NIC 2018 - RRES

Project Progress Report 7

16th June 2020

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Contents

Document Control

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1 Executive Summary

The purpose of this document is to report on the progress the project has made since the last PPR submission on the 31st March 2020. The report contains a summary of the progress made from SGN, with subsequent reports from ULC Robotics as the principle project partner. Also, the planned progress and the key milestones to be delivered over the next PPR period is included.

RRES is an innovative and advanced robotic system which will be designed to improve existing methods of excavation, repair and maintenance operations performed daily at SGN and the other GDN's. The objective is to reduce the excavation size, costs, labour and equipment while making the work safer.

Since the last PPR, we have progressed as planned with the shop testing of the RRES prototype, integrated the subsystems with the robotic arm and testing of RRES' sensing and excavation technology has continued.

- Sensing module was tested on our mock roadway
- Chainsaw was tested to cut various sized keyholes
- Excavation shop testing on hard compacted clay was performed
- Design of the control and monitoring system completed

Furthermore, with Utility Week Live 2020 being postponed until November, we are moving forward with our engagement plan through virtual means. The project team introduced RRES to the industry via a full booked webinar jointly hosted by the industry bodies IGEM (Institute of Gas Engineers and Managers) and PIG (Pipeline Industries Guild). This platform was used to describe the developmental milestones successfully completed two years into this three-year project and is available to view on the PIG YouTube channel. This also provided an opportunity to disseminate the learnings from the project to other sectors, with attendees from the construction and water sector attaneding as well as those from academia.

The content of this report and the identified project progress aligns with the project plan conveyed in the submission although some of the above developments will appear in the preceding PPR following engineering document approval.

2 Background

Utility excavations are necessary to inspect and maintain buried infrastructure, but are disruptive, labour-intensive and can lead to unintentional damage to neighbouring plant. Reducing the requirement for extensive safe digging practices could significantly reduce both the social cost of works and associated emissions. By combining cutting edge robotics, advanced custom tooling and artificial intelligence, RRES will improve existing methods of excavation, repair and maintenance operations performed daily within the utility sector.

Figure 1 - Components of RRES

The goal of the project is to develop a prototype RRES system that can demonstrate automation of the excavation and reinstatement process and the installation of a Universal Access Fitting (UAF).

Two field tests will be executed: one on dead pipe and the following one on a representative live gas main. Collectively, the two field tests will demonstrate the following:

a) Transport and setup of the RRES (including a vehicle and a mobile platform with a robotic arm and excavation sensors/tooling)
b) Removal and reinstatement of asphalt, concrete and soil
c) Soil vacuum excavation in urban and rural environments
d) Prevention of damage to buried assets throughout the excavation process
e) Detection and avoidance of other buried objects
f) Exposure of the target pipe for operations
g) Preparation of a low-pressure distribution pipe for UAF installation
h) Installation of the UAF on a low-pressure distribution pipe

The project is arranged around the development of the following elements:

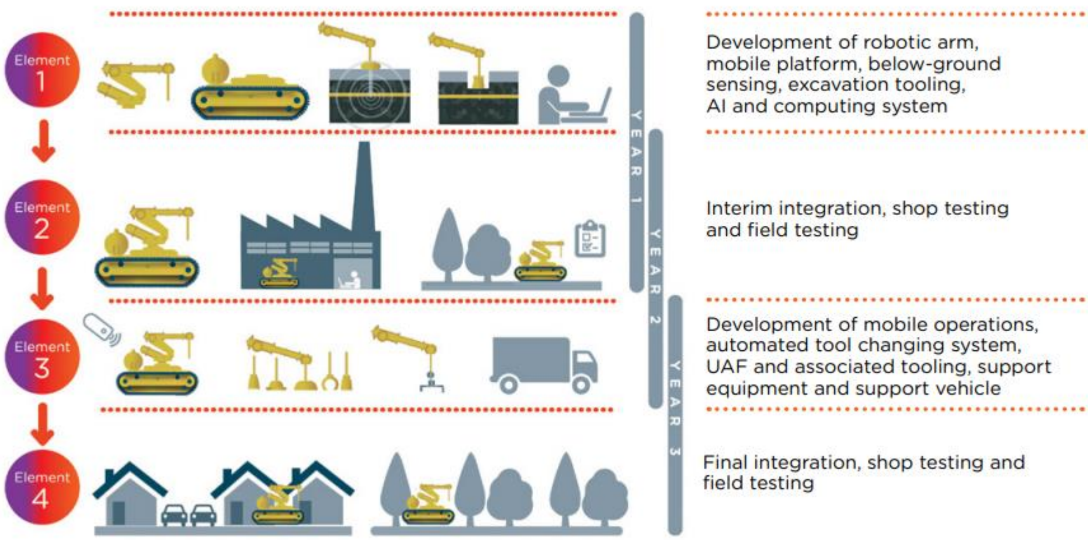

Figure 2 – Project Elements

Excavation

Conventional excavation, when compared with the RRES, requires a much larger excavation to allow direct access for operatives to carry out repairs or install fittings. Due to the larger excavation footprint and the amount of gas and third-party plant exposed within them, the risk of damage is high. If there is too much third-party plant in the excavation, the process must be carried out manually by the operatives using hand tools. This process is time-consuming, physically taxing and carried out in hazardous environments. The RRES core removal technique, ‘soft-touch’ excavation capabilities and automated above ground tooling will significantly reduce the footprint of the excavation and the risk to third party damage.

Sensing

Prior to starting excavation, and during the excavation process, the robot operation will utilize sensors to scan in “layers” to identify buried assets in its excavation path.

To better focus research and development efforts, the sensing operation is broken down into two main categories of sensors. (1) Pre-Excavation Sensing and (2) Post Excavation Sensing

Pre-Excavation Sensors will be used to scan the roadway above the excavation zone prior to cutting the road surface to identify utility lines and other obstructions in the first layer of the work path. Although not a focus, ULC will also review sensors that may be used with the system increase the accuracy of robotic operations in target location.

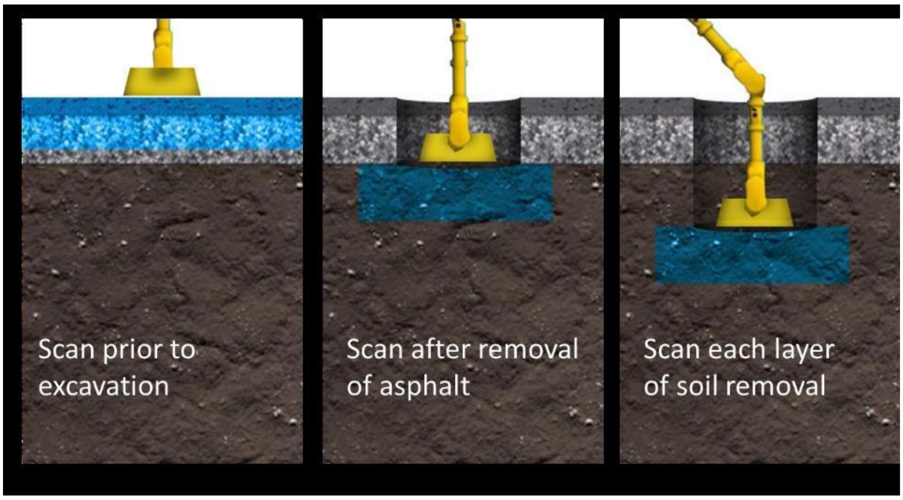

Figure 3 – Below Ground Sensing

Post-excavation sensing system can be used after every stage of excavation to create a point cloud and texture model of the bottom of the keyhole. A point cloud is a set of data points which represent points in 3D space and can be used for measurement, navigation and to generate accurate 3D models of environments. Point clouds are generally produced by 3D scanners, which measure many points on the external surfaces of objects around them.

Deployment System

The deployment system consists of the robotic arm, the mobile platform and the computing system that carries out all robotic operations. To properly identify, develop and specify different components for the system, and to design the most optimal deployment method, preliminary specifications and capabilities required to perform each of the operations have been defined. These specifications will be adjusted based on the new findings from site visits as well as the feedback from SGN.

3 Project Managers Summary

The project has entered an essential period where each of the subsystems of element 1 have been integrated with the robotic arm and is being put through extensive testing. Also, development of the supporting subsystems critical to the operation of the RRES has commenced. The Universal access fitting and tool changer is at the early stage of development, both of which will enable RRES to perform efficiently and safely.

Sensing

Sensors will be used to scan the roadway above the excavation zone before cutting the road surface with the goal to identify utility lines and other obstructions in the first layer of the work path. As proposed in the bid document, the excavation will be carried out in layers. After removing each layer of soil, a combination of one or more sensors will be used to gain more accurate information about the presence of obstacles in the path of excavation.

Testing Procedure

As the robot has been mobilised, the system was ready for field deployment for real-life scenario data collection and processing. Our mock roadway was used as the testing site which will allow the performance of the system to be asses and amendment identified over various assets of different sizes and material. The size of the scan area that will be tests is 1350mm x 2300 mm which is determined by the maximum reach of the robot arm. During these tests, two specific areas on the mock roadway 1 were selected for scanning. These areas are demonstrated in Figure 4. After data collection, the results were processed using the software developed for RRES and the results are as follows.

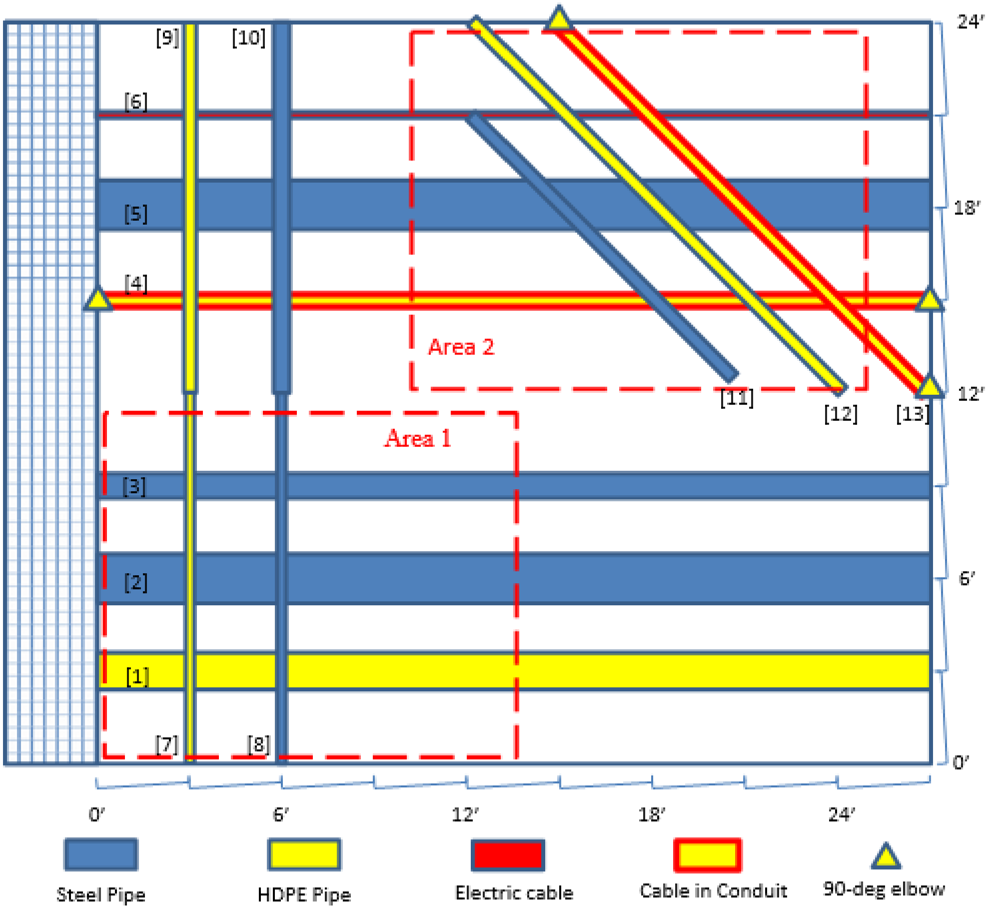

Figure 4- Mock Roadway demonstrating the selected areas for testing the belowground sensing capabilities of RRES

Figure 5 – Testing of the Sensor Module

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Data Visualization

Development of how the assets will be visualised on a 3D model is also advancing. Using data algorithms, and machine learning, the data will be grouped, and different asset material and diameters will be determined and visualised as can be seen below in Figure 10.

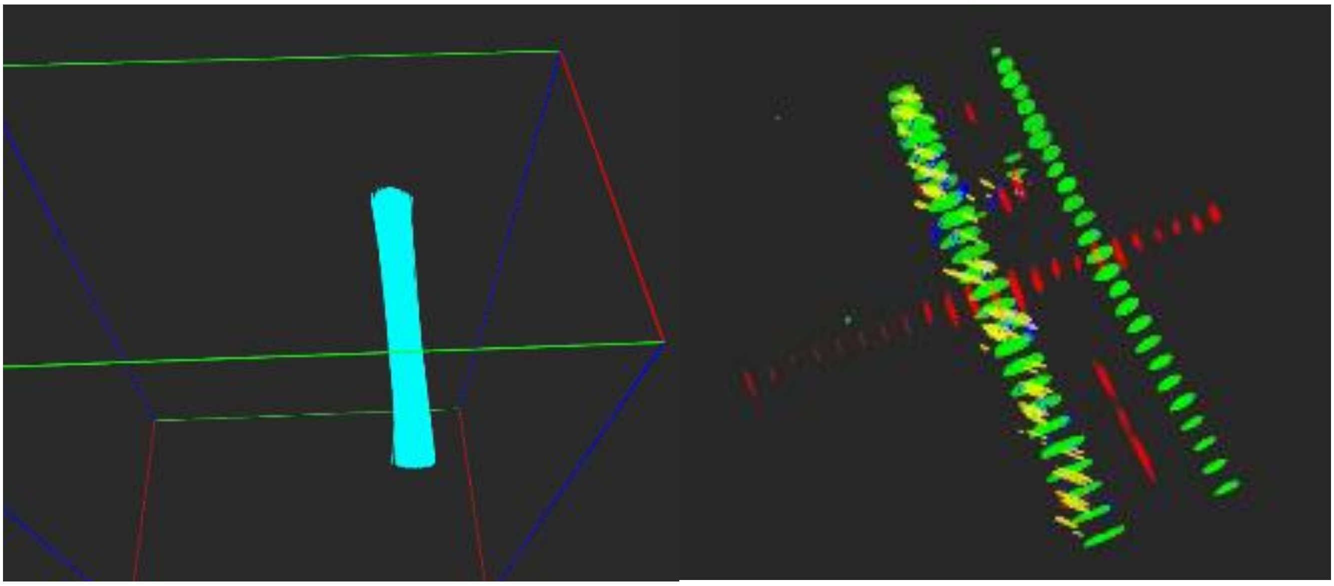
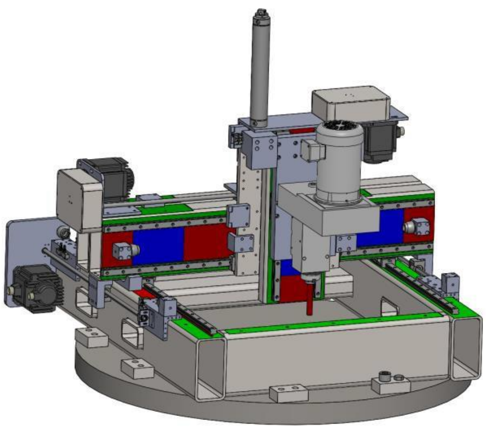


Figure 10 – 3D Visualisation of Underground Assets

Keyhole Cutting

Part of the Robotic Roadworks research and development project includes innovative methods of cutting the road surface. ULC Robotics has determined that there is substantial value in developing a high power, high accuracy mechanized chainsaw for this aspect of the project.

In order to test the tools developed for this task, 16cm thick 4500 PSI reinforced concrete slabs were built. The chainsaw design was initially installed on a custom-designed CNC machine, demonstrated in Figure 11, and after testing and validating its capabilities it was transferred to the robot arm of the RRES.



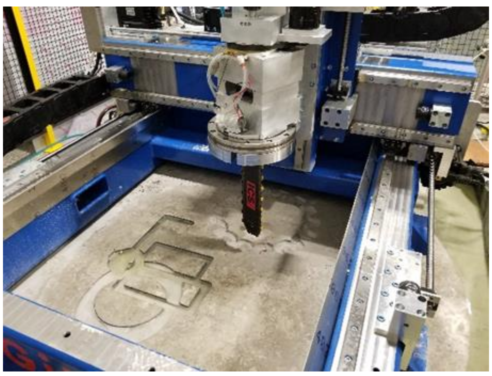


Figure 11 - CNC machine, designed and built for testing the cutting tools

Initial development of the chainsaw incorporated an off the shelf high speed 7.5kw motor that was used to power a unique gearbox system to drive the chain. While this showed promising results, it struggled with cutting wire/steel reinforcement in the test road surface samples. This version of the chainsaw is shown in Figure 12.

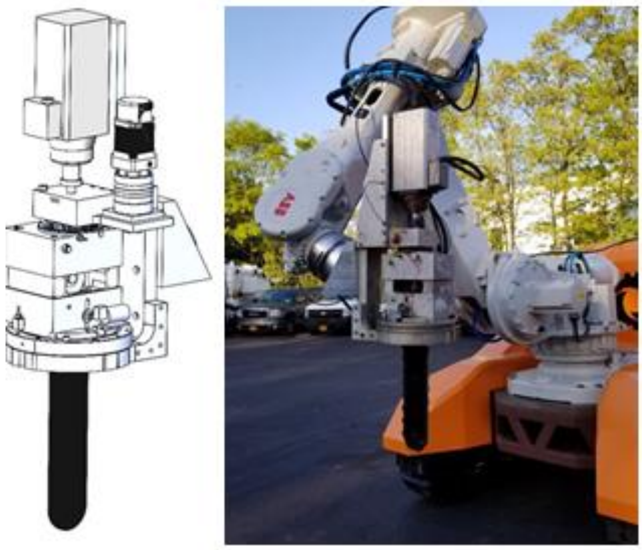


Figure 12 - First iteration of the chainsaw with 7.5kW motor

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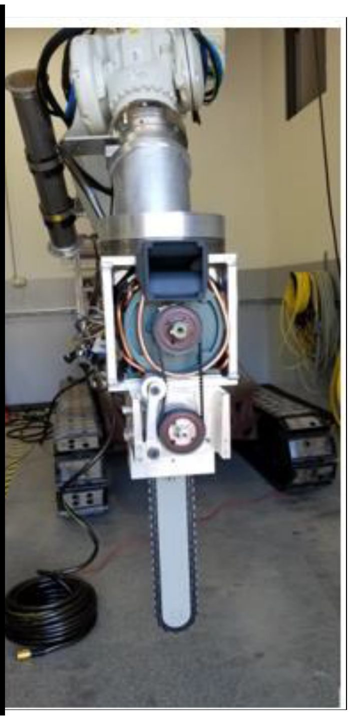
[redacted] 

Figure 13 - Second version of the chainsaw with 35kW motor

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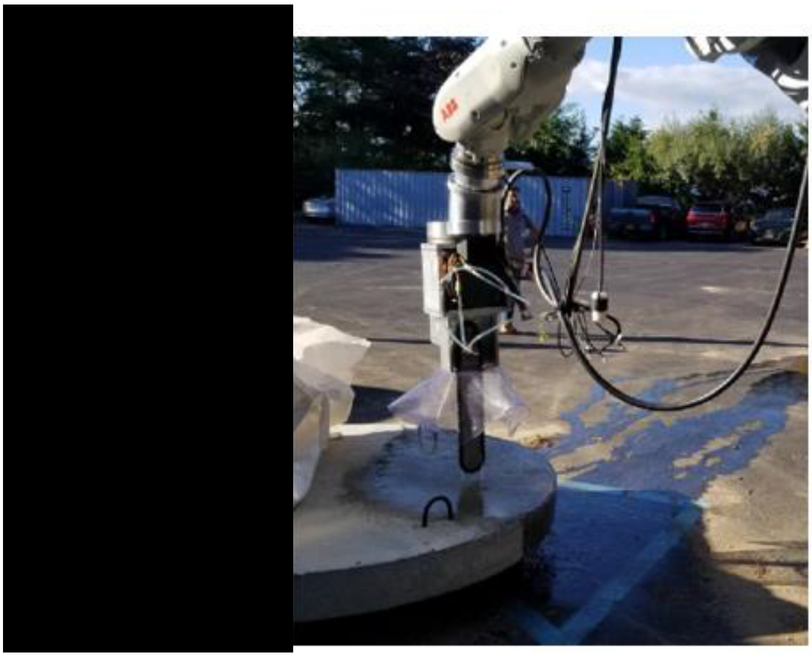

Figure 14 - Version 2.1 of the chainsaw

Initial testing with version 2.1 of the chainsaw showed substantial improvement in cut results. Also, cut speed in concrete doubled, and the unit's ability to cut through the wire reinforcement went from very difficult to where it now cuts rebar with minimal strain.

In order to improve the longevity of the chain and the bar and to simplify maintenance procedure, more changes were made to the design of the chainsaw. [redacted]

[redacted]

[redacted]

Keyhole Cutting Procedure – Robotic Control

The system requires a cut path to be generated in order to coordinate the angle of the bar with the motion of the end effector of the robotic arm. There are a few different ways this can be accomplished with the various software packages available to the system.

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Excavation

The gradual changes in the design and testing results of different iteration of the soft-touch excavator head were described. Since the last submitted report on soil excavation, the ULC team has been focused on improving the consistency of the operation, automated excavation, and improved soil containment. Also, more development work has been conducted to solve the clogging issue which is an ongoing challenge in the vacuum excavation industry.

Design of the Excavator Head

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Based on the test results the current process is very successful in breaking up all the soil chunks into powder to allow for easier removal. However, clogging remerged as a problem when trying to excavate a wet clay mix. Further research into the subject showed that this is a major problem in not only the vacuum excavation industry but in horizontal drilling as well. As soon as the wet clay meets a restriction, it starts to re-compact in the vacuum hose and builds up. The tests conducted by ULC showed that this build-up would eventually cause the main vacuum pipe to compact and clog and stop the excavation. [redacted]

[redacted]

Excavation Containment

The last improvement to the excavation was an upgrade to the excavation containment system. Previously, the cage that we used to keep the excavated material contained was very cumbersome to set up. These challenges were described in some of the previously submitted reports. Therefore, ULC designed a cartesian excavation cage. This design consists of heavy-duty harsh environment linear rails capable of withstanding the heavy material weight and has very good coarse material protection. To fill the spaces during the excavation motion, sewn bellows were used that were fastened to the moving carriage. This design provides coverage over excavations with any size and shapes up to 4 feet in either direction. The design is shown in Figure 23.

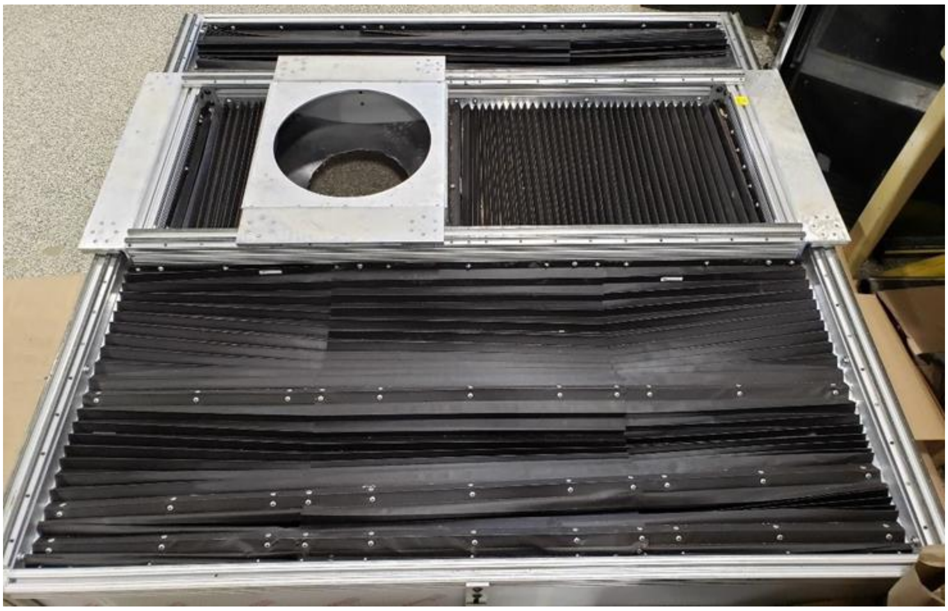

Figure 23 - Cartesian cover designed and built to contain the excavation

Excavation Procedure – Robotic Control

Through multiple phases of development, changes were made to the procedure that the robotic arm went through to conduct the excavation using the soft-touch excavator head. The pros and cons of each procedure and the design process to identify the best procedure for excavation operation are described in the previously submitted reports.

[redacted]

Figure 24 - Cartesian cover in operation with the excavator

Hose Configuration

After conducting further tests on hard compacted clay, the excavator was subject to clogging. The nozzles were 6-8 inches away from the soil with another 4-6 inches of agitated soil underneath. Early in the excavation test, no clogging was observed. As the hole depth increased, there appeared to be more moisture in the soil and clogging started to become an issue. [redacted]

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Supporting Equipment

Element 3 of the project focuses on the development of the supporting subsystems that will permit RRES to operate efficiently and safely.

Support Vehicle

ULC Robotics has identified all the necessary tools and support equipment to conduct the operation and is currently working on different scenarios to integrate this equipment into one vehicle or identify the right combination of equipment and vehicles to be available at every job site for operation. ULC has also conducted research and design work for vehicles to transport and deploy the robot at a job site.

To further design and finalize the methods of transportation, ULC has reached out to a variety of groups and SMEs with a cumulative knowledge to ensure that all aspects of deployment and operation are considered. During the design process, multiple deployment and transportation scenarios of the RRES system were explored and the top three solutions that comply with the regulations in the UK are presented below.

Scenario 1 – Custom Support Vehicle Towing the RRES on a Trailer

The first concept is composed of a support vehicle that carries all the necessary equipment for the robotic operation. The same vehicle will tow a trailer that houses the robot and its control centre. The trailer is a drop deck style trailer that allows the RRES to be loaded without navigating an incline. An example of a drop deck trailer with its specifications is presented in Figure 26. The details of the necessary equipment to be mounted on the support vehicle are presented in the next section of this report.

The trailer that houses the robot would have a small command centre at the front, which allows for remote operation, and a spot on the rear for a secured tool cart. The tool cart houses all the tools (i.e. excavator head, sensors, etc.) that the robot would need to carry out different operations. The arrangement of all the vehicles and equipment at a typical job site over a distribution service is demonstrated in Figure 27.

Figure 26 - "drop deck" style trailer for RRES transportation

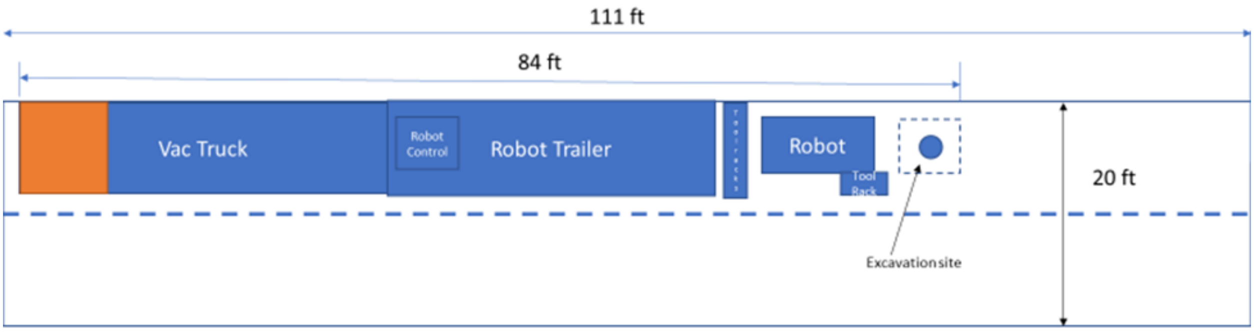

Figure 27 - Scenario 1, Custom Vac Truck towing the RRES on a Trailer

The pros and cons of using this method of deployment are as presented below

Pros

1. A single driver can bring the robot and the support equipment to the site.
2. The robot does not need to climb a ramp to get into the trailer.
3. The robot, command centre, and all the tools are stored and transported together.
4. The system can be transported (towed) by other vehicles as well.

Cons

1. The combination of a truck, towing a trailer is relatively complicated to drive and hard to manoeuvre in tight streets.
2. According to the transportation regulations in the UK, to tow a 7.9-ton trailer, the truck must weigh at least 13 tons. Based on the 7.5 ton estimated weight of the RRES, it is anticipated that the trailer, containing the robot will weight higher than 7.9 tons which will require even a larger vehicle for transportation.
3. Having a trailer hook-up on a support vehicle that houses the vacuum system will be difficult due to component placement (i.e. a boom and spoil container which are usually mounted at the end of the truck).

Scenario 2 – RRES, Tools, and Command Centre Dropped off at the Site

This solution consists of an independent support vehicle that carries all the necessary equipment to a job site and a second vehicle that houses the RRES, tools, and a mobile command centre. This vehicle can be a truck with a tilt body and flatbed that allows for the robot to drive up and down a ramp for loading and unloading, like the vehicle demonstrated in Figure 28.

In this scenario, a tilt body flatbed or equivalent truck that has the RRES and its tools pulls up to the site and unloads the robot and the equipment which will be set around the site for operation. The vehicle will then depart from the site so that the occupied space at the site is minimized. The support vehicle that carries all the operational equipment such as vacuum system will arrive separately and position itself near the excavation site. Once the operation is completed, the robot and its tools will be loaded back on the flatbed and returned to the storage facility. The operation site arrangement is demonstrated in Figure 29.

Figure 28 - An example of a tilt body flatbed vehicle suitable for RRES transportation

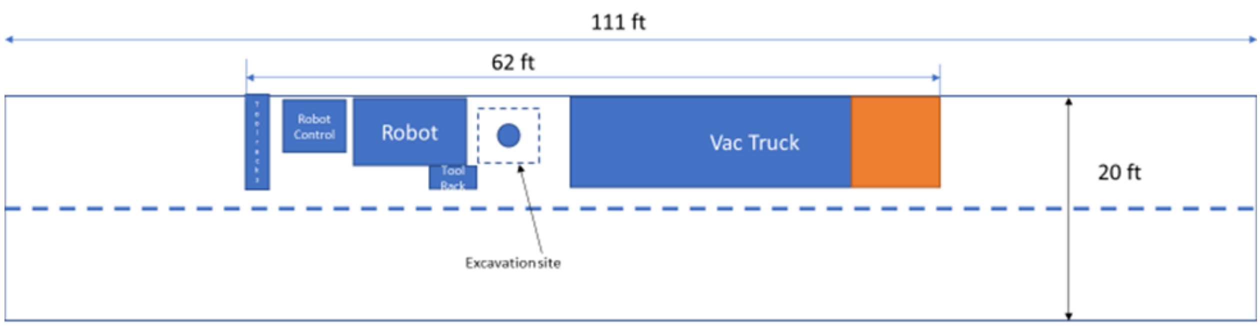

Figure 29 - Scenario 2, Site arrangement when the robot is unloaded for operation and the truck has left the site

The pros and cons of using this solution for deployment and transportation of the RRES are presented below:

Pros

1. Since the vehicle that carries the robot can drop everything off and leave, this scenario has the minimum site footprint among all the presented scenarios.

2. The system can be transported to the site with any similar vehicle that meets the specifications.
3. Since robot transportation is independent of the support vehicle, different vehicles can be hired or procured to support the operation.

Cons

1. Two or more vehicles (i.e. robot carrier, vacuum truck, compressor) must be driven to the site independently to conduct the operation.
2. The robot and the tool storage compartment must climb an incline for storage and transportation.

Scenario 3 – Custom Container to House RRES, Command Centre and Tools

In this scenario, a custom container will be designed and fabricated to house the robot, the command centre, and all the tools. The container can then be transported to a job site with different vehicles and can be used as a safe storage space for the RRES. The support equipment can be transferred to the site separately on different vehicles or all combined into one vehicle. A conceptual design of a container that meets all the transportation standards in the UK is demonstrated in Figure 30. Although the compartments and interior design of the container are tailored to house the robot and its tools, its outer shell matches the standard dimensions of 20 ft long container.

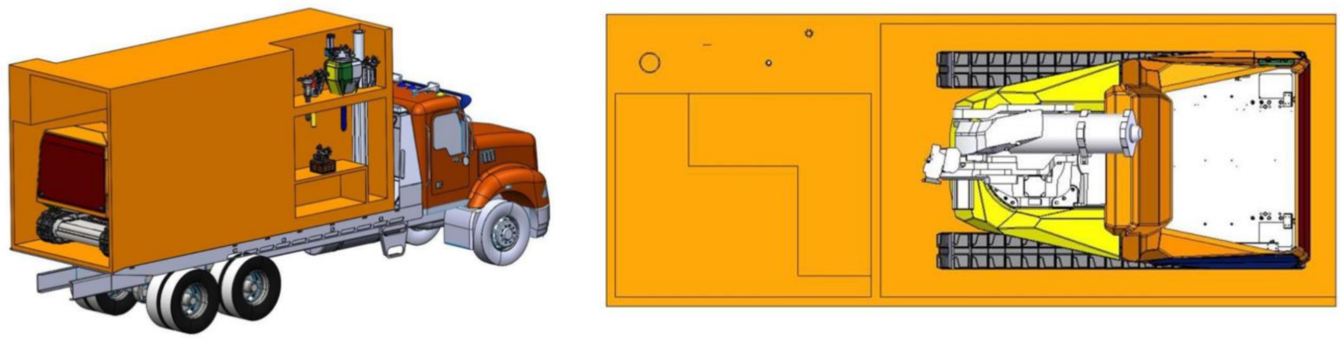

Figure 30 - Conceptual design of a custom-made container for robot transportation

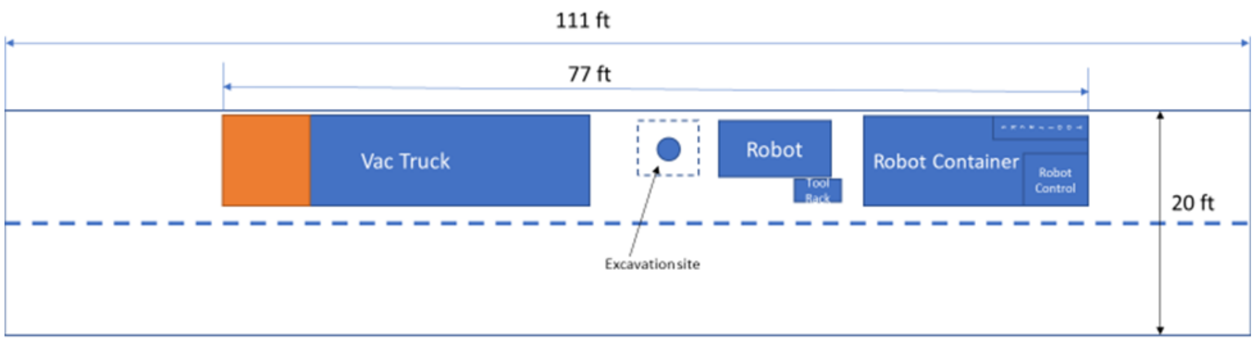

Figure 31 - Scenario 3, Job site configuration with a custom-built container

For site deployment, a truck brings and drops the container at the job site and departs the area. The robot drives out of the container and gets situated for the operation while an operator can supervise the entire job from the control cabin that is embedded into the container. The container remains at the site for the duration of the excavation. The support vehicle can arrive at the site by other means and can be a combination of multiple vehicles depending on the necessary equipment for the operation. At the end of the day, the RRES drives back into the container for transportation or safe storage at the site. When the excavation is complete, a truck picks up the container and can transport it to the next job site or to a storage facility. This arrangement of tools and equipment at the job site is demonstrated in Figure 31.

The pros and cons of this method of deployment and transportation are as follows:

Pros

1. The RRES and all its equipment can be securely locked up at the excavation site.
2. The robot and all the necessary tools for its operation as well as the command centre are housed within one container and will always be transported together.
3. Any truck that can carry a standard container can be used for robot transportation.
4. The interior of the container can be customized to fit the needs of the robot and the operation.

Cons

1. The support vehicle will be a separate entity and must be driven or brought to the site separately.
2. The container will take up a considerable amount of space at the job site.

The project team met with our Operations and Policy representatives from SGN, who met to discuss what option would be best to proceed with. Based on the following reasons, the decision was to move forward with option 3:

- takes up reasonable space at the job site
- provides appropriate safety for personnel and equipment
- allows the operators to seamlessly complete the operation
- has adequate storage for all required equipment will be chosen for further design work and fabrication.

Design of the container has progressed with the tooling cart and control area being added. Once final design has been completed and approved by our steering group, construction will commence.

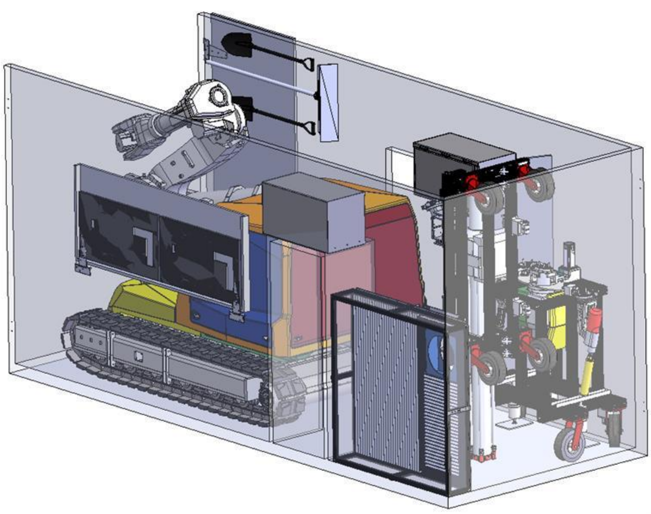

Figure 32 – Conceptual Design of Scenario 3 with the tool cart and control area.

Support Equipment

For the robot to successfully conduct the entire operation, several important pieces of equipment need to be available at every site such as vacuum system and compressed air. During different development phases of the project, a variety of equipment were rented or procured by ULC robotics to support the tests and field trials in the US. The procurement and hiring of different equipment helped the design team at ULC to identify the requirements for every robotic operation which lead to the development of a specification document for every necessary support system. This specification document would allow the operating team to procure the suitable equipment required for the operation at every job site. The document can also be used to design a custom vehicle that includes every equipment in one unit. [redacted]

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Reel Cart for System Tether

During the bid submission for this phase of the project it was anticipated that the robot's support equipment will include a tether connected to the RRES that would supply power, communication, and pneumatics, a reel cart for storage of the tether, an operator user interface for monitoring and operating the RRES. However, based on the design and fabrication work during Element 1 of the project, the project team created provisions for the robot to be operated completely untethered. In this design, the power to operate the robotic arm and all the control systems onboard of the robot is supplied from a battery pack onboard of the system. Also, the control system was designed such that the entire operation can be controlled and supervised remotely. There is therefore no need for the design and fabrication of a reel cart to handle a tether.

4 Future Progress

The table below lists the key milestones that are planned to be delivered over the next progress period:

Milestone	Title	Description	Due Date
27	**Progress Report 7 -** Test plan/report for UAF	Fabricate and test universal access fitting	16/6/2020
28	Design and build documentation for operator consoles	Design and fabricate operator consoles	23/7/2020
29	Documentation of RRES assembly	Assemble full RRES	15/9/2020
30	**Progress Report 8** – Test plan/report for UAF tooling	Complete shop testing of UAF tooling	19/11/2020

Table 3 – Planned Milestones over next PPR period

5 Business Case Update

No modifications have been required to the business case which remains valid in its current form.

6 Progress against Plan

The project has progressed as planned. The following Gantt chart (Figure 34) illustrates the project plan:

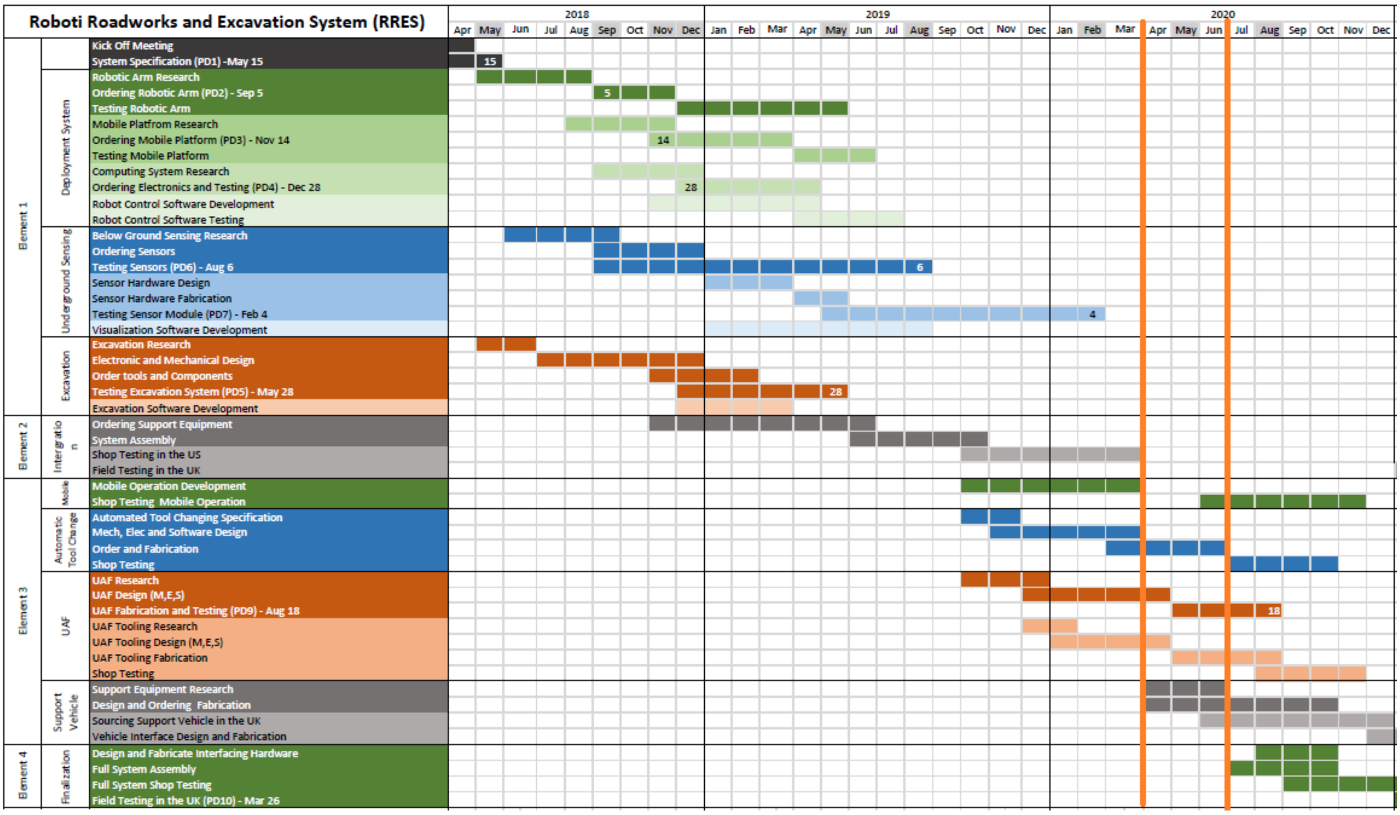

Figure 34 – Project Plan

Below are the milestones that were delivered as part of this PPR period:

Milestone	Title	Description	Planned Date	Delivered Date
23	**Progress Report 6** – Test plan/report for shop testing of prototype RRES	Complete shop testing of prototype RRES	31/3/2020	Completed
24	Test plan/report for interim field testing	Perform field testing on prototype RRES	26/5/2020	Postponed to 22/3/2021
25	Design documentation for tether and support vehicle	Source RRES tether and support vehicle	28/4/2020	Completed
26	Design and build documentation for reel cart	Design and fabricate reel cart	26/5/2020	Completed
27	**Progress Report 7** -Test plan/report for UAF	Fabricate and test universal access fitting	16/6/2020	On Time

Table 4 –Delivered Key Milestones

Due to the disruption caused by the COVID-19 virus, the project team have decided to move the Interim field testing in the UK to early 2021. To ensure we maintain the project timeline, we have brought future milestones forward. More information can be found in Section 11 – Material Change.

7 Progress against Budget

As the project has progressed as planned, the total expenditure to date is £5,166,927 with a further £111,646 set to be released by the 16/07 for the deliverable of milestone 26.

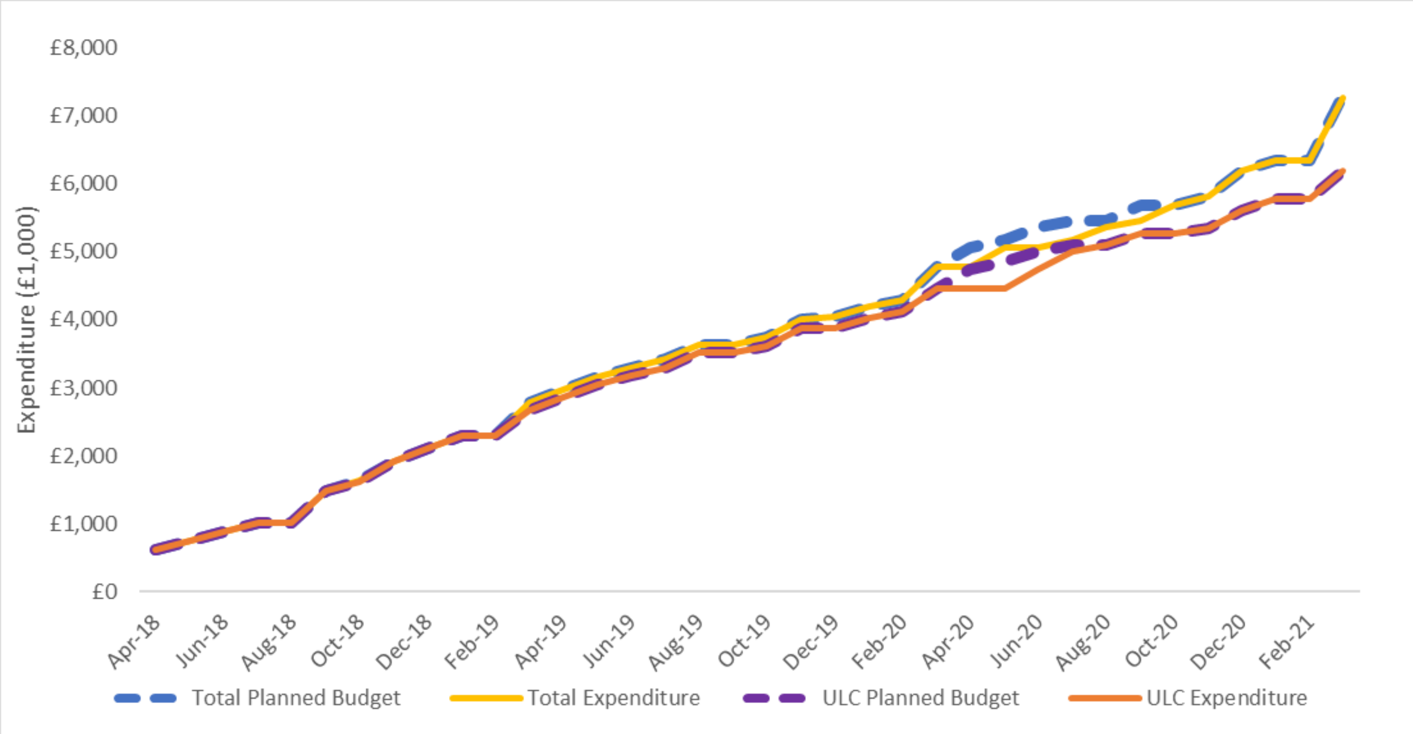

Figure 35 –Financial Overview

The key project deliverables are attributed below:

Milestone	Title	Main Project Achievements	Amount	Project Total	Status
23	Test plan/report for shop testing of prototype RRES	• Update toolpath generation and environment mapping software for use on mobile platform	£151,891	£4,777,400	Paid
25	Design documentation for tether and support vehicle	• Source vehicle chassis in UK • Design and fabricate interfaces between vehicle and support equipment • Design and fabricate interfaces between vehicle and RRES (including docking station and ramp)	£267,347	£5,044,747	Paid
26	Design and build documentation for reel cart	• Develop specifications for support equipment • Design and source tether • Design and fabricate reel cart	£162,403	£5,207,150	Paid

		• Design and fabricate operator consoles • Source miscellaneous components			

Table 5 –Key Project Deliverables

8 Project Bank Account

The statements for the transactions of the bank accounts for the NIC funds over this reporting period are available in appendix B.

9 Project Deliverables

In addition to the milestones completed as per the previous project progress reports, there have been a further 3 milestones delivered. The subsequent reports have been submitted to SGN and are available on request.

Test Plan/Report for Shop Testing Prototype:

The purpose of this document is to summarize the findings during the development procedure of each aspect of the robotic operation. The test results from testing and validating each of these subsystems are also presented in this document.

Design Document for Support Equipment:

As all the necessary tools and support equipment to conduct the operation has been identified, various scenarios of how the system will be transported, deployed and utilised. The purpose of this report is to present the design work and transportation solutions for the RRES project.

Design and Build Document for Reel Cart

As we moved to a completely tether less system during the design process of Element 1, the cart is no longer needed. In this report, the detailed design of the control and monitoring system that allows for wireless control and operation of the robot in place of the tether is presented.

10 Learning Outcomes

The main outputs of this project are the technical and engineering knowledge gained whilst researching new methods to access and potentially remediate the existing gas distribution network. Therefore, it is essential that learning opportunities generated by this project are successfully disseminated for GB GDN's, the wider gas community, national and international standard bodies, academia, local authorities and other key stakeholders. Learning has been and will continue to be disseminated so that the RRES system can be utilised by all GB GDNs upon successful completion of the project.

At present a large proportion of the design work and specification can't be shared with external parties due to the IPR conditions concerning the design. Dissemination of this information prior to patent approval could jeopardise the commercial aspects of the system, and impact on the financial return to the GB gas consumer and SGN. This has been factored in to the Stakeholder engagement plan, with most key events planned after the expected approval date of the patents. An update on the IPR conditions of the project can be found in Section 12 of this report.

Although Utility Week Live has been postponed from May to November 2020, we intend to continue to disseminate project information via virtual media.

Key Learning Outcomes
Cutting the road surface -Our testing has creating substantial learning in determining the performance criteria that impacts cement road surfaces.
Excavator Head - The most effective approach to agitate and excavate the soil was determined.
Pre-Excavation Sensing - Proper rotation of the GPR antenna can improve the detectability of the buried utilities.
Internal Dissemination
RRES update as part of innovation update within our executive monthly report
Steering Group Meeting was held in February with representatives from across the business including; legal, operations, Safety and Policy. In addition, the technical representatives from Policy and Ops are meeting biweekly with the project team to steer technical decision to help ensure RRES will be fit for purpose.
A Technical steering group has been formed between policy and operations who meet biweekly with the project team to discuss project development and decide on direction of
External Dissemination
At Utility Week Live, SGN and ULC had stands where RRES project information was disseminated to the utility industry. Also, RRES was presented as part of the keynote and innovation session.
An update of the progress made by the RRES team was presented at the online seminar – Introducing RRES Robotics & AI For The Future of Utilities.
Article in May's Gas International magazine which articulated the collaborative effort behind RRES.
RRES promotional video created by ULC and shared on YouTube

Table 6– Summary of learning outcomes

The project team hosted a live seminar in collaboration with the Pipeline Industry Guilds and the Insinuation of Gas Engineers and Managers. The revolutionary RRES robot was due to be unveiled at Utility Week Live this year, but due to the ongoing pandemic the system was introduced to the industry via a sold-out webinar. This platform was used to describe the developmental milestones successfully completed two years into this three-year project. We had a diverse audience from various areas of the gas industry spanning across GB and even had some participants from the US and China. After presenting the technological developments, a live workshop demo of the robot from the work shown, followed by a Q&A. The event was well received with great feedback and engagement. The recording of the event is available to interested parties and we plan to carry out more events like these for our internal and external stakeholders.

Figure 36– RRES Seminar Advert

11 IPR

In accordance with the Gas network Innovation Competition Governance Document, ULC Robotics will report on intellectual property rights (IPR) being pursued on the project. There is one application outstanding, however as the project progresses, additional filings will be pursued as several key parts of the system are finalised.

Application Type	Description	Application No.	Receipt Date.
US Provisional Patent	GROUND PENETRATING RADAR SYSTEM AND METHOD	62/821,107	20/03/19
US Provisional Patent	CHAINSAW CUTTING SYSTEM	62/893,464	29/08/19

Table 7 – Summary of patents

12 Risk Management

The live risk register that identifies risks and scores them appropriately is attached in appendix C. Notable updates to risk register are shown below:

Project Delivery

The risk score of delivering the project within the allocated schedule has increased due to the uncertainty around the COVID-19 virus. Within this PPR period, our plan was to perform field trails in the UK, however due to the travel restrictions, we have taken the decision to delay shipping the system. To mitigate this risk and ensure the project is delivered on time, we have decided to bring milestone 23 -28 forward and will conduct the field trails later. This rescheduling will ensure the requirements of the project plan are fulfilled on time. We will continue to assess how the response plays out and if any additional action is required.

[redacted]

13 Accuracy Assurance Statement

The commercial and technical deliverables associated with this project are progressing on time and within budget. We confirm that we are following relevant SGN process and procedures in order to ensure that the information provided within this report are accurate and complete at the time of writing.

14 Material Change Information

As per the project direction, our 8th deliverable which is to perform an interim field test in the UK scheduled to be completed for the 26/05/2020 has been delayed due to the travel restrictions that COVID-19 has caused. The project milestones have been rescheduled to ensure no time is lost and the field trail will be conducted in March 2021.

Milestone	Description	Original Date	
23	Progress Report 6 – Test plan/report for shop testing of prototype RRES	31/03/2020	Delivered
24	Test plan/report for interim field testing	26/05/2020	22/3/2021
25	Design documentation for tether and support vehicle	4/6/2020	28/4/2020
26	Design and build documentation for reel cart	21/07/2020	26/5/2020
27	Progress Report 7 – Test plan/report for UAF	18/08/2020	16/6/2020
28	Design and build documentation for operator consoles	15/09/2020	23/7/2020
29	Documentation of RRES assembly	13/10/2020	15/9/2020
30	Progress Report 8 – Test plan/report for UAF tooling	10/11/2020	19/11/2020
31	Design and build documentation for system interfaces	12/1/2021	17/12/2020
32	Test plan/report for shop testing of full RRES	29/01/2021	7/1/2021

33	Progress Report 9 – Test plan/report for final field testing	26/03/2021	26/03/2021

Table 8 – New Project Schedule due to COVID-19 Disruption

Appendix A - Additional Reports

Below are the milestone reports that are available on request:

Report
Test Plan/Report for Shop Testing Prototype
Design Document for Support Equipment
Design and Build Document for Reel Cart

Table 9 –Milestone Reports across PPR7

Appendix B - Bank Statements

April Statement

[redacted]

May Statement

[redacted]

June Statement

[redacted]

Appendix C - Risk Register

Ref No	Risk	Business Risk	Inherent Risk			Controls & Mitigation	Owner	Anticipated Date for Retiring Risk (DD/MM/YYYY)	Residual Risk		
			Likelihood	Impact	Score				Likelihood	Impact	Score
1	**Project Team Resource Requirements** There is a risk that ULC Robotics and SGN will not be able to hire personnel in time for the project start date. *SGN have decreased the risk of resources by hiring a designated officer to the project.*	Time / Financial	2	3	**3**	A - Generate requisitions and start hiring as soon as bid is approved. B - A 6-month lag between project award announcement and project start date to allow time for the required resource to be found and appointed before the project starts. C - ULC has a the option of moving resource from other projects or utilise additional resource available at the MTC.	ULC, SGN	01/04/2018	1	3	**3**
2	**Challenges with Single Arm-to-Toolhead Interface** IF a single robot arm-to-toolhead interface design cannot accommodate all end effectors due to variations in toolhead size, weight, power, and technical complexity, it may result in increased operational complexity.	Time / Financial / Technical	3	3	**9**	A - Development of the preliminary arm-to-toolhead interface specification has been scheduled to accommodate estimated toolhead specifications. B - Design, development, and testing of tools to be reviewed by robotic arm expert for feedback and modification of the design.	ULC, TSP	28/05/2019	1	3	**3**
3	**Limited Below Ground Detection Capability** The sensor suite is unable to detect all buried objects due to varying object types and sizes, sensor capabilities, and depth of excavation additional process may need to be added to the operation of the RRES which could increase the time and cost of the operation.	Technical	3	5	**10**	A - Soft touch excavation tooling will provide additional safety redundancy to support risk mitigation. B -Initial research has been carried out in early concept phases of the project to identify the sensor types available which meet the current requirements. C - Build a test environment that simulates the variations in the relevant ground conditions and buried infrastructure. D - Consult with sensor vendor and develop additional sensor data processing techniques to improve buried object visualization. E - Use a combination of different sensors to increase the level of confidence in accurately detecting the targets	ULC, SGN, TSP	02/02/2021	1	3	**3**
4	**Truck Size Exceeds Maximum Size Limit** All of the necessary tools, sensors, mobile drive platform with arm, operator control station, support equipment and other accessories need to be transported to site in a vehicle which maintains a minimal site footprint and comply with UK highway vehicle regulations.	Time / Financial / Technical	2	5	**10**	A - Create 3D model of truck with sensors, tools and mobile platform. Develop layout and operator control workstation volume mark out. Determine estimate of size requirements. B - Design modifications to truck to increase storage volume and develop alternate mounting concepts. C - Evaluate low utilization tools, sensors and support equipment and consider transporting them to site only on-demand. D - Review vehicle specification requirements for the target areas of operation and the potential to separate out support equipment into multiple small vehicles instead of one larger one. E - Decrease the overall weight of the system through design and build optimizations	ULC, SGN, TSP	16/03/2021	1	4	**4**
5	**Field Trial Location Challenges** Suitable field trial locations for initial controlled testing, urban and rural sites cannot be found.	Time	2	2	**4**	A - SGN to carry out a review of criteria and identify multiple site locations which could be used for the trial. C - SGN and ULC to survey potential sites to determine suitability well in advance of the trials B - Engagement sessions with local authorities will be carried out in advance of the trial to ensure relevant stakeholders are supportive of the project and trial requirements.	ULC, SGN,	02/08/2021	1	2	**2**
6	**A Commercially available Robotic Arm Cannot Meet project Specification** ULC will identify and purchase an commercially available robotic arm to perform the excavation, pipe preparation, and installation of the UAF. If there isn't an arm that can complete all operations for the budgeted value there is a risk to the project budget and scope.	Time / Financial	3	4	**12**	A - Develop the operational strategy, tool specifications and end effector specification early when developing robot arm requirements. B - Consider options for increasing the capabilities by using other strategies such as multiple arms, end-effectors with increased degrees-of-freedom, robot arm support mechanisms to withstand larger loads etc.	ULC	12/05/2020	2	4	**8**
7	**Suitability of UAF for live gas installation** If the UAF design and installation procedure doesn't meet the required industry standards or performance criteria there is a risk it's use on live gas infrastructure will not be approved.	Technical	3	4	**12**	A - The relevant design and performance specification and designs will be identified and influence the UAF design. B - A test criteria will be agreed and extensive shop testing will be performed using field pipe of various conditions. C - An independent review of the fitting will be carried out and the process for the application of relevant industry approvals will have begun.	ULC, SGN, TSP	27/10/2020	2	3	**6**
8	**Use of the RRES does not meet SGN's Safety Management Framework Requirements (SMF)** If SGN does not provide approval for the RRES to operate in a field test due to inability to meet SMF requirements, the RRES design or operation may have to be modified, resulting in increased cost and time.	Financial/ Technical	3	3	**9**	A - The SGN Project Steering Group will contain leads from the Engineering Policy, Safety Health & Environment and operations to influence the development process and ensure the design meets all safety requirements. B - Engage with SGN Policy and Safety leads and consult with industry bodies including Ofgem and HSE to ensure all requirements are met. C - SGN will appoint an independent Technical Service Provider with a detailed understanding of industry requirements to review the development process.	ULC, SGN, TSP	27/04/2021	1	3	**3**
9	**RRES Usage is Limited Due to Component Compatibility with Hazard Area Requirements** Once the system has been conceptually designed a review will be carried out to assess its suitability for key components use in all of the target environments. If the specification does not meet the requirements of the review or control measures are required it could cause a delay to the project and additional cost.	Financial/ Technical	3	5	**15**	A - Incorporate a safety review process into the design of each component. Develop a checklist for collaborative design reviews with the project team. B - Incorporate a safety risk management program that identifies, assesses and mitigates safety risks. C - An independent review will be carried out by the technical Service Provider at key stages of the project to identify risk as they become apparent.	ULC, SGN, TSP	11/05/2021	1	5	**5**
10	**Scope Creep** If agreed system requirements or the agreed project scope changes late in the project the cost and time needed to complete the project could increase.	Financial/ Technical	2	3	**6**	A - ULC and SGN collaborate and finalise the specifications. B - SGN will create a Project Steering Group with leads from key areas of the business. The key component specification will be agreed with all members before being finalised to ensure all requirements have been met to mitigate the risk of any changes to the specification being requested later in the development process.	ULC, SGN, TSP	30/10/2018	1	3	**3**
11	**Communication between Project Team** Communication channels between the project team who are spread across the UK and USA at different time zones cannot be maintained.	Time / Financial	2	4	**8**	A - Face-to-face meetings for key stage gate deliverables B - Use of virtual meeting center and secure file share C - Regular interface meetings with the project team	ULC, SGN, TSP	27/10/2020	1	4	**4**
12	**Vendor Supply** Sub-contractor manufacturers and supplier delays could affect the overall schedule.	Time / Financial	3	4	**12**	A - Review project plan if required for sourcing sub-contracted vendors B - Engage a number of different suppliers to ensure continuity of supply where possible.	ULC	15/04/2021	2	4	**8**
13	**Stakeholder Opposition** A negative customer and wider industries perception of the project could cause issues with obtaining the necessary approvals for access to trial sites and impact wider industry	Reputation	2	4	**8**	A - Implement and maintain a stakeholder management plan. B - Input from the SGN Regulation and Corporate Communications Officer to ensure high level of engagement with customers as early as possible.	SGN, ULC	02/03/2021	1	4	**4**

	acceptance of the technique.						C – Presentations at industry events				
14	**Logistical Challenges** There is a risk that customs and shipping difficulties could delay deployment of the system to the UK from the US.	Time / Financial	3	3	9	A - Additional shipping time has been including in the project schedule for shipping and customs. B - Controlled testing facilitates will be identified to allow final preperations works to take place in the geographical area of SGN's network, allowing the system to be shipped ahead of the live field trial with limited impact on the test schedule.	ULC	15/04/2021	1	3	3
15	**Poor RRES Market Uptake** If the RRES market uptake is poor, the full value of the RRES as described in the cost-benefit analysis may not be realised.	Financial	1	4	4	A – Distribute customer and stakeholder questionnaires to ensure that customer needs are being addressed B – Design of soft-touch excavation tooling and below ground sensing systems will be evaluated for use without the use of robotics so as to enable operation and commercialisation without the use of a robotic arm C – Disseminate Interface Control Drawing (ICD) for open-source tooling to enable maximum market size potential through alternative application development D – Continue to seek out project partners in the utilities and industrial sectors	SGN, ULC	TBD	1	3	3
16	**Low RRES Utilisation** If the RRES utilisation is low, the cost per excavation will continue to increase and the full value of the RRES outlined in the cost-benefit analysis may not be realised.	Financial	2	4	8	A – Design control algorithms for mobile platform and toolpath generation such that the size and shape of excavations that can be performed is maximised B – Disseminate Interface Control Drawing (ICD) for open-source tooling so as to maximise the number repair and inspection operations which can be performed on excavated infrastructure	SGN, ULC	TBD	1	3	3
17	**Project Delivery** There is a risk that the project scope cannot be delivered within the allocated budget and schedule.	Time / Financial	3	3	9	A – Use a phased approach to project planning with go/no-go milestones such that the project can be reevaluated upon completion of key milestones and terminated if needed B – Maintain a prioritised list of potential scope reductions that can be exercised if needed (e.g. elimination of automated tool changing, UAF installation tooling, etc.); C - Pursue funding from alternative sources such as customers in industrial markets or venture capital firms	SGN, ULC	TBD	1	3	3
18	**Challenges with cutting the road surface** There is a risk that the designed chainsaw tool for cutting the road surface cannot cut the core in a timely manner	Time / Financial	2	3	6	A – Design alternative solutions for setting the core such as endmill or a traditional core drill B - Conduct tests in different surface environments with a variety of depths of cut C - Development of different chains and cutting teeth for the chainsaw for operation in different environments D - Engage with tool manufacturers to develop custom made tools for the designed chainsaw	ULC	28/05/2019	1	3	3

Table 10 -Risk Register