Inland Revenue
Te Tari Taake

IR1238

Research & Development Tax Incentive (RDTI)

R&D activity eligibility

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 'RDTI Eligibility'

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 'RDTI Eligibility'.

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.

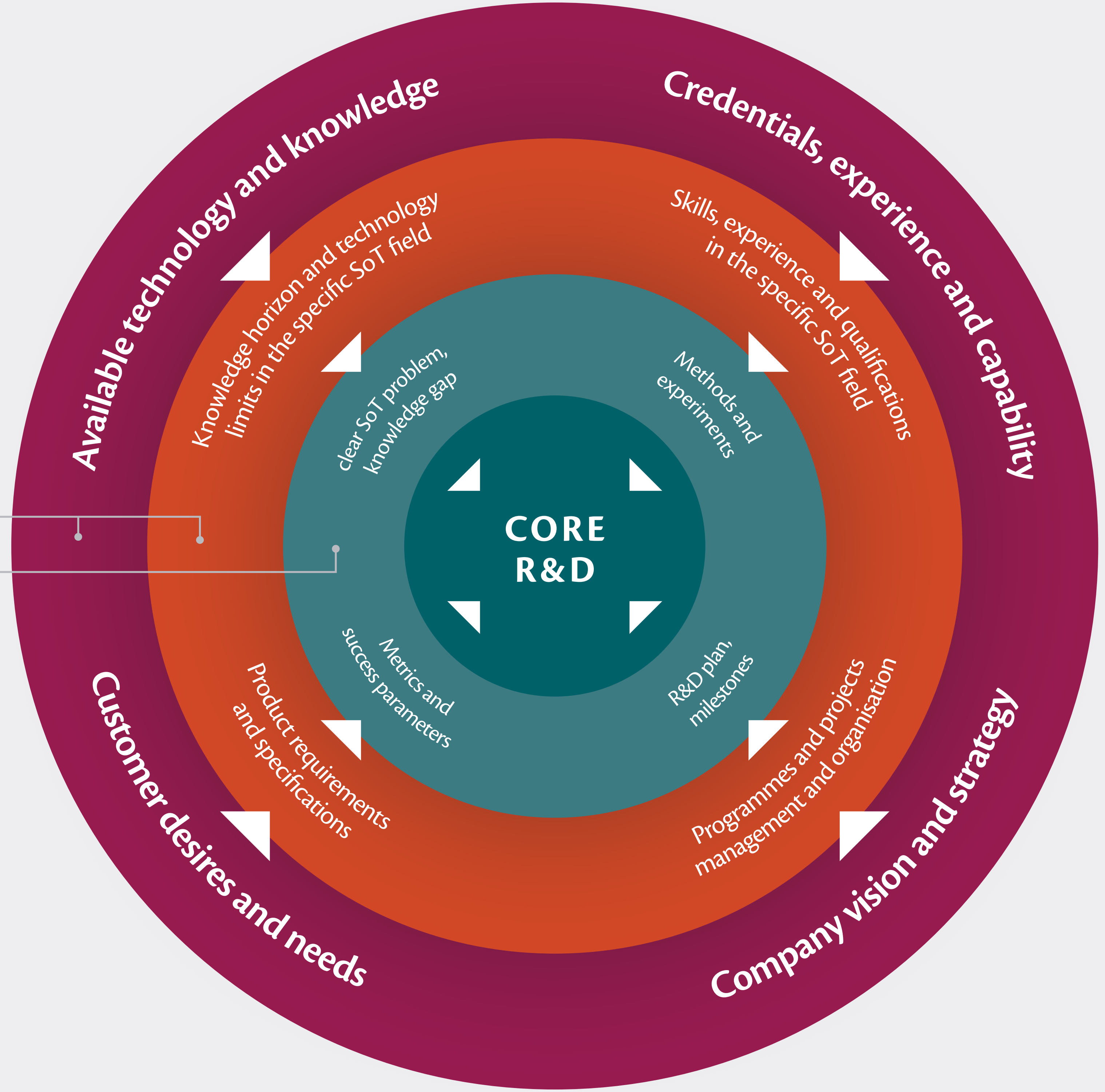
We have developed a tool to help you provide this information. The tool is similar in nature to a dart-board. The information required to process your claim must hit the teal bullseye. Information from the outer red and orange sections of the dart board can provide useful context for the R&D, but you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

Examples of questions you should be seeking to answer when completing your General Approval are from the 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 **red** and **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 **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:

- Cognitive / Analytics
- Security
- Future networking
- Digital reality
- Cloud
- Robotics
- Quantum technologies

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				
		General principles of RDTI eligibility	Benchmarking technological uncertainties	Core vs supporting R&D	R&D start & finish	Systematic approach
The development of a security system on a building site	Cloud based facial recognition engine	✓	✓	✓	✓	
The development of a legal search platform for the building code	Machine learning-based natural language processing (NLP) and rule-based models	✓		✓	✓	
The development of a computer vision platform for identification of wheat flowering stages	Computer vision model development	✓	✓	✓		✓
Example 4	In development					

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 (additional detail IR: Eligible R&D activities (ird.govt.nz) RDTI hub: What R&D activities are eligible? | RDTI NZ)
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?

The development of a security system on 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 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 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

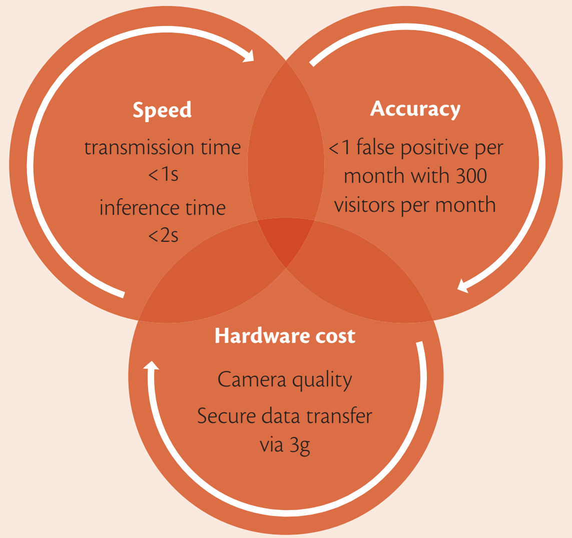
The technical problem

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

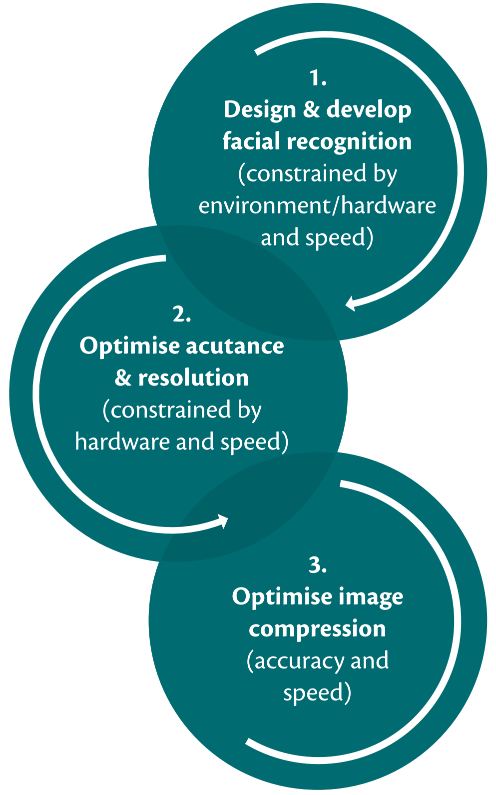
The general principles of RDTI eligibility

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.

Benchmarking the technological uncertainties

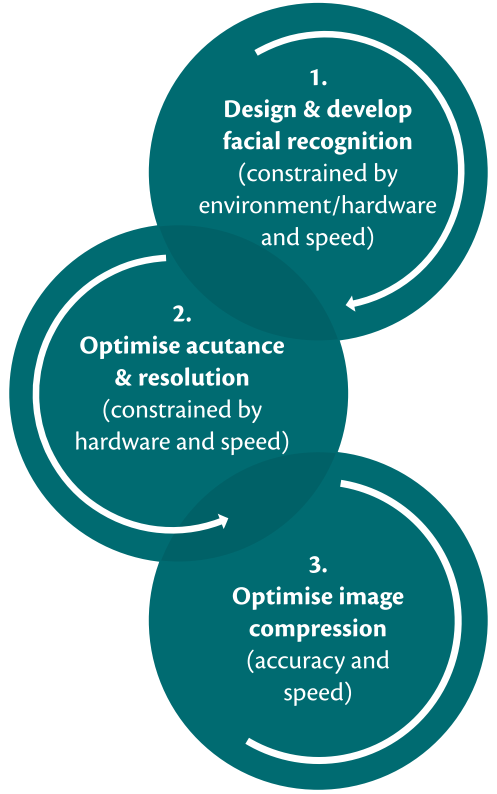
Remember, a key matter to consider is how to demonstrate that the knowledge required to resolve the technological uncertainties are not publicly available, or deducible by a competent professional in the relevant field.

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

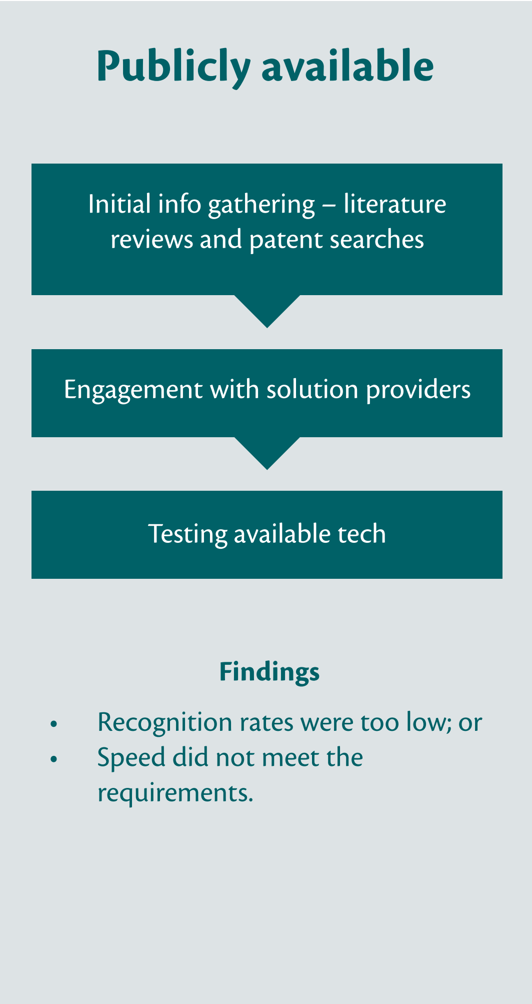
The publicly available test	There is a known solution for facial recognition and security. For example, e-passport scanning at Customs. Therefore, it is important to explain why this R&D is different.
The competent professional test	This test is demonstrated in the scientific and technological methods 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.

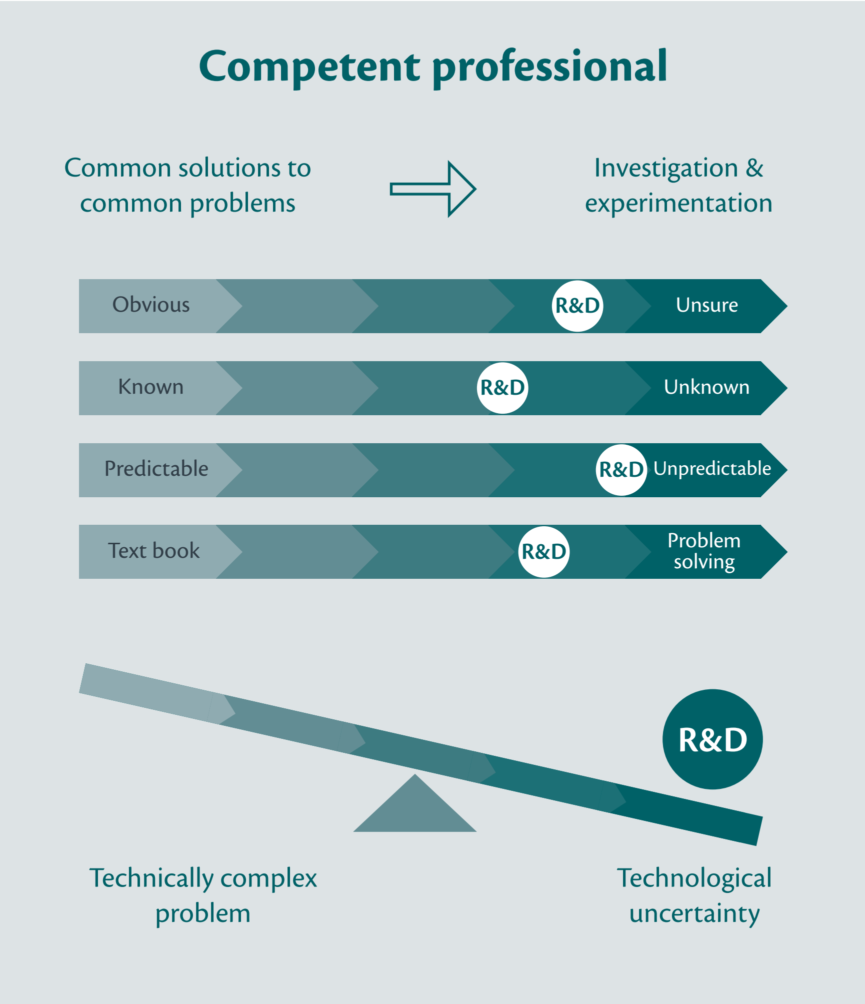
Remember – the General Approval application example provides a full description of the eligible RDTI activities. This is the expected level of detail required by us. You must focus on the bullseye (dart board tool) and be technical in nature.

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.

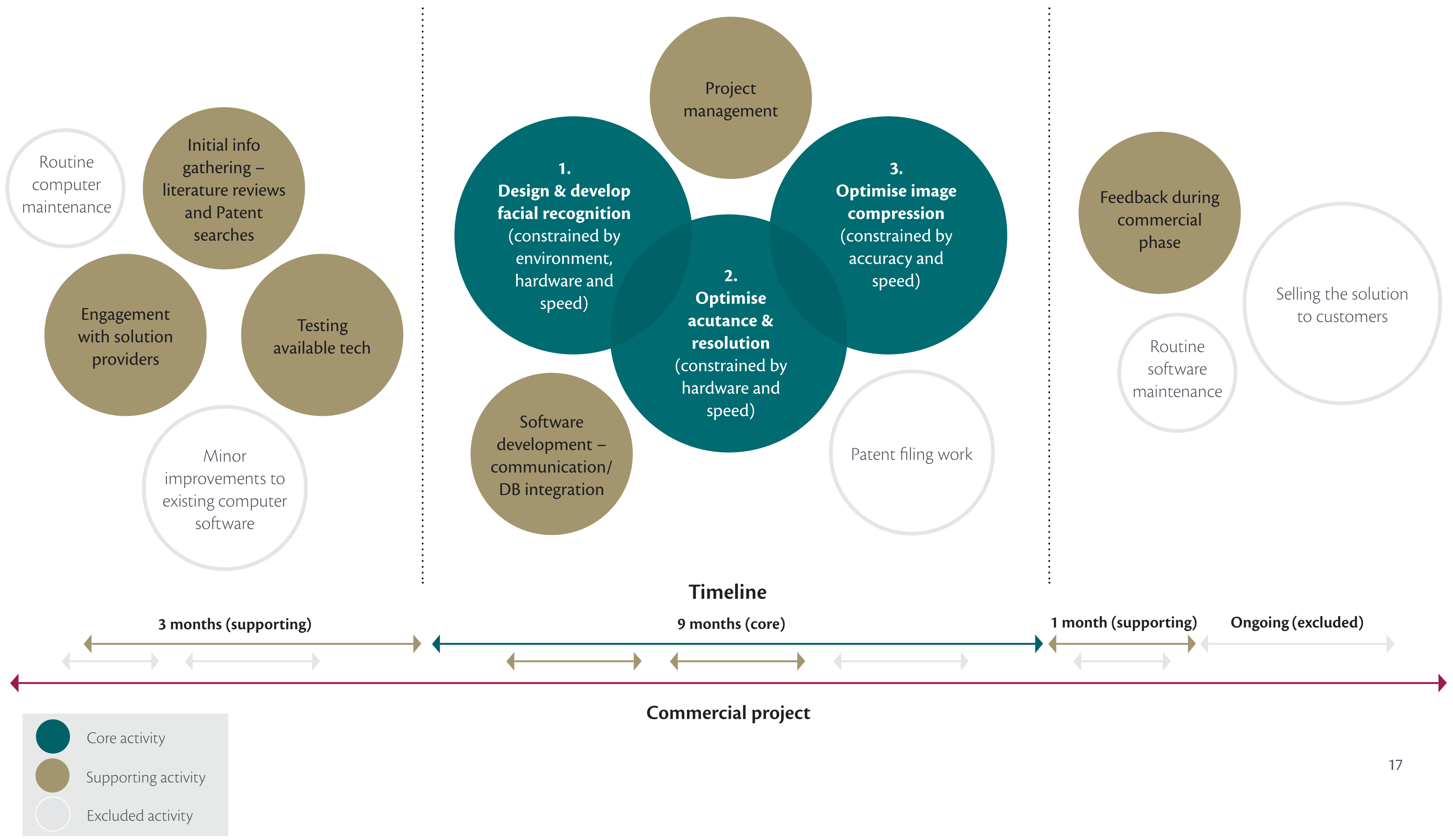
Further information on supporting R&D activities can be found on the IRD website. Go to **www.ird.govt.nz/** Enter keywords: 'r&d eligible activities' or 'ineligible activities' in search box.

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 & Support	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

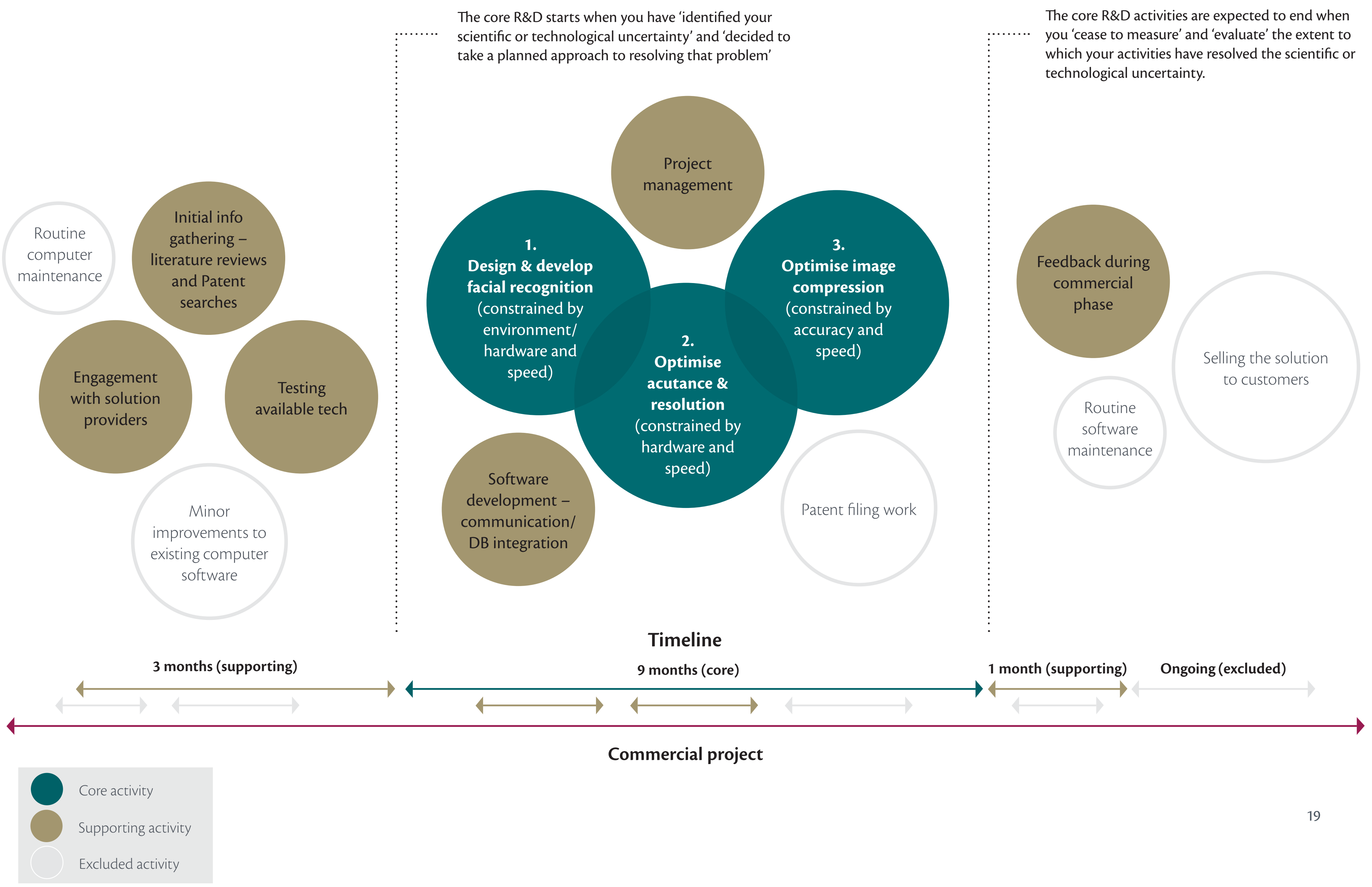
The Core R&D starts when you have identified your scientific or technological uncertainty and decided to take a planned approach to resolving that problem.

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. Note: 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.

When does the R&D start and finish?



The development of 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 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 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.

Refresher

Excluded activities

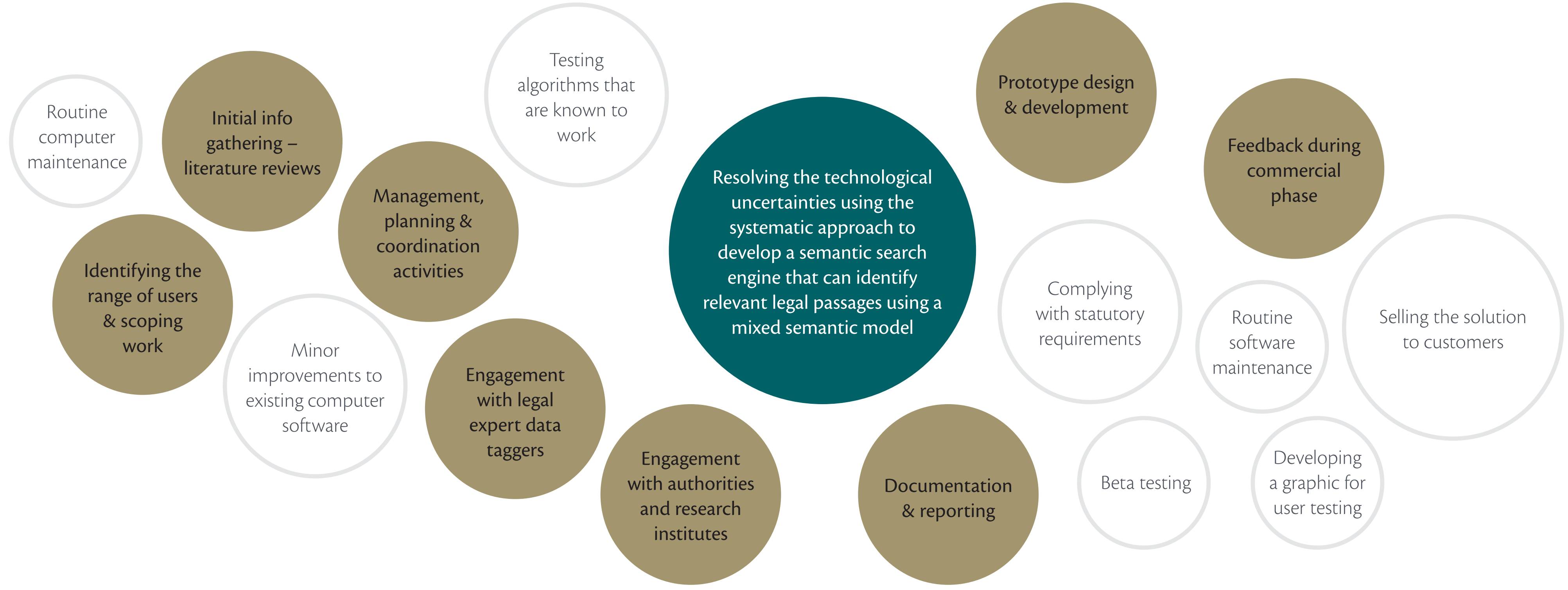
Certain activities are ineligible core R&D activities. A smaller number are ineligible supporting R&D activities.

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 '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 & Support	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. Note: 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).

When does the R&D start and finish?

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

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

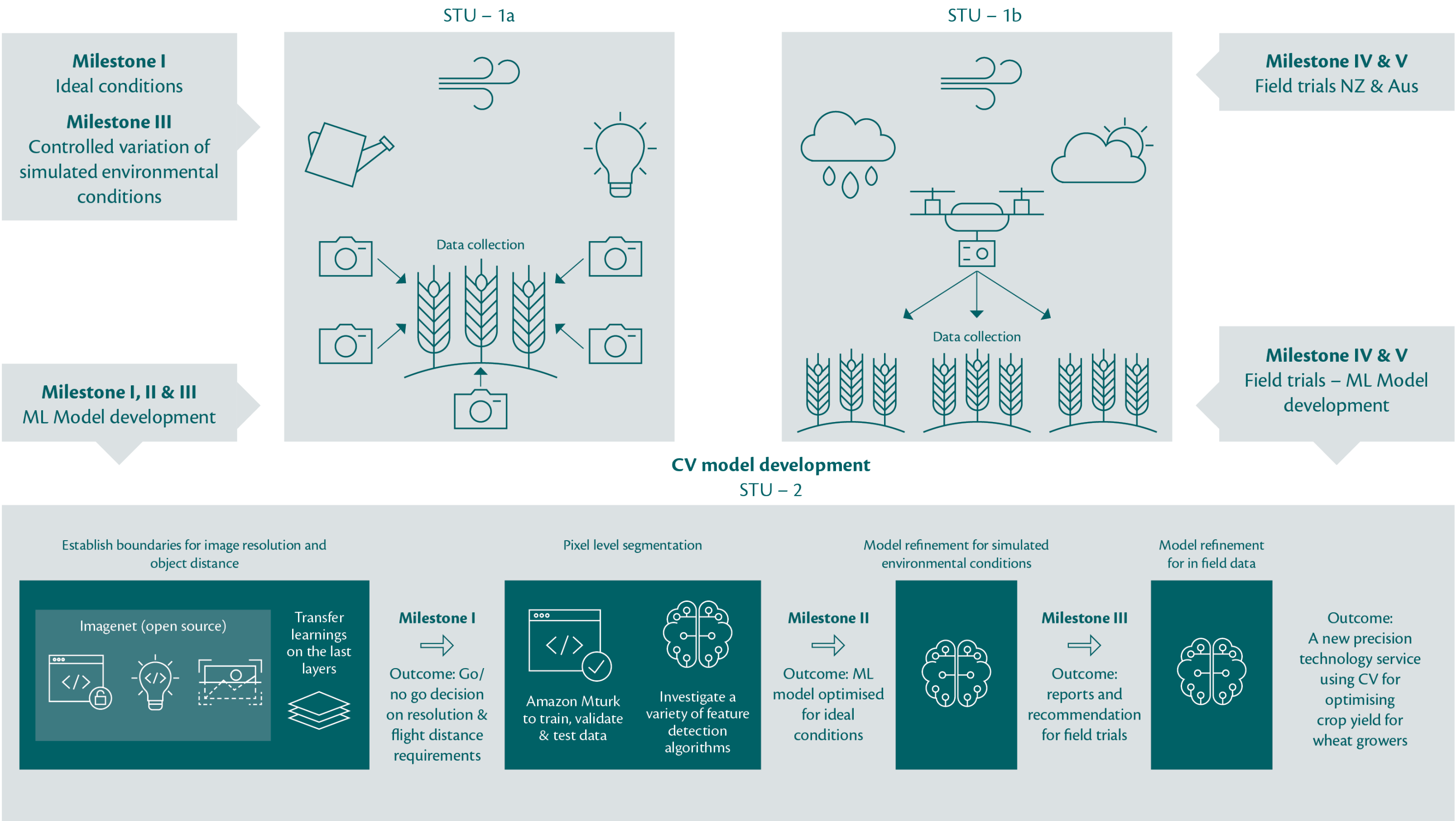
Example 3

Development of computer vision 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.



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 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 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 →

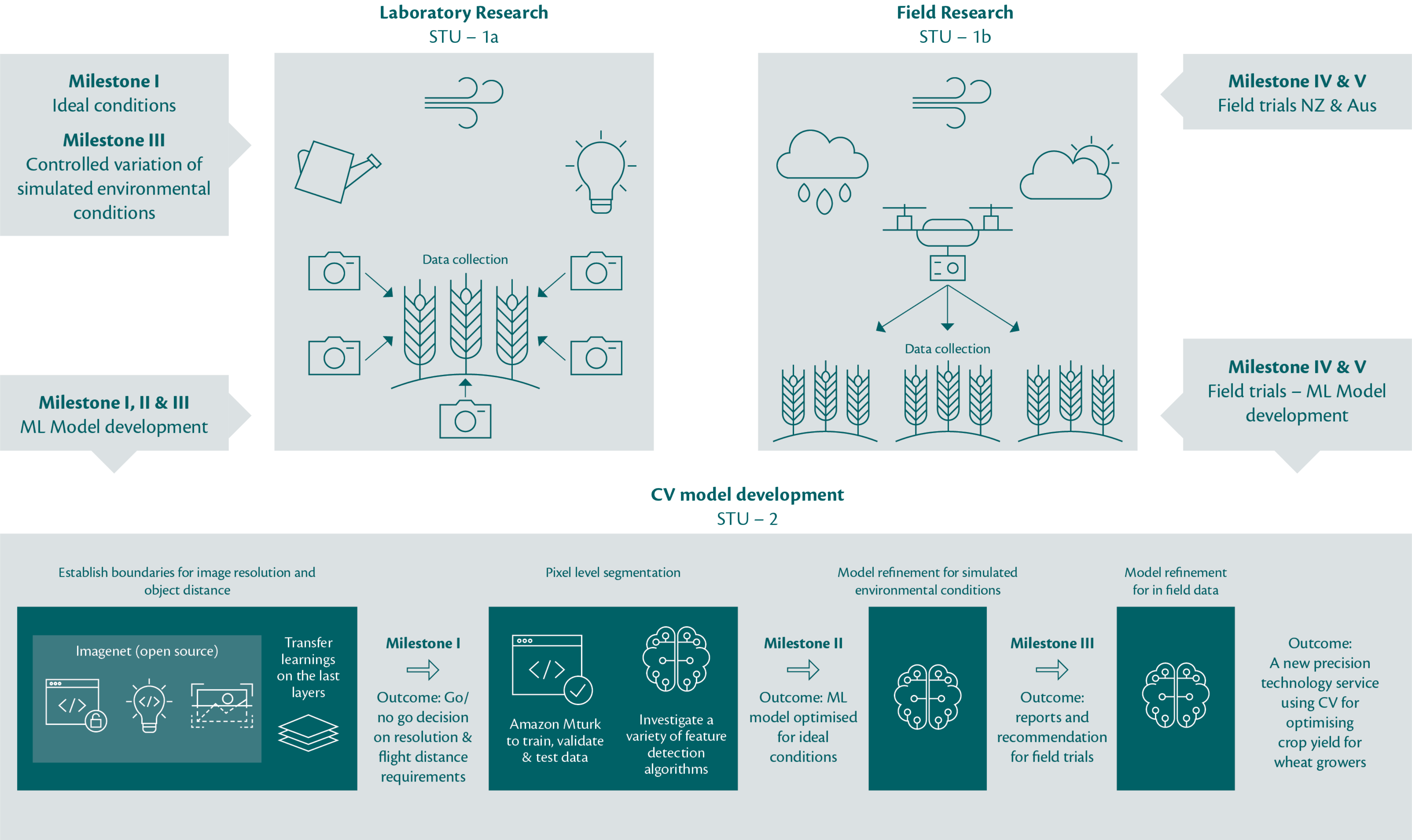
*refer to example 3 of the General Approval application in the Appendix for additional detail.

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.



R & D plan & investigate	Performance parameters
Milestone I: Ideal conditions in the laboratory	
Establish boundaries for parameters: • image resolution • object distance 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 & Aust respectively)	
• 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 Collecting the above real-world data and model refinement for continued improvement in accuracy	90% accuracy for real conditions in NZ, building to >95% accuracy Australia & NZ conditions combined

Points to note

Benchmarking the technological uncertainties

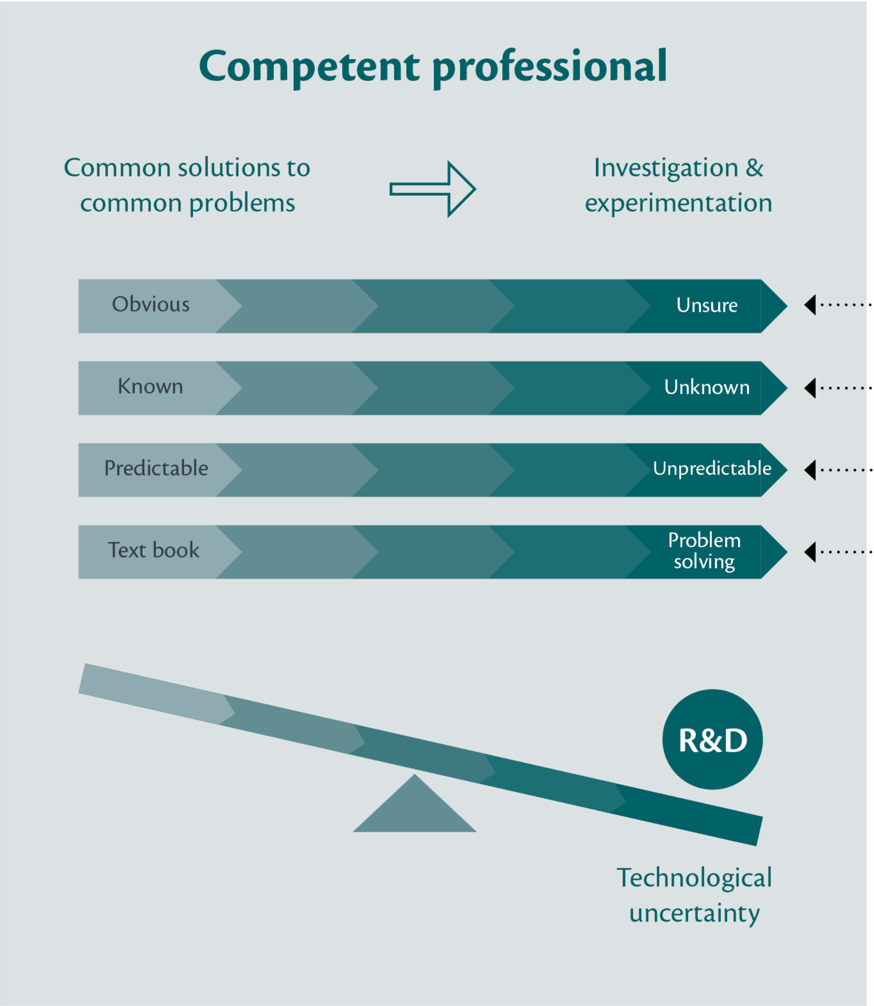
Remember, a key matter to consider is how to demonstrate that the knowledge required to resolve the technological uncertainties are not publicly available, or deducible by a competent professional in the relevant field.

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 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 computer vision 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 computer vision 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.

General examples: Competent professional



a competent professional is aware of the current state of knowledge in the field and is unsure how to solve the scientific or technological problem

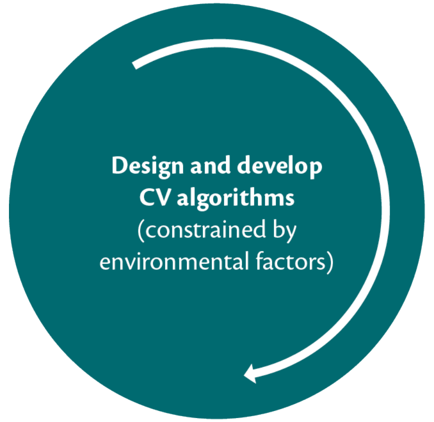
you may be confident that an objective can be achieved but it is unknown how to achieve it

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

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

Core activity

The technological uncertainties



Benchmarking the technological uncertainties

Publicly available

Initial info gathering - literature reviews and patent searches

Existing algorithms unsuitable

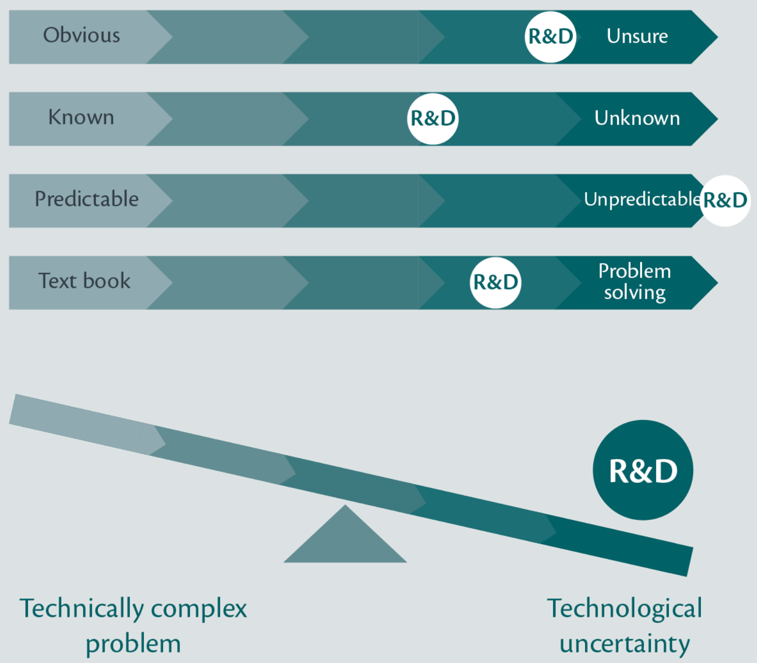
Existing CV models unable to detect minor colour variations

Findings

- Resolution might be too low
- Unable to detect minor colour variations in different environmental conditions

Competent professional

Common solutions to common problems → Investigation & experimentation



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.

Refresher

Excluded activities

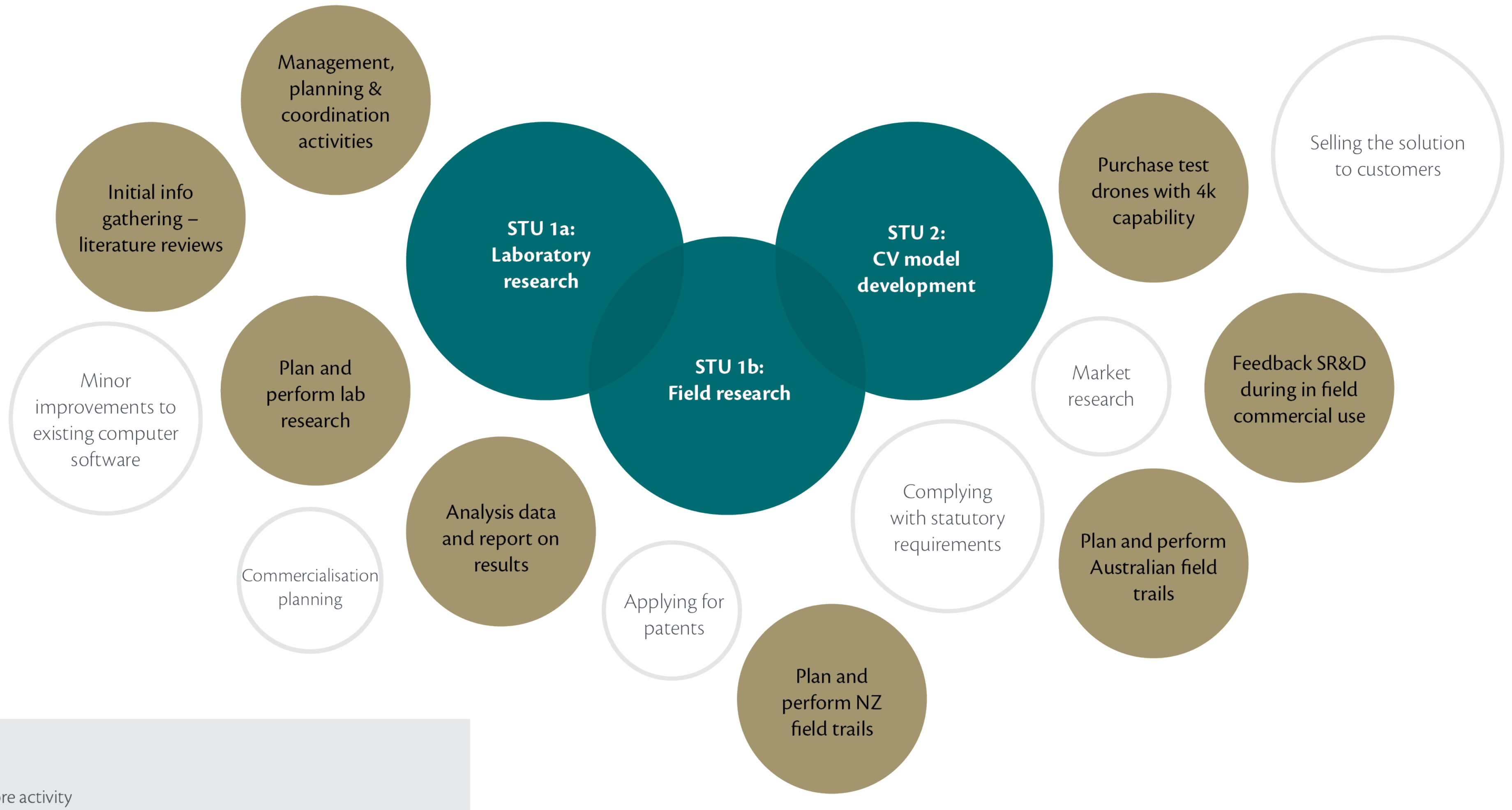
Certain activities are ineligible core R&D activities. A smaller number are ineligible supporting R&D activities.

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 '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 & Support	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?



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

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

Core & Support	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 Computer Vision 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 Computer Vision 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 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).

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

The development of a security system on a building site

Projects

An **eligible** & approved application

Project identifier

The real-time staff site identification (RSSI) project

Start date: 1 April 2019	**End date:** 31 March 2020

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.

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

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

The development of a security system on a building site

Projects

An **ineligible** and declined application

Project identifier

The real-time staff site identification (RSSI) project

Start date: 1 April 2019

End date: 31 March 2020

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

The development of 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 2020 | **End date:** 31 March 2021

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

New knowledge. New or improved services goods or processes

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

The development of drone-based computer vision technology for identification of wheat flowering stages

Projects

An **eligible** & approved application

Project identifier

Computer vision technology for identification of wheat flowering stages

Start date: 1 April 2021	**End date:** 31 March 2024

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 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 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 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 - 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 - 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.

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 AU field trials.

Aim to achieve 90% accuracy for real conditions.

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

Milestone V - AU field trials & final model refinement.

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

Example 3