NIA ENWL030
Hyperspectral Imaging

Closedown Report

31 July 2023

VERSION HISTORY

Version	Date	Author	Status	Comments
V1	14/06/23	Elizabeth Pattison	Final	

REVIEW

Name	Role	Date
Geraldine Paterson	Innovation Manager	19/07/23
Ben Ingham	Innovation Technical Manager	19/07/23

APPROVAL

Name	Role	Date
Victoria Turnham	Head of Network Innovation	19/07/23

CONTENTS

GLOSSARY

Term	Description
HSI	Hyperspectral Imaging
MTC	Manufacturing Technology Centre
NIA	Network Innovation Allowance
NIR	Near Infrared
SWIR	Short-Wave Infrared
VNIR	Very Near Infrared

1 EXECUTIVE SUMMARY

1.1 Aims

This project investigated and trialled the use of hyperspectral imaging (HSI) technology in the detection and classification of contaminants in spoil. The aim was to demonstrate the viability of HSI technology for differentiating between hazardous and non-hazardous materials to accurately classify excavated waste and enable cost-effective disposal.

1.2 Methodology

Our project partners, Manufacturing Technology Centre (MTC), first carried out desktop research to confirm the inspection requirements, then gathered information about commercially available HSI cameras and scored them based on these requirements. This was followed by laboratory trials, partially conducted within MTC and partially at a third-party facility, designed to demonstrate proof of concept.

1.3 Outcomes

The project met all objectives and success criteria, producing all expected learning on the current state and effectiveness of HSI technology for the classification of soil.

1.4 Key learning

There is potential for using HSI technology to identify the presence of contaminants, and to identify some specific contaminants, in soil.

Future projects should focus on testing HSI technology with a larger range of genuine soil samples and in field conditions to get a true picture of how accurate results would be in a real-life scenario.

It is possible that the solution would require higher investment than originally anticipated.

1.5 Conclusions

Whilst there is potential for using HSI technology to identify the presence of contaminants, and in some cases specific contaminants, in soil, further work is required.

Before further exploration, it will be necessary to complete an exercise to identify potential use case scenarios and construct a cost benefit analysis, based on project learning.

1.6 Closedown reporting

This project was compliant with Network Innovation Allowance (NIA) governance and this report has been structured in accordance with those requirements.

This report and the associated documents are available via the Energy Networks Association's Smarter Networks learning portal at www.smarternetworks.org or via the Electricity North West website.

1 PROJECT FUNDAMENTALS

Title	Hyperspectral Imaging
Project reference	NIA_ENWL030
Funding licensee(s)	Electricity North West Limited
Project start date	January 2022
Project duration	18 months
Nominated project contact(s)	Elizabeth Pattison

2 PROJECT BACKGROUND

Until now, utilities companies have been granted an exemption in the regulations around excavated waste arising from utilities installation and repair. In June 2022 this came to an end, and, following a transition period, it will be necessary to classify spoil and process any contaminated or hazardous material in line with environmental regulations.

This project was proposed to Electricity North West by the Manufacturing Technology Centre (MTC) as a way to address this challenge.

3 PROJECT SCOPE

This project investigated the use of HSI technology in the classification of soil. The project consists of two phases: the first was a development phase where testing was carried out to demonstrate the capability of a HSI device for detecting and classifying contaminants in soil; the second, not yet started, will comprise a series of field tests to confirm suitability of the device for use in real world conditions. There will be a stage-gate at the end of phase one to allow ENWL to bring the project to an end should a device of this nature not appear practical following the initial laboratory testing.

4 OBJECTIVES

The project objectives are as follows:

- Identify appropriate, commercially available HSI cameras suitable for identification of selected contaminants in soil.
- Trial the use of HSI for detecting and classifying contaminants in soil in a laboratory setting.
- Demonstrate the ability to utilise this technology under field conditions (phase two of the project, post stage-gate).

5 SUCCESS CRITERIA

For phase one, this project will be successful if it can create the following learning:

- Definition of the problem and identification of the technical requirements of this solution.
- Review of the commercially available HSI cameras and scoring against the identified technical requirements to inform selection for trials.
- Lab trials of selected cameras to establish suitability of using HSI technology for identification of hazardous materials in spoil and recommendations for further trials.

There is a stage-gate at the end of phase one for this project. To progress to the second phase, the project team will have to demonstrate through lab testing that HSI technology can detect hazardous contaminants in spoil.

The second project phase – post stage-gate – will be successful if it can identify/ produce a device that demonstrates the viability of using HSI technology in field conditions to detect and identify hazardous spoil contaminants.

6 PERFORMANCE COMPARED TO THE ORIGINAL PROJECT AIMS, OBJECTIVES AND SUCCESS CRITERIA

Phase one of this project is now complete, with all aims, objectives and success criteria met and ready for further review now that the project has reached its stage-gate, as planned. This review is currently underway, and will be completed before a decision is made on whether to continue to the second project phase.

6.1 Phase one

Project performance in relation to the project aim, to demonstrate the viability of HSI technology for differentiating between hazardous and non-hazardous materials, objectives and success criteria, as outlined above, is summarised below and detailed in the associated project deliverable reports. These reports are linked below and published on ENWL's website.

6.1.1 Problem definition

The first deliverable report, "Problem definition", provides context on the problem to be solved and how HSI technology works, and details the established inspection requirements. The report outlines the downselection process that will be used to quantify the suitability of commercially available HSI devices, and explores a number of criteria to consider, including:

- Detection – environmental conditions, technical specification and considerations regarding specific contaminants.
- Practical – cost, size, durability, ease of use, power, spectral range, etc.

6.1.2 HSI downselection

The second deliverable report, "First stage downselection", identifies and reviews the commercially available HSI cameras and scores them against the criteria established in the first deliverable based on the manufacturers' specifications and their expected performance based on MTC's expertise.

These scores inform selection of HSI cameras for the practical lab trials in the third deliverable.

6.1.3 Lab trials

The third deliverable report, “Trials”, describes the laboratory trials that took place as part of the project. The trials tested three HSI cameras across the very near infrared (VNIR), near infrared (NIR), and short-wave infrared (SWIR) ranges: the Specim FX10, FX17 and SWIR. These were used to image reference materials representing contaminated and uncontaminated soils, based on the contaminants identified in the first deliverable report, to determine the potential for detection of contaminants.

This report describes:

- The practical trials and results
- Variability in measured spectra and characteristic features of contaminants/ soil types
- The processing of image data and spectra to characterise special features
- A review of the cameras trialled
- Recommendations for the next steps

6.2 Phase two

Work on this phase has not started and will depend on further review of the project outcomes.

If the project continues to phase two, it would aim to demonstrate the ability of HSI technology under field conditions to differentiate between hazardous and non-hazardous materials for accurate classification of excavated waste.

7 THE OUTCOME OF THE PROJECT

The project has produced learning that suggests there is potential for using HSI technology to identify the presence of contaminants, and potentially also specific contaminants, in soil.

However, the third deliverable report recommends that further work should be undertaken before HSI technology is considered for deployment. This is due to the limitations outlined below, which would benefit from further exploration:

- Reference materials were not representative of genuine soil. They were guaranteed to contain only one contaminant, when genuine soil would likely contain a mix of contaminants.
- Contaminants were limited in the range of concentrations, as they were pre-prepared samples.
- Trials were conducted using artificial lighting, which ensures consistency and is therefore not representative of natural light in real world conditions.
- Full evaluation would require further samples to cover all contaminant types that might be encountered in soil.

The third report also suggests that a VNIR camera, the lowest-cost option, is unlikely to be suitable for this purpose, but that the NIR camera has the ability to identify the presence of contaminants, and the SWIR camera, the highest-cost option, has the ability to identify some specific contaminants in a soil sample. It will therefore be necessary to conduct further work to construct and evaluate potential use-case scenarios and identify the associated cost and benefit.

8 REQUIRED MODIFICATIONS TO THE PLANNED APPROACH DURING THE COURSE OF THE PROJECT

8.1 HSI camera availability

After selection of the commercial HSI cameras for trial, it became apparent there was a limit to the cameras available for testing within the timeframe of the project.

Originally, the plan was to test a selection of NIR cameras produced by different manufacturers; the Specim FX17, the Headwall Micro-Hyperspec Extended VNIR or SWIR 640, and the Resonon Pika IR+ or IR-L+. However, of those selected, only the Specim FX17 was available for trial.

As such, the decision was taken to also trial the VNIR Specim FX10, which was useful for comparison, but testing with only one manufacturer meant that the team was unable to compare effectiveness or establish replicability across manufacturers.

8.2 Additional testing with Tellux

Following testing with both the Specim FX10 and the FX17, a preliminary review of imaged spectra suggested a lack of specificity in identifiable features of contaminants in these ranges. The decision was therefore taken to conduct additional testing in the SWIR range, with the Specim SWIR, to provide the most direct comparison of imaging in NIR and SWIR. The Specim SWIR captures images in 384 wavebands in the 1000 – 2500 nm range, overlapping the range of the FX17 and is otherwise similar in functionality and operation. These cameras are more expensive, but imaging in longer wavelengths increases the potential for characteristic features to be captured.

Quantum Design UK, who facilitated hire of the FX10 and FX17, identified Tellux as having the capability to carry out imaging with a Specim SWIR camera, as the camera was unavailable for hire. Tellux is a French startup specialising in hyperspectral imaging of soils for identification and analysis of pollutants.

8.3 Availability of reference material samples

Great care was taken to ensure all conditions were consistent across testing of the three cameras, to allow direct comparison; however, it was not always possible to test the same reference material samples.

Tellux’s facility is based in Petit-Couronne, France, and due to issues with the supply of reference materials, some were available only to MTC, and some only to Tellux. To compensate for unavailable reference materials, Tellux prepared the closest-possible equivalent samples by doping of the ‘clean’ reference materials. Details of the sample compositions are included in the third deliverable report.

9 PROJECT COSTS

Item	Category	Estimated costs (£k)	Final costs £k	Variance
1	Project mobilisation	22,688	22,688	0
2	WP1 – Problem definition report	7,784	7,784	0
3	WP2 – First stage downselection	13,119	13,119	0
4	WP3 – Trials	32,035	32,035	0
	Total	**75,626**	**75,626**	**0**

Even though it was necessary to make some changes to the approach, as described in section 8 above, the overall project costs were not affected.

10 LESSONS LEARNED FOR FUTURE PROJECTS

There is potential for the use of HSI technology in the detection of contaminants in soil, which could lead to a reduction in the costs associated with disposal of hazardous waste, dependent on further investigation.

Future projects should focus on testing the following to determine whether results would be reliable and replicable in field conditions:

- Testing genuine soil samples that might contain a mix of contaminants at a range of concentrations.
- Testing using natural lighting and in a range of field conditions.
- Testing a wider range of samples to investigate whether all contaminant types that might be encountered in genuine soil can be identified.
- Testing a range of cameras produced by different manufacturers.

During the project it became apparent that availability of technology from third parties may be limited, so this should be factored into the planning phase of future projects to ensure that the required apparatus can be tested within the project timeframe.

Learning also demonstrated that a solution might require higher investment than originally anticipated, as the HSI camera with most potential for identifying specific contaminants is the high-cost SWIR camera, which may also be less practical for use outside of a lab setting. Therefore, it will also be necessary to develop some potential use case scenarios and produce a cost benefit analysis to determine how suitable HSI technology is for this purpose.

11 PLANNED IMPLEMENTATION

This research has demonstrated that there could be some benefit to using HSI technology in the future. However, further work is required to establish the effectiveness of the technology in field conditions, in addition to the possible use case scenarios and their associated cost and benefit.

Further work will be able to establish whether the technology can be implemented in business-as-usual practises or whether it would require further development.

12 DATA ACCESS

There was no data gathered as part of this project.

Electricity North West's innovation data sharing policy can be found on our website.

13 FOREGROUND IPR

There is no foreground IPR associated with this project.

14 FACILITATE REPLICATION

All learning from this project is published on ENWL's website and will be shared on the Smarter Networks Portal to ensure that other network operators can build on the project work or consider it for their business practices.

15 OTHER COMMENTS

None.