3 seconds from capture to decision to allow or deny access: and
- as the site had no internet connections site data needed to be transmitted from a mobile connection at the work site, with a minimum of a 3G connection using TCP/IP and SSL protocols: and
- transmission time to be less than 1 second, with less than 2 seconds of inference time (the time to process and recognise): and
- less than 5% false negatives and less than .5% false positives, with an average 300 visits per month.

Systematic approach to resolve uncertainty

We undertook a systematic approach of research and development of novel compression algorithms for images so that a decision could be made which settings would provide the best overall performance.

We conducted tests in various environmental conditions of throughput speeds for different compression algorithms while satisfying the requirement for accuracy, developing a matrix showing the various accuracies with various compressions compared to throughput speeds.

Describe new knowledge; new or improved processes, services or goods

Through the development of new knowledge in compression algorithms, new processes and services have been developed with the intention of enabling online facial recognition comparison at speeds not achieved previously.

Activity 2.

Research and development of acutance and resolution standards for security camera images for facial recognition.

Scientific or technological uncertainty

It is unknown what acutance (constrained by cost of hardware) and resolution (constrained by cost in hardware and total identification time) would be needed to meet the required recognition performance metrics while still meeting the time and cost constraints.

Systematic approach to resolve uncertainty

We undertook a systematic approach of research and development to establish the minimum acutance and resolution of images that could still achieve the required accuracy results.

Based on reviews of available technology we chose three different camera systems which presented varying acutance levels and tested the minimum acutance for recognition in lab conditions using ISO12233 charts to measure MTF and confirm manufacturer claims.

We then tested the cameras under differing environmental conditions (weather, lighting) to determine how they impacted on the image acutance. We performed tests at different resolutions to determine the impact on recognition accuracy and throughput in the inference engine.

Describe new knowledge; new or improved processes, services or goods

The outcome of this activity was to establish new knowledge of which cameras offering secure data transfer via a 3G connection:

- produced the best results through various facial recognition engines in the majority of environmental conditions,
- had the acutance levels and resolution to meet the required recognition performance metrics for recognition and identification.

Activity 3.

Development of facial recognition engine for cooperative 1:N matching- capture and pre-processing on the edge, training and inference in the cloud.

Scientific or technological uncertainty

We were uncertain:

- which facial recognition engines/models were suitable for use with the images we were capturing:
- which facial recognition models worked best in changing and challenging environments:
- what was most efficient for speed of throughput - edge based facial recognition vs cloud engines for facial recognition.

We had a requirement to meet the following performance parameters:

- a total identification throughput turnaround of less than 3 seconds from capture to decision to allow or deny access: and
- as the site had no internet connections site data needed to be transmitted from a mobile connection at the work site, with a minimum of a 3G connection using TCP/IP and SSL protocols: and
- transmission time to be less than 1 second, with less than 2 seconds of inference time (the time to process and recognise): and
- less than 5% false negatives and less than .5% false positives, with an average 300 visits per month.

Systematic approach to resolve uncertainty

We undertook:

- a significant literature review of facial recognition engines and models, establishing the requirements and possibilities of edge-based processing of images, which showed that the current technology in security cameras did not allow us to provide recognition services at a quality and speed that would satisfy our requirements, and we quickly pivoted to a cloud-based approach for recognition.
- a systematic approach of research and iterative development of a novel facial recognition engine. This involved the creation of a deep convolutional neural network (DCNN) utilising a MongoDB on AWS which provided detection of images that contain a face, image segmentation to locate and mark the face on an image, facial alignment and normalisation, feature extraction and face recognition.
- an iterative approach of testing, modifying and retesting - matching face images against multiple known faces in a prepared database, testing edge-based processing against processing in a dedicated cloud- based server to measure throughput times, while training the recognition models and optimising hyperparameters through seven steps of machine learning.

Describe new knowledge; new or improved processes, services or goods

Through the development of new knowledge in facial recognition services, new processes and services have been developed with the intention of enabling accurate online facial recognition comparison at speeds not previously achieved.

Supporting activities

Camera MTF evaluation

In order to confirm that the manufacturer specifications matched the product, we needed to conduct tests to ensure the veracity of the manufacturer's MTF claims.

Without confirming the MTF performance of the cameras, we could not be certain we were accurately measuring the impact of acutance of image recognition and inference.

Research and development of acutance and resolution standards for security camera images for facial recognition.

Literature reviews and patent searches

In order to establish whether we could use existing technology, or would have to develop our own, we needed to know the state and limitations of the technology.

Without knowing the knowledge gap, it is not possible to develop a plan for creating new knowledge.

Development of facial recognition engine for cooperative 1:N matching-capture and pre-processing on the edge, training and inference in the cloud.

Research and development of acutance and resolution standards for security camera images for facial recognition.

Development of compression algorithms to enable cooperative 1:N matching-capture and pre-processing on the edge, training and inference in the cloud.

Building the test platform

In order to test the performance of the cameras in different environmental conditions, a number of test platforms had to be created in different locations.

In order to test the cameras, test platforms needed to be produced.

Research and development of acutance and resolution standards for security camera images for facial recognition.

AWS server and MongoDB setup

In order to test the recognition and inference engines, a cloud-based software platform needed to be established.

Without the setup of a cloud-based server we would not be able to perform our core R&D of development of compression algorithms to ensure performance requirements were met on the cloud-based server.

Development of compression algorithms to enable cooperative 1:N matching-capture and pre-processing on the edge, training and inference in the cloud.

Appendix

A security system for a building site

Projects

An **ineligible** and declined application

Project identifier

The real-time staff site identification (RSSI) project

Start date: 1 April 2022	**End date:** 31 March 2023

Project objective

Develop a smart facial recognition security system to identify authorised personnel entering multiple building sites in New Zealand. We conducted an intensive investigation into possible solutions in the facial recognition systems for small businesses, assessing and evaluating possible solutions before choosing and adapting the best solution for our business.

The project required:

- Security cameras with a full http stack to capture facial images,
- An investigation into existing technology for small businesses using edge processing and security cameras with an http stack. This demonstrated the limitations of some of the existing technology and a preference for a cloud based facial matching system.
- The acquisition of a new cloud-based system which would upload facial images into the cloud server to perform the facial recognition matching technology.
- A successful recognition match to send an approve signal to open the automated gate or, if no successful recognition, to send a request to the site manager to consider 'validating manually'.

Feasibility studies reveal staff have accepted the privacy implications of their photographs being held in the cloud but are concerned about the possibility of false negative or positive results impacting safety and timeliness of entry. Staff have commented that "nobody wants to wait outside in the rain and cold for a computer to decide that somebody who's worked for the company for 20 years is okay to get into work." Hence, the key performance requirements for a facial recognition security system for this company are speed, accuracy, reliability, and affordability.

Core activity

Installation, configuration, and assessment of facial recognition systems for use in security applications.

The real-time staff site identification (RSSI) project

We embarked on an R&D project with the primary objective of solving the problem of ensuring identification of personnel on building sites in different locations with a minimum impact on workers. We set a requirement for automatic and secure real-time identification and confirmation that a person visiting a site is on an approved list.

This core activity was to resolve the technological uncertainty of finding a facial recognition product that would match images taken by our on-site security cameras with images that are stored in a database of images.

Feasibility discussions resulted in a process being developed to use security cameras to capture facial images and send the images to a cloud-based server to perform the facial recognition and matching technology. The camera must take an accurate picture in all weathers to ensure the facial recognition software can produce an accurate result.

We conducted reviews of possible solutions in the facial recognition market and established there were five potential products that might meet the requirements. It was unknown which product would be the most appropriate for our needs.

Each solution had a multitude of configuration possibilities and we set about a systematic process to determine which was most likely to meet the requirements. It was established that our competent professionals would require an investigative and experimental approach to create new knowledge in this field that would lead to a new or improved process and service.

Benchmarking the technological uncertainties

1. **Is the knowledge to resolve the uncertainty publicly available?**

We have researched the available products available in the market and have found there are five potential products in the market. We are reviewing the performance of each of the products to determine whether any can be configured to meet the criteria for our business circumstances including installation areas at out building sites.

2. **Is the knowledge to resolve the uncertainty deducible by a competent professional in the relevant scientific or technological field?**

On reviewing the manuals of each product our expert was not able to deduce whether it was possible to reconfigure the parameters to meet our business requirements.

Scientific or technological uncertainty

We were uncertain which facial recognition product was most suitable for our use to capture images which would produce the most accurate results for our business. The manuals that came with the software, while incredibly detailed and complicated, did not provide the information to enable us to choose the best solution without undertaking a systematic process of investigation involving significant trial and error. Our scientific or technological uncertainty was:

- how best to configure the applications to produce the best results, learning and creating new knowledge for the company as we went through the activity.
- the software configuration was technically challenging, and it was uncertain at the start of the activity whether we were going to even have a working solution to meet our needs.
- we spent many hours researching potential configurations provided by the chosen software vendors. We tested the different configurations to see whether they met our required performance parameters, i.e.:
    - a total identification throughput turnaround of around 3-5 seconds from capture to decision to allow or deny access: and
    - as the site had no internet connections site data needed to be transmitted from a mobile connection at the work site, with a minimum of a 3G connection using TCP/IP and SSL protocols: and
    - transmission time to be less than 2 seconds, with around 4 seconds of inference time (the time to process and recognise): and
    - less than 5% false negatives and less than .5% false positives, with an average 300 visits per month.

Systematic approach to resolve uncertainty

We undertook a systematic approach of research and iterative testing of five separate facial recognition software products.
This involved:

- the installation and configuration of software which provided detection of images that contain a face,
- image segmentation to locate and mark the face on an image,
- facial alignment and normalisation,
- feature extraction, and
- face recognition.

We followed an iterative approach of testing and retesting each product and the different configurations available to discover the throughput times and accuracy of the alternative configurations.

Describe new knowledge; new or improved processes, services or goods

Through the development of new knowledge in installation and configuration of facial recognition services, we now understand which of the different types of facial recognition systems can provide the best results for security on our building sites.

Supporting activities

Installation of Facial Recognition software on cloud server architecture

Software installation on cloud server architecture.

Without installation of the software, we would be unable to test different configuration options.

Installation, configuration, and assessment of facial recognition systems for use in security applications.

Review of available software solutions

Research into available solutions.

Without knowing what is available in the market it is not possible to know which applications would be best to test.

Installation, configuration, and assessment of facial recognition systems for use in security applications.

Security camera installation

In order to test the facial recognition software, we had to install some security cameras first to capture the images.

You need cameras to create images, so without the cameras, the testing could not be performed.

Installation, configuration, and assessment of facial recognition systems for use in security applications.

AWS server and MongoDB setup

To test the facial recognition software, a cloud-based software platform needed to be established.

Without the setup of a cloud-based server we would not be able to test our facial recognition software options.

Installation, configuration, and assessment of facial recognition systems for use in security applications.

Appendix

A legal search platform for the building code

Projects

An **eligible** and approved application

Project identifier

Legal search platform and interpretation tool for the interrelated rules and language in the NZ building legislation and regulation

Start date: 1 April 2023	**End date:** 31 March 2024

Example 2

Project objective

Complex and interrelated legislation and regulations govern all building work in New Zealand. The primary legislation is the New Zealand Building Act 2004 (the Building Act) for building and construction and the New Zealand Building Regulations 1992 (the Building Code) which lists minimum building and performance standards required.

The building rules change as new materials or techniques are integrated. Building quality and performance have trended downwards over recent years, highlighting stakeholders' legal exposure. Human expertise is required to navigate the legislation, identify relevant passages, and understand roles and obligations.

This application is for R&D work on a legal search platform using a mix of machine learning based natural language processing (NLP) and rule-based models to make the Building Act accessible to users with little to no legal background, while providing a valuable and useful tool to legal and construction professionals. The aim is to provide better building code look up and automatic interpretation for a large variety of users including owners, builders, and local authorities.

Core activity

The modelling and lookup functionality technical problem to be solved

The ultimate solution is to develop a machine learning based NLP algorithm to allow an automated lookup. Although the amount of raw data is limited to the contents of the Building Act, the Building Code and relevant case law, the preparation of the relevant text (corpus) suitable for NLP is complex and expensive.

Without such a modelling and lookup tool experts in building law familiar with the Building Code handbooks currently work manually through the primary literature (Building Act and Building Code) and tag semantic meaning of words and concepts against these texts. This is a costly exercise. This means constraints must be placed on the size of the corpus used, which impacts the accuracy of the tool.

Important modelling constraints and opportunities:

- Balancing the relative importance of different rules and classes of building work requires statistical analysis to ensure the rules focus on the most important. i.e., the number of irrelevant passages may far outweigh the number of relevant passages, or vice versa. Thus, the corpus for the tool can be limited to and focus on the relevant passages.
- NLP engines require fine tuning to model complexity to achieve viable model performance with limited training data. Whereas rule-based engines are generally more robust but rely on human expertise.

Therefore, this project is designed to apply a mixed semantic model by:

1. Investigating an automated NLP, and
2. Developing and evaluating rule-based models that require more human expertise but have a better chance of providing useful performance for the search function when dealing with a limited data set.

This will help to make the most of the available data for the building code search and recommendation platform and inform future NLP models for other applications.

This financial year we are working on lookup functionality and will start with preliminary work for automatic text summarisation.

Benchmarking the technological uncertainties

1. **Is the knowledge to resolve the uncertainty publicly available?**

NLP techniques and algorithms have been applied globally to corpuses in many fields including legal text. To our knowledge, this is the first practical application to the NZ building legislation and regulations.

2. **Is the knowledge to resolve the uncertainty deducible by a competent professional in the relevant scientific or technological field?**

This is a hard task for a bespoke legal search platform and interpretation tool which requires informed statistical analysis and significant problem solving. This means it cannot be predicted with certainty the most accurate and efficient mix of the models (being the automated NLP or rule-based models) will be sufficiently accurate, speedy, and cost efficient within the search platform criteria.

The work will involve several experts who will research and systematically investigate the chosen data sets included in the corpus to find the plain English answer to expected search questions. Thus, the answer to resolving the core activity is not able to be deduced by competent professionals in the relevant fields without undertaking a systematic course of investigation and experimentation.

Scientific or technological uncertainty

This raises uncertainty about achievable lookup accuracy and if the achievable model performance and inference speed are going to be sufficient for the use case.

While POS tagging and other lexical attributes are well solved, the biggest challenge is the unknown domain-dependent context sensitivity or semantic depth needed.

Therefore, the technological uncertainties to be resolved are:

- Whether the semantic structure in the legislation is suitable for tagging by a rule based or other system and a set of rules can be identified that covers the relevant sample set of documents.
- Whether a machine learning model:
  - can resolve inconsistencies arising from the innate ambiguity in natural and legal texts which is reflected in competing legal interpretations and opinions: and
  - can discover the relevant semantic structure (auxiliary words etc) better than random, especially when common keywords might account for 70% of the majority class.

Success will be achieved when relevant legal passages for a particular role can be extracted automatically at close to 100% completeness while minimising false negatives.

Systematic approach to resolve uncertainty

- Preliminary work on rule encoding and annotation. This will help define what exactly should be annotated in the context of the building code search engine. Identify roles and obligations.
- Annotate corpus and ensure a variation of legal opinions (at least two different lawyers) and semantic structure are captured.

Pre- and post-processing (for example, using NLTK, Word2vec etc):

- POS tagging (nouns, verbs etc).
- Named entity recognition.
- Text summarisation techniques.
- Try out a range of technical encoding standards and pre-processing to identify optimum format for machine learning and rule-based engine (for example, regular expressions).
- Develop benchmark for manual performance.

Statistical sampling:

- Random sampling of cases, identify strata and use stratified examples to refine cases.
- Adjust weights to oversample relevant minority classes to improve model performance.
- Create rule-based models at sentence, paragraph, clause levels. This will guide machine learning input.
- Evaluate utility of ML models that can represent context (for example, explore application of transformer models).
- Run and evaluate models against each other and against manual benchmarks.

Describe new knowledge; new or improved processes, services or goods

This R&D work is part of the development of a new legislation lookup service aimed at a variety of users in New Zealand.

Supporting activities

- Engagement with authorities (for example, councils) and research institutes (for example BRANZ)
- Engagement with legal expert data taggers
- Planning, management, and coordination activities
- Identifying the range of users and scoping work
- Preliminary research and literature review (including key documents - building code, Building Act 2004, etc.)
- Prototype design and development - system set up, pre & post processing
- Documentation and reporting.

Appendix

A drone-based computer vision (CV) technology for wheat growing

Projects

An **eligible** & approved application

Project identifier

Drone based computer vision (CV) technology identifying wheat flowering stages

Start date: 1 April 2023 | **End date:** 31 March 2026

Example 3

Project objective

This project is aimed at the development of a computer vision (CV) based technology for identification of wheat flowering stages. This will help with detection of certain diseases and allow application of fungicides at the optimal time.

Due to the growth patterns of the plants, there is often low spatial resolution as they overlap substantially. By combining 2 existing methods (2 different feature detection algorithms) we anticipate increasing the accuracy of automatic observation or decreasing the absolute error. Our prototypical detection algorithm needs to be robust enough to work in outdoor light conditions and other environmental variations.

In recent years precision technology has been developed and used to accurately plan and manage operations in agriculture. We have set out to develop a precision technology service using CV for management of Fusarium head blight (FHB) in wheat.

Fusarium head blight (FHB)

Fusarium head blight of wheat, also known as head scab, is most easily recognised on immature heads where 1 or more spikelets in each head appear prematurely bleached. Sometimes large areas of heads may be affected, and where infection is severe, pink or orange spore masses can be seen on diseased spikelets. This disease can cause yield losses of 30-70% where conditions favour the disease, but more importantly grain from affected crops may be less palatable to stock than healthy grain and may contain mycotoxins.

Wheat is most susceptible to primary infection during flowering when florets are infected, especially during wet, warm conditions. While most New Zealand wheat crops have a low risk of serious levels of FHB, climate change studies suggest that these conditions will become more prevalent throughout New Zealand, affecting areas like the South Island which were not previously affected. Overseas and New Zealand research suggests that some fungicides such as Bavistin and Folicur may control FHB if applied close to mid-flowering.

This work is intended to create a new precision technology service using CV for optimising crop yield for wheat growers.

The project initially focuses on establishing technological feasibility of a fully automated heading stage monitoring system with computer vision using:

- 4k drones,
- convolutional neural networks (CNN), and
- statistical modelling.

If successful, later stages will go beyond monitoring with the addition of an agricultural expert recommender system.

Core activity

Development of CV model/machine learning (ML) algorithms

The core activity is the development of a CV model and algorithms that can recognise the various stages of wheat ear development and identify indications of disease.

This will involve an initial study to probe the known and unknown technological limitations of the proposed solution and ascertain if accurate monitoring is achievable under controlled conditions. The initial steps include lab tests under ideal conditions in combination with CV model development followed by further lab testing of the prototype under simulated suboptimal conditions including:

- variation in lighting,
- variation in camera angles, and
- occlusion (eg simulating sudden wind gusts, effect of rainwater on the plants).

The setup in the lab will utilise a single ultra-high resolution digital single lens reflex (DSLR) camera. This allows down sampling experiments to investigate resolution boundaries. The initial setup will have the plants on a turntable to take still images of plants from day 4 through to day 8 of the heading stage. (e.g. images every 6 hours in 45-degree increments).

The initial convolutional neural networks (CNN) model will be set up after a literature review. It is likely this will be an off-the-shelf network (eg ImageNet, Yolov5, etc) that might be adapted with transfer learning on the last couple of layers. Later we will optimise accuracy with more specialised/sophisticated models for each processing step (pre-processing, feature detection, images segmentation etc).

Following the initial lab tests, field trials will be undertaken to further develop the CV model and improve the accuracy under real environmental conditions.

Scientific or technological uncertainty

There are numerous applications of computer vision technology in agricultural automation. These include yield estimation, disease detection, and weed identification. Such methods tend to be based on:

- colour segmentation,
- spatio-temporal analysis, or
- image segmentation.

The main technological challenge that persists is when there is negligible colour difference between the object and its background. This is evident in the early growth stages of wheat where the new ears cannot be distinguished from the existing leaves.

At onset of flowering the protruding part of the wheat ears may only take up a few pixels on an image and is difficult to distinguish by colour from other parts of the plant, so the existing camera specifications (height, placement and image resolution) may have an impact on our ability to determine heading stages.

There is natural colour variation due to changes in the lighting conditions.

Under real conditions, drones are limited by a minimum altitude. This creates a trade-off between image resolution and object distance. The boundaries of these parameters are unknown for our application, and it is not clear if ear detection accuracy under suboptimal conditions will be sufficient. The aim is to identify the time when 75% of the plants have passed from Feekes 10.5.0 (where the wheat head has completely emerged) to Feekes 10.51 (the beginning of flowering). The flowering begins in the middle of the head and progresses up and down the head. This is the optimal stage to apply fungicides to protect against head diseases. Applications earlier than this stage are not as effective as applications after this stage. There is a narrow time window of up to 7 days in which fungicide is most efficacious.

Systematic approach to resolve uncertainty

Year 1 – Laboratory research and model development (Milestones I, II, III)

Milestone I - Laboratory (Lab) environment under ideal conditions to establish boundaries for parameters (image resolution, object distance).

Off-the-shelf CNN model (eg ImageNet) with transfer learning on the last couple of layers, maybe Yolov5.

Outcome: Go/no go decision on resolution and flight distance requirements.

Milestone II - Machine learning (ML) model development.

Pixel level segmentation:

- use Amazon MTurk to prepare training, validation and test data
- test feasibility using existing models/frameworks, eg Detectron to analyse segmentation results, eg ROC chart (sensitivity versus specificity).

Investigate a variety of feature detection algorithms.

Outcome: ML model optimised for ideal conditions and learnings for strategy to improve monitoring accuracy in outdoor conditions.

Aim: 70-80% accuracy for lab conditions.

Milestone III - Simulate real environmental conditions in the lab including lighting, rainwater on the lens/plants, effect of plants moving in wind (sudden gusts), occlusion. This stage includes further model refinement.

Outcome: reports and recommendation for business decision to continue with field trials.

Aim 90% accuracy for simulated non-ideal conditions.

Year 2 – New Zealand field trials and model development (Milestone IV)

Milestone IV - New Zealand Field trials & model refinement.

A test field to be prepared which will be used for the trails.

Testing potential flight patterns to discover optimal path.

Testing on larger scale.

Outcome: real world data, first CV model optimised for real New Zealand conditions, go/no go decision for Australian field trials.

Aim to achieve 90% accuracy for real conditions.

Year 3 – Australian field trials and model development (Milestone V)

Milestone V - Australian field trials & final model refinement.

If New Zealand field trials are successful, we will undertake Australian field trials. This will provide data for Australian environmental conditions, further increase robustness of the CV model and prepare future use of this new service in the Australian market.

Aim to achieve >95% accuracy.

Describe new knowledge; new or improved processes, services or goods

The aim is to make the results of our R&D available as a new monitoring service for New Zealand and international wheat growers. There are many existing CV-based methods but none that can easily observe low-contrast scenarios. To our knowledge no ML models for determining head stages of wheat exist.

There are no off-the-shelf commercial products that can be applied to such agricultural requirements.

Supporting activities

- Preliminary research including literature review of models for machine vision in outdoor environments
- Plan lab research (DSLR camera, drone camera machine learning models).
- Analyse data and report on results
- Purchase test drones with 4k capability
- Plan and conduct field trials in New Zealand and Australia.

Appendix

A low-cost, satellite-based Internet of Things (IoT) location tracker

Projects

An **eligible** & approved application

Project identifier

A low-cost, satellite-based tracking device

Start date: 1 April 2024

End date: 31 March 2027

Example 4

The business is undertaking a 3-year product development where the intended product specifications, scientific or technological uncertainties (STU), and core and supporting R&D activities evolve over the course of the project. The business would apply for an initial general approval for its activities, and then either apply for a variation of its approval (if materially different to the original application) or apply for a new approval of new activities.

This appendix provides a summary of the core R&D activities, the uncertainties in the core activities and the systematic approach to the activities undertaken as the project progressed. It will guide you through the example and how this would form the respective parts of a general approval application.

In addition, the diagram below shows how the core R&D activities extend across the product development life cycle. The stages of the product development lifecycle are included for reference purposes only and are not a required part of the RDTI.

Describe the core activity

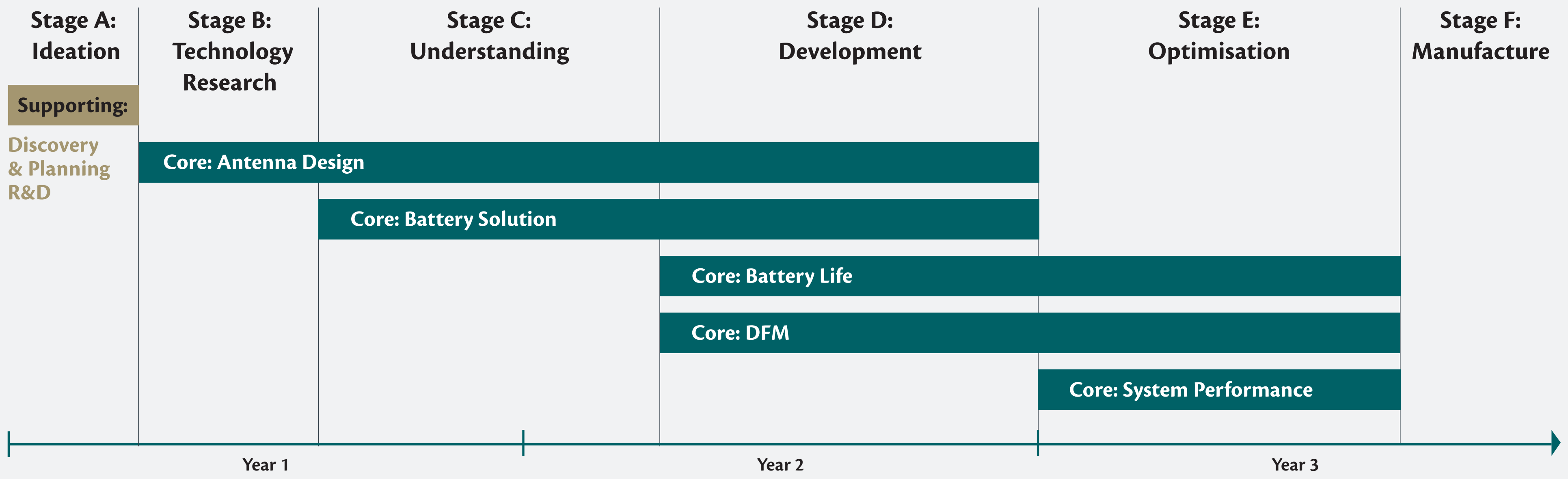
The diagram below demonstrates that the core activity to resolve the STU for the location tracker antenna design and transmitting power starts in stage B and is expected to be completed during the third year. The initial ideation stage A when the product is being developed qualifies as a supporting activity as it is an essential precursory activity needed before the core R&D commences.

Systematic approach

The **light** and **dark teal** highlighted investigative steps help demonstrate a systematic approach to product development focusing on resolving the STU.

Each are important pieces of information to demonstrate the Problem > R&D Plan > Investigate > Outcome, showing how aspects of a product specification can be interdependent and can pull against one another.

Overview: The core activities



Project objective

The company has identified a new niche product opportunity for a retail low-cost small satellite tracking device for remote areas with no access to other communication networks. The tracking device could be attached to an animal's collar or on a person out hunting or tramping. The engineers have looked at the proposed product and have identified two main technological problems, antenna design and transmitting power. The team have some answers to solve these problems, but the risks of failure are high. Prior to investing in a full product development, the company undertakes R&D to reduce that risk.

There may be no technical solution to achieve the aspired target performances. If the risks cannot be reduced, the product development will not start.

Stage A: Ideation

Pre-core activity

Discovery and planning R&D for a new product opportunity

A product manager describes a new product opportunity to the engineers whose literature searches did not identify an existing solution. The team worked through the technical requirements to produce a product specification and the engineers identified how the product technological uncertainties might be solved, developing a R&D plan for that purpose.

If the antenna design fails, the project may be scrapped. This is preparation work before the start of the proposed core activity. It cannot be claimed as support activity unless the project goes ahead, and the core activity commences in stage B.

Example 4

Benchmarking the technological uncertainties

1. Publicly available

We have researched similar product technology around the world and not found such an affordable, small, durable IoT tracking device for use in challenging outdoor situations and conditions with no access to other communication networks.

2. Competent professional test

Our engineers have reviewed the specifications and do not know if it is possible to meet all the design constraints and are expecting to have to re-evaluate and experiment with unexpected solutions, changing the product design as the project progresses.

Stage B: Technological R&D begins with antenna design

Project objective

The team is committed to the idea of this new product, with its first focus on undertaking R&D to explore the key features of antenna gain and transmit power, within the power constraints.

Core activity

Antenna design

The product manager has defined an outline specification for the product to have an internal antenna of 3dBi gain and power with battery constraints of a size of 4cms by 3cms by 1cm and longevity of >5 years.

Scientific or technological uncertainty

The initial engineering hypothesis proposes a transmit power of 23dBm and an antenna gain of 3dBi. The question causing the technological uncertainty is can such a tracker target performance be achieved when attached to an animal or person and still achieve a suitable radiated power? One design is to use an internal patch antenna with a prototype transmitter and bench power supply.

Systematic approach to resolve uncertainty

We undertake the following activities:

1. Simulate potential antenna designs and transmitters by building 3D print mock-ups for different internal antenna designs and transmitters.
2. Test each design and identify which approach might reach the internal target specifications.
3. Consider using different antenna designs. Identify possible candidates and experiment to find out which antenna can achieve the required 3dB criteria.

Describe new knowledge; new or improved processes, services or goods

Applying advanced knowledge in antenna development, design a unique small internal antenna for a small IoT device for tracking animals or people in difficult terrain and weather conditions. The antenna must conform with product size, functionality, and longevity constraints, adapting technology in new ways.

Stage C: Understanding

Project objective

The core activities focus on two areas in the context of all the product constraints; antenna design and the development of a battery solution. The antenna types need to include an external design option for flexibility to improve the feasibility of all other constraints and reduce the chance of product failure.

Core activity

Antenna design

The antenna type, whether internal or external, needs to perform within a 3dB gain across the target frequencies and meet its target specification as a component of a product with other constraints.

Scientific or technological uncertainty

All other electronic and mechanical components, including the introduction of other transmitters, (Wi-Fi and Bluetooth) affect the performance of the proposed antenna. We expect significant performance degradation due to these constraints and the presence of interference between different or competing components.

Systematic approach to resolve uncertainty

1. Develop systems designs by:
   - producing electronics/printed circuit boards (PCBs), and
   - creating 3D prints for each internal and external option.
2. Assemble designs and performance test on the system.
3. Simulate model antenna performance using new knowledge gained from physical experimentation.
4. Based on observed results iteratively change components and their placement in the design.
5. Pre-compliance test to find out if the designs are likely to pass regulatory requirements.

Core activity

Battery chemistry and design technology

We estimate we need a specific energy density of more than 300Wh/kg and volumetric energy density of greater than 600Wh/L. This is beyond the current battery chemistry and design technology used for this type of product.

Scientific or technological uncertainty

Our battery chemist has a hypothesis that the tracker target performance may be possible using the new battery chemistry and design technology for electric vehicles (EV).

Systematic approach to resolve uncertainty

1. At the direction of our NZ battery chemist, build battery test units in South Korea to investigate EV technology for use in an IoT tracker device.
2. Consider battery performance results by designing tracker prototypes to test performance.
3. For each design, the South Korean team undertakes pre-compliance tests to confirm the design may pass regulatory compliance.

Describe new knowledge; new or improved processes, services or goods

We are beginning the process of designing a small, PCB to test the antenna and its battery solution working together, applying other known science and technologies never used in such a product with such constraints. Alternative methods for the key product functions are evaluated against the criteria.

Stage D: Development

Project objective

This is the main development stage where new technological uncertainty is created by upgrades made to the product specifications. These new constraints include a reduction in product size effecting the antenna and mechanical designs, and the uncertain impact on target battery life.

Core activity

Antenna design

Despite an internal antenna preference, the IoT tracker device size has been reduced to 3cms by 2cms by 0.5cm, with an external antenna an acceptable option if no more than 2cms long. The transmitter team have achieved 30dBm rather than the original target of 23dBm. The core activity will:

- investigate the performance impact of reducing the product size and using an external antenna
- continue working on the design of an internal antenna.

Scientific or technological uncertainty

Technological uncertainty now arises from:

- the design of the external antenna after reducing the device size and the size constraints
- continuing experimentation on the internal antenna design with the more powerful transmitter.

Systematic approach to resolve uncertainty

1. Design and measure the external antenna performance for a smaller product size and electronic design.
2. Investigate the internal antenna in the context of the improved transmitter power. Consider embedding the antenna in a panel (see the core activity Design for Manufacture (DFM) on page 88).
3. Assemble the designs and undertake system performance testing.
4. Simulate antenna performance based on new knowledge gained from physical experimentation.

Core activity

Battery life

The transmitter results show it is possible to increase the transmit power to 30dBm. While the increased power improves the range of the antenna, it creates uncertainty in reaching the desired battery life. This needs further investigation to identify solutions.

Scientific or technological uncertainty

The new battery technology was designed for transmitter power of 23dBm whereas the new proposal to operate at 30dBm consumes more power, creating significant battery life uncertainty. We propose developing battery management algorithms to selectively shut down system components when not in use, expecting these shutdowns to have minimal performance impact on tracking the animals.

Systematic approach to resolve uncertainty

1. Measure battery areas inside the product (i.e., space needed for battery).
2. Model power usage to estimate battery life and compare to other known measurements.
3. Estimate systems components to be shut down, creating software algorithms to manage power.
4. Test the proposed algorithms in both model simulations and benchmark measurements.

Core activity

Design for manufacture (DFM)

The cost of goods sold (COGS) for building the product at less than $20 and an assembly time of 30s is 50% lower than similar sized company products. Establishing technological solutions to meet the target COGS may also impact the other technological uncertainties.

Scientific or technological uncertainty

Technological uncertainty arises during the manufacturing and assembly process, including the choice of durable low-cost materials. The antenna assembly is time consuming with mechanical components screwed together. Investigate changing the technological design to attach each section to the PCB, clipping together during assembly. This new assembly technique creates technological uncertainty when sealing the edges to achieve the original target specification of IP65. Robot automation could speed up assembly time and reduce cost.

Systematic approach to resolve uncertainty

1. Benchmark and estimate the assembly time.
2. Develop new mechanical components for automated assembly using prototype tooling.
3. Investigate automated assembly methods to seal around the mechanical components.
4. Measure technological performance according to IP65 rating requirements for dust protection and waterproofing.
5. Measure the automated assembly time, increase the assembly speed, and observe the impact on technological performance.
6. Tune assembly methods and choose a sealing technique.

Describe new knowledge; new or improved processes, services or goods

At this stage upgrades are made to the product specifications with modifications to design constraints, including a reduction in product size affecting the antenna and mechanical designs, and solutions using planned shutdowns to optimise battery life. Costs are evaluated including alternate assembly alternatives. A viable product is identified for sale with most of the key STUs resolved.

Stage E: Optimisation

Project objective

This activity seeks to resolve the remaining aspects of system uncertainty focusing on three principal areas; battery, DFM, and system performance.

Core activity

Battery life

The component shut down algorithm (firmware) has increased the battery life. The product manager has reduced the target battery life from >5 years to >3 years. We are still 0.2 years short of the target battery life and will continue to work on algorithm improvement.

Scientific or technological uncertainty

Technological uncertainty arose due to the battery saving firmware improvements. The next step is to identify and selectively shut down components with no observable user impact to reach the >3-year target battery life.

Systematic approach to resolve uncertainty

1. Identify product areas to shut down when not needed, even when impacting performance. Identify and model potential solutions to improve battery life.
2. Develop the battery management algorithms further while minimising user impact.
3. Test the algorithm changes iteratively to shut down different system components.

Core activity

Design for manufacture (DFM)

The optimisation stage E technological design changes were successful. However, the manufacturer has advised some of the smaller mechanical components, e.g., injection mouldings are challenging to make, and the proposal is to use metal pins instead, creating further technological design uncertainty impacting antenna performance.

Scientific or technological uncertainty

The change of technological design has caused technological uncertainty by introducing metal components, impacting the antenna performance and product compliance. The previous antenna gains may need corrective action.

Systematic approach to resolve uncertainty

1. Model and 3D print the manufacturer's proposed system design changes.
2. Build complete units to undertake pre-compliance and antenna tests.
3. Iterate the technological design to improve performance, including further PCB changes.

Core activity

System performance

Technological uncertainty exists for IoT due to the system performance risk for all the components working together in the final product. Pre-compliance testing has revealed a weakness in the product's mechanical shielding performance and improvements are proposed to increase performance success.

Supporting activity

System performance testing

In the final optimisation stage pre-compliance and compliance testing is required for the new product candidate to complete the core R&D activity and ensure regulatory standards are met prior to commencing commercial production. Such tests are support activities to the extent of having the main purpose of completing the core R&D. This activity can also reveal more elements of a core activity if technological modifications are required to resolve newly discovered uncertainties.

Scientific or technological uncertainty

System uncertainty can arise for a new product where the components are known but the outcome is unknown until the entire system is complete. Pre-compliance tests are undertaken on the product's regulatory constraints using the available test equipment to improve the chances of passing the requirements. Once the product has officially passed a region's regulatory requirements, the technological uncertainties caused by those regulations are considered resolved.

The engineers have reviewed the design and identified the riskiest aspects for the interference effects of the Wi-Fi transmitter and any weakness in electromagnetic interference (EMI) performance. The engineers suspect mechanical shielding improvements are needed.

Systematic approach to resolve uncertainty

1. Build complete units for pre-compliance testing. Based on the results, make changes to the system including the mechanical shielding.
2. Build complete units for actual compliance testing, making final necessary design changes.

Describe new knowledge; new or improved processes, services or goods

At this stage algorithms are being fine-tuned, accepting product modifications to complete the R&D core activity and produce a new product. The product is a unique portable IoT device for tracking animals or people in remote areas with no access to other communication networks. The IoT tracker conforms to the final criteria for the product size, functionality, longevity, and price constraints, adapting old and recent science and technology in new ways. Regulatory compliance has been undertaken representing the final step for the new product.

Stage F: Manufacture

At this stage the product is being manufactured, is fit for first release and sale. The original product specification is partly amended, and the product manager yielded on some performance specifications. All the STUs are resolved, and the company is commercialising its R&D result.

Example 4

Inland Revenue
Te Tari Taake

MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT
HĪKINA WHAKATUTUKI

CallaghanInnovation
New Zealand's Innovation Agency

www.ird.govt.nz