Scotia Gas Networks

Gas Network Innovation Competition Full Submission Pro-forma

Robotics

August 2013

Project Code/Version No:
SGN_GN_01/resubmission v1

Gas Network Innovation Competition Full Submission Pro-forma

Section 1: Project Summary

1.1 Project Title:
Robotics

1.2 Funding Licensee:
Southern Gas Networks (SGN)

1.3 Project Summary:

This innovative and world-leading Project has the potential to allow extensive work to be carried out on the gas network without the associated disruptive road works.

It's objective is to develop new robotic technologies which operate inside the live gas main which can not only remotely repair leaking joints, but support our pipe fracture risk management process through enhanced inspection in larger our diameter pipes.

The Project scope will cover:

- Detailed design and manufacture of modular robotic platforms.
- Development of management and operational procedures.
- Full testing to ensure the robots can be operated safely inside a live gas pipe.
- A detailed commercial appraisal.

If our Project is accepted, we believe the development of these robotic technologies could fundamentally change the way the United Kingdom (UK) gas industry operates in the maintenance of gas distribution pipes, enhancing safety at the same time.

The primary participants in the project will be SGN and ULC Robotics. Other smaller suppliers will be selected through our established procurement processes and of course subject to competitive tender.

The Project duration is two years, with a proposed start date of 6 January 2014.

1.4 Funding

1.4.2 NIC Funding Request (£k): 6,532

1.4.3 Network Licensee Contribution (£): 0

1.4.4 External Funding - excluding from NIC/LCNF (£k): 0

1.4.5 Total Project cost (£k): 7,378

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Section 1: Project Summary continued

1.5 Cross industry ventures: If your Project is one part of a wider cross industry venture please complete the following section. A cross industry venture consists of two or more Projects which are interlinked with one Project requesting funding from the Gas Network Innovation Competition (NIC) and the other Project(s) applying for funding from the Electricity NIC and/or Low Carbon Networks (LCN) Fund.

1.5.1 Funding requested from the LCN Fund or Electricity NIC (£k, please state which other competition):

1.5.2 Please confirm if the Gas NIC Project could proceed in absence of funding being awarded for the LCN Fund or Electricity NIC Project:

☐ **YES – the Project would proceed in the absence of funding for the interlinked Project**

☐ **NO – the Project would not proceed in the absence of funding for the interlinked Project**

1.6 List of Project Partners, External Funders and Project Supporters:

There are two key Project participants; ULC Robotics and SGN.

ULC Robotics specialises in the development of unique solutions for energy industry technical challenges, from the creation of simple tools to complex electromechanical systems.

The company is based in Long Island, New York in the United States of America (USA).

Further details of the Project participants are in Appendix B.

1.7 Timescale

1.7.1 Project Start Date: 6 January 2014	**1.7.2 Project End Date:** 31 December 2015

1.8 Project Manager Contact Details

1.8.1 Contact Name & Job Title: Angus McIntosh Innovation & New Technology Manager	**1.8.3 Contact Address:** Scotia Gas Networks Axis House 5 Lonehead Drive Newbridge Edinburgh EH28 8TG
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Section 2: Project Description

This section should be between 8 and 10 pages.

2.1 Aim and Objectives:

All gas network operators aim to operate their networks in a safe and efficient manner. Despite an ongoing transformation to plastic pipe, we still have over 80,000km of Great Britain (GB) gas distribution mains are metallic and subject to aging and deterioration. They are costly to operate and require continuous inspection, repair or replacement.

There are three key drivers for intervention in relation to these assets; leakage,,risk management and third party damage.

(i) Leakage – the largest proportion of network leakage occurs from joints on metallic gas mains. This is the gas transporters' biggest impact on the environment and is reflected in the networks' shrinkage declarations. Methane, the primary component of natural gas, is around 21 times more harmful than carbon dioxide (CO_2) and lost gas per annum across all the distribution networks has a carbon equivalent of 4.56Mtonnes of carbon dioxide equivalent (CO_2e). The current method of repairing gas main joints requires a separate excavation on each joint which is both costly and causes considerable disruption to the public, particularly road users. Our robotics proposal will eliminate the need for the overwhelming majority of these excavations as the joints will be repaired invisibly and internally.

(ii) Risk Management - A common risk model is used by all the gas distribution networks to manage their replacement programmes. Today the recognised method of risk removal for small diameter pipes is full replacement. Under RIIO (Revenue = Incentives + Innovation + Outputs), there is an opportunity to explore alternative methods of risk reduction for both tier 2 and 3 pipes, and our development of robotics to measure stress and strain in pipe walls will allow alternative risk removal techniques to be applied.

(iii) Third Party Damage – Robotics will allow the accurate mapping of gas pipes to be undertaken. Sharing is important and this information will be of use to other utility companies as well as local and highway authorities excavating in the roads. This could also reduce the risk of accidental damage to gas pipes and accurate mapping would also reduce the number of aborted excavations undertaken when making service connections to our pipes.

There are therefore four key areas of potential benefit if our Project is successful:

1) Reduction in repair costs
2) Reduction of third party damage
3) Improved risk management of metallic mains
4) Reduction in leakage from the gas distribution network

As we said in the summary, this innovative and world-leading Project will potentially allow extensive work to be carried out on the gas network without the need for disruptive roadworks. The introduction of new robotic technologies operating inside the live gas network, repairing leaking joints, support the risk management of pipe fracture through accurate empirical inspection.

The outcome from this project were it to proceed would be several commercial ready prototype devices which could be deployed across the whole of GB gas network, for the

Project Description continued

benefit of all companies, people and communities. At the completion of this Project ULC Robotics will be ready to provide commercial level services utilising the field commercial prototype devices to all GB gas network licensees.

In order to address this broad scope, the work has been divided into specific Elements which represent sub-projects under the greater project scope. A description of each Element along with a description of the means being developed to solve each problem, are as follows.

- *Element 1 – Development of a robotic 'platform' and launch system to enable deployment of modular repair and inspection devices for tier 2 and tier 3 pipe*
- *Element 2 – Development of an internal mechanical joint installation module and Weco seal repair method for tier 2 and tier 3 pipe*
- *Element 3 – Robotic visual and non-visual inspection*
- *Element 4 – Automated live asset replacement for distribution services and mains for tier 1 mains*

Elements 1 and 2 have been grouped together since they will be performed as a single development by one team of engineers.

2.1.1 Element 1 and Element 2 - Description of problem

2.1.1.1 The Problem:

In GB, gas distribution networks (GDN) have a considerable amount of post war spun cast iron mains which utilise mechanical joints at their connection points. Mechanical joints generally comprise two parallel backing rings held together using bolts and nuts. A rubber gasket is forced into the space between the bell and spigot of a cast iron joint by the two parallel backing rings, which provide a seal. Over time, gaskets can dry out and shrink or bolts and nuts corrode; creating leak paths for pressurised gas.

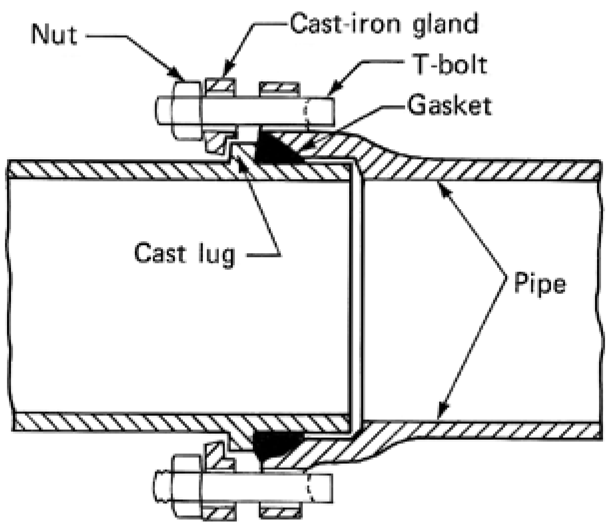

Figure 1 - Mechanical Joint Design Example

Historically within specific areas of GB the Weco sealing process was popular for performing repairs on mechanical joints in ≥24" diameter mains. Weco seals are mechanical seals comprised of a rubber ring and a mechanical support. These are installed on the inside of the pipe directly over cast iron joints.

Repair by Weco sealing requires multiple excavations, the gas main to be taken out of service and for a person to enter the main to physically install the seals by hand. Because this person must enter the pipe to install the seals, there were associated health and safety risks, so much so, this method is no longer employed in Britain.

Figure 2 - Weco Seal Installed In Pipe

Figure 3 - Encapsulation Kit

In order to perform repairs to leaking mechanical joints on tier 2 and tier 3 gas mains, distribution operators are forced to excavate over each joint. These excavations represent significant civil engineering works, generally involving shoring of the excavation walls, access and egress.

Once exposed, the joint as well as a portion of the pipe on both sides of the joint, must be sand blasted to clean the metal. In a process called encapsulation, a flexible semi-rigid fabric mould is installed around the joint. The mould is filled with an expanding urethane compound which quickly sets to form a gasket around the exterior of the joint (see Figure 3).

2.1.1.2 The Method (see conceptual drawings in Appendix C):

A means of performing live, internal sealing on non-Weco sealed mechanical joints, along with a method of internally repairing previously installed Weco seals, from inside the pipe, would alleviate considerable costs, while providing substantial environmental and customer benefits.

In order to internally seal mechanical joints and to perform repairs on previously installed Weco seals, it is proposed to develop a robotic platform capable of vertically launching into live tier 2 and 3 gas pipes. The platform will accommodate a module capable of installing internal mechanical seals and for repairing Weco seals in situ.

The system is anticipated to operate with minimal disruption to the public. Multiple joints will be repaired internally from one excavation point, with a minimum target travel distance of 150m in each direction (300m total) from the point of entry. A launch tube system will be designed to prevent gas from escaping during the setup, operation and removal of the device, while keeping the mains live and without disrupting gas service to customers.

As part of the Project we will review the proposed repair method, carry out a risk assessment and gap analysis against the identified performance specifications referenced in Appendix D,

Project Description continued

2.1.1.3 The Trial:

Once the robot, launch tube, and repair module have been developed, prototyped and off site testing complete, field testing will be performed in GB. Field testing will focus on proving the technology and ensuring that the goals of the Project have been met.
Expected outcomes of the trials are as follows:

1. Proof-of-concept demonstration of an internal pipeline robotics system.
2. Internal repair of multiple mechanical joints and failed Weco seals from a single excavation point.
3. Successful operation in pipelines within tiers 2 and 3 and ability to negotiate up to 90 degree horizontal bends.

2.1.1.4 The Solution:

The robotic system developed under Element 1 and 2 will be capable of internally sealing mechanical joints and also repairing failed Weco Seals with significantly less excavation and disruption to customers than traditional methods. This robotic system will be able to enter the gas mains via a launch tube, travel down the pipe making repairs, and then return to the launch point for retrieval.

Advantages of this internal robotic joint repair system, when compared with encapsulation or direct burial replacement include:

- Reducing the need for street opening permits.
- Reducing the amount of excavation and restoration required.
- Reducing public disruption to both gas service and roadways.
- Providing a much smaller carbon footprint than conventional repair methods.

2.1.2 Element 3 – Robotic visual and non-visual inspection

2.1.2.1 The Problem:

Metallic pipelines are typically iron or steel (ST). ST and ductile iron (DI) mains are more susceptible to corrosion and cast iron (CI) mains are more susceptible to stress cracking. Stress cracking leads to failure of the pipeline below the expected yield stress of the material.

In order to locate and quantify the levels of corrosion, wall loss and stress in pipes, without significant excavation or taking the main off line and generating disruptions for customers, a means of live, in pipe assessment is needed.

2.1.2.2 The Method:

ULC Robotics proposes to research and develop a suite of sensors, which can be mounted, pushed, pulled or transported into live gas mains via the robotic transport platform developed under Element 1. This modular sensor package will be utilized to evaluate internal corrosion, wall thickness, stress cracks and pipe condition in cast iron and steel pipe as appropriate.

Project Description continued

Internal robotic inspection of the mains will provide an accurate means of pipeline assessment without disrupting gas supplies to customers, incurring large engineering costs or performing oversized excavations. It is anticipated that the device will utilise the same or a similar launch tube as the platform developed under Element 1.

To determine the type of sensor equipment which will provide the most effective measurement of corrosion level, pipe stresses and wall loss, ULC Robotics will work with sensor manufacturers and research various inspection techniques and methods.

After identifying an appropriate sensor technology, or combination of sensors for evaluating pipeline structural integrity, we will confirm the suitability of the sensor technology outputs as an indicator of pipe condition that can inform pipe risk. This will have included a review of the intended outputs against the original pipe standards (as shown in Appendix D) and an independent assessment by one of our technical service providers.

Following a suitability assessment an appropriate vendor will be identified to provide the sensor at best price and within budget. ULC Robotics will evaluate the capabilities of the vendor to ensure that the product can be delivered on schedule and as per the sensor requirements.

2.1.2.3 The Trial:

The sensors will be field tested in the UK. The module will be deployed in conjunction with the robotic transport platform and launch system developed under Element 1. The sensors will be used to assess the condition of the pipe. Testing will be aimed towards the demonstration of the technology with the goal of providing useful data on pipe condition and in minimizing the risk of pipeline failures.

Expected outcomes of the trials are as follows:

1. Demonstration of internal robotic pipeline inspection technology
2. Live data collection on pipe wall thickness, stress cracks, joint integrity, and other information
3. Custom reporting of pipeline structural integrity data to the distribution network
4. Identification of critical locations at high risk of leak or rupture

2.1.2.4 The Solution:

Data provided by the sensors will identify defects in the pipe wall which have caused or will likely cause a leak, crack or rupture in the pipeline. This information will reduce the safety risk and environmental impact associated with leaking gas.

Advantages of this method of internal robotic inspection include:

- Assessing the integrity of the main without turning gas off to customers
- Minimising the costs and disruptions associated with excavations or other conventional inspection methods
- Identifying locations for preventative maintenance and repair

2.1.3 Element 4 – Automated live asset replacement for distribution services and mains

2.1.3.1 The Problem:

The replacement of gas distribution pipe requires the excavation of trenches into which the pipe is laid. However, a technique known as pipe insertion allows for the installation of distribution piping with reduced excavation, resources, permitry and restoration costs. Pipe insertion is the process of inserting a smaller pipe into an existing, larger one. It currently provides a means for gas companies to cost effectively replace large sections of main. Pipe insertion is a good option in situations where a lower capacity of gas would satisfy the needs of a given area or where the network pressure can be increased in order to match or exceed the existing network capacity.

Pipe insertion can be further broken down into two commonly applied methods, dead insertion and live insertion.

For dead insertion a pipe is temporarily disconnected from the existing gas distribution network. Typically, an excavation is made at suitable access points on the existing gas main. A cut-out of an excavated section of main is created and a new polyethylene (PE) pipe is pulled or pushed into the section of existing main.

For dead insertion methods, typically used for insertion lengths of under 200m, customers are interrupted for the duration of these works. For live insertion, a pipe is inserted into a live gas main and services replaced using specialist foam off technique developed by Steve Vick™.

Once the entire length of main has a new PE pipe inserted inside of it each individual service pipe connection must be connected to the new piping. The customer's service is the pipe, which extends from the main in the street to the customer's emergency control valve, just upstream of their gas meter. In order to connect the newly inserted PE main to the customer service, excavations are created at the point in which each customer service line meets the existing main. The connection between the new main and the existing service is performed manually by a skilled operative. The requirement for excavating over each service creates significant planning and execution costs and increases supply interruption and disruption to customers. Each excavation created requires a unique permit to be applied for.

In order to eliminate the need to excavate over each service an in situ means of connecting newly inserted PE pipe to service lines is needed.

2.1.3.2 The Method:

This project proposes to develop a system capable of remotely reconnecting service lines to inserted pipe without the need to perform excavation over each service connection. The robotic device will enter and travel down the gas main between the gas main and the inserted PE pipeline or inside the newly inserted PE pipe to perform a remote reconnection of the service line. It is anticipated that the system will work in 4" to 8" gas mains, the most

Project Description continued

common diameters in tier 1.

It is anticipated that ULC Robotics will work closely with manufacturers of PE piping to acquire or develop a PE pipe capable of being pushed down existing steel services and into the main. This piping will be flexible enough to negotiate bends, without exceeding the rated minimum bend radius of the material, but will also be rigid enough to travel from the customer gas meter location to the gas main.

We will review the proposed replacement method, carry out a risk assessment and gap analysis against the identified specifications (as shown in Appendix D) in order to determine what the off site and on site testing success criteria will be. This will include an independent assessment by one of our technical service providers.

2.1.3.3 The Trial:

Once the remotely operated devices, repair methodology and tooling have been developed, prototyped and off site tested, field testing will be performed in GB. Field testing will focus on proving the technology and ensuring that the goals of the project have been met.

Expected outcomes of the trials are as follows:

1. Demonstration of a remotely controlled robotic system to reconnect PE service lines.
2. Robotic installation and reconnection of multiple PE services from a single excavation point.
3. Operation with minimal disruption as compared to traditional methods.

2.1.3.4 The Solution:

Element 4 is focused on robotic service replacement for tier 1. The robot developed for Element 4 will travel in small diameter mains and will probably, at least in part, travel in the annular space between the existing main and inserted PE pipe. The tools carried by the Element 4 module will be strictly designed for tapping and fitting a new PE service, and it is not expected that the development of the seal repair tool for Element 2 will provide any compatible learning for Element 4.

Considering the requirements, environments, and desired outcomes of these two proposed robotic systems are different, we will treat the development of the Elements 4 system and the Element 1 to 3 system as separate sub-projects within the overall project. As such, independent engineering teams will perform the work needed to bring each robotic design to a field-ready stage as described in the project plan. This work is expected to run concurrently in order to benefit from the established project management, project governance, communication and travel efficiencies. The work performed for Element 4 will not be dependent on the learning outcomes of Elements 1 to 3.

Therefore, Element 4 will aim to provide a remotely operated tool capable of reinstating service lines following a main being inserted would provide the following advantages when compared with traditional methods:

Project Description continued

- Reduced customer service downtime
- Reduction in the amount of excavation required
- Reduced costs of resources, permitry and restoration

2.2 Technical Description of Project:

2.2.1 Element 1 and Element 2 - Technical Description

ULC Robotics proposes to develop a tethered robotic system capable of vertically launching into live gas pipes within tiers 2 and 3 with pressures up to 29psi. It is anticipated that the modular robotic system will include:

- Robotic Transport Platform - Capable of entering live gas mains via the launch system, performing internal video inspection, transporting the sensor modules through the gas main.
- Interchangeable modules (mechanical joint repair module, Weco seal repair module, sensor modules).
- Gas tight (no release of gas during operation) launching system.
- Control system.
- Additional support equipment.

Module development will be focused on providing solutions that will lengthen pipe asset life, reduce carbon footprint, minimise excavation and ultimately provide a cost saving to gas customers.

Development of the robotic transport platform is anticipated to include the following steps:
Mechanical Design:

- Mechanical specification document development
- Development of conceptual designs
- 3D Design of mechanical components
- Selection and procurement of motors, gears and bearings for propulsion system
- Creation of detailed fabrication and manufacturing documentation
- Parts fabrication and assembly

Electrical Design:

- Electrical specification document development
- Electrical and software system block diagram development
- Electrical schematic design and parts selection
- Circuit card layout and fabrication
- Microprocessor firmware programming
- User interface and control system design and programming
- Tether design and procurement
- Bench testing of electrical system
- Integration of electrical system into mechanical prototype

2.2.2 Element 3 – Technical Description

Anticipated engineering work required for sensor package development include:

- Electrical specification development

- Electrical and software system block diagram development
- Electrical schematic design and parts selection
- Modification or adaptation of existing off-the-shelf sensor equipment
- Circuit card layout and fabrication
- Microprocessor firmware programming
- User interface and control system design and programming
- Tether interface and data transmission
- Bench testing of electrical system
- Integration of electrical system into modular package for deployment

A report outlining the results of off-site testing will be provided to us. The following outcomes would be included in the report:

- Ability for sensors to operate down full tether length
- Ability for sensors to measure wall thickness
- Accuracy of data collected
- Overall assessment capability of sensors
- Concerns and lessons learned during testing
- A test plan which will guide the selection field testing sites and which will ensure that field testing is executed as efficiently and effectively as possible

After off-site testing has been completed, minor modifications are expected to prepare the sensor package for field testing. The sensor package will be integrated with the robotic transport platform developed for Element 1 and 2 and shipped to GB for field testing. The test plan developed as an outcome of off-site testing will be used as guidance for field testing. Field testing will be performed at sites provided by us and will determine the:

- Ability to successfully deploy the sensor package via the robotic transport platform
- Maximum useful travel distance for relaying sensor data to the operator
- Fidelity and clarity of data that can be used to assess pipe integrity in the field
- Ability to locate and assess leaks or other damaged areas
- Modifications required prior to system commercialisation
- Estimated Unit Pricing for Commercial Work Performed

2.2.3 Element 4 – Technical Description:

Between 2003 and 2006, ULC Robotics developed a prototype system consisting of two robots to perform service replacement. Both robots were designed to deploy in the annular space between an existing 4 inch main and an inserted 2 inch PE main under dead conditions. The first robot would travel along the main and locate the service connection using video cameras, and would then tap a hole in the PE main. The second robot would travel to the newly created hole and attach an electrofusion by compression PE fitting. ½ inch medium-density PE tubing would then be inserted from the customer's meter and pushed through the service line until it attached to the newly installed PE fitting.

The prototype designed by ULC Robotics was functional but it was never tested in the field or used to reconnect services. The PE tubing inserted from the customer service side was not flexible enough to manoeuvre through the 90 degree street elbow and 90 degree tee (unique to US gas distribution), and doing so exceeded the manufacturer-specified maximum bend radius of the tubing.

The prototype demonstrated that operating a service replacement robot in the annular space was technically possible. ULC Robotics engineers will draw upon the experience gained during that project to develop an entirely new system with greater capability under this project proposal. The new robot designed under Element 4 will have several innovative features that were not present in the earlier prototype. The robot will be designed to operate under live conditions, whereas the prototype did not. The new robot will most likely function in a completely different way than the prototype; it is anticipated that at least part of the robot will travel inside the PE main itself while a separate portion of the system may travel in the annular space. The design of the new system will incorporate components that were not available when the prototype was developed. Additionally, SGN and ULC Robotics plan to work with a tubing manufacturer capable of producing a flexible service line which can manoeuvre through the bends.

Based on past development work and innovative new ideas, a system to perform robotic service replacement for inserted PE pipe under live conditions is technically feasible, but Element 4 of this proposal will not just be a continuation of that project. An entirely new design will be created, functioning under live conditions and operating in a different way that the earlier prototype.

It's anticipated complete robotic system will include:

- Robotic transport mechanism, capable of:
  - Entering the annular space between the newly inserted PE Pipe and the existing main or inside of the newly inserted PE pipe.
  - Traversing to a service location.
  - Utilizing Integrated Camera and light emitting diode (LED) lighting or other sensor to locate a service requiring reinstatement.
  - Transporting a fitting to the location.
- An equipment package carried by the robotic transport mechanism, capable of:
  - Tapping a hole in the PE mains pipe.
  - Attaching a PE fitting at the hole location, and providing a means of permanently installing the fitting.
  - Connecting the inserted PE service pipe to the fitting.
  - Inspecting the new service-mains connection to assess its integrity.
- Control System with integrated video displays, robot controls, power supplies and data acquisition equipment (as required).
- Additional support equipment.

Field testing will be performed at sites provided by us and will determine:

- Engineering and planning steps necessary prior to deployment.
- Maximum travel distance and ability to remotely reconnect service lines.
- Impact on customers.
- Ability for system to operate and remotely install service connection on newly inserted PE pipelines.
- Deployment methodology.
- Modifications prior to system commercialization.

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Section 3: Project Business Case

This section should be between 3 and 6 pages.

3.1 Introduction:

Our Project is aimed at developing methods to minimise cost of mains repair and replacement by delivering multiple solutions and benefits. These developments are necessary to demonstrate new business models for mains activity to ensure GB gas network companies can play a role in the future low carbon gas system, efficiently and economically.

3.2 Business Case Context:

The latest gas distribution price control (RIIO) is the first price control to be conducted under the new RIIO model. The objective of RIIO is to encourage gas distribution network owners like ourselves, to play a full role in the delivery of a sustainable energy sector and to do so in a way that delivers value for money for customers.

In relation to network safety outputs, consistent with the new Health and Safety Executive (HSE) iron mains policy (which provides greater flexibility for GDNs in managing the risk associated with iron mains) we, as distribution network owners, are tasked to reduce the safety risk by 40 to 60% during RIIO. We're also expected to reduce gas transport losses, which comprise approximately 95% of our carbon footprint, by 15 to 20% by the end of the period, therefore it is essential any alternative risk management method ensures the same outcome as replacement.

On top of this, we are committed to delivering improvements in customer service which this Project will help with.

Finally, reliability output measures will require us to maintain the integrity of network assets, as well as meet the current network capacity and security of supply standards.
The Government's Carbon Plan sets the UK's progress towards and framework for meeting carbon targets. Currently, greenhouse gas (GHG) emissions caused by leakage from the UK's gas network, although relatively low in terms of units of energy lost, are the most significant source of GHG emissions from the UK network. Far greater than our operational emissions. We see an enduring role in the future for the gas network, transporting many sources of new unconventional and low-carbon gas while being utilised for different purposes including innovative heating solutions and transport. Reducing leakage and cutting GHG emissions from the network is therefore a very important aspect of increasing our sustainability and we recognise this project will help us towards this goal.

The use of internal repair and replacement methodologies on the gas distribution system offers a solution to both these problems allowing accelerated leakage reduction and minimising highway disruption while securing safe supplies to customers at least cost.
The project consists of four progressive elements that combine to create substantial environmental, customer and financial benefits when compared with business as usual methods of working.

Within the context of the Project scope, each element will entail:

- Detailed design and manufacture of modular robotic platform or devices
- Development of management and operational procedures
- Full testing to ensure the robots can be operated safely inside a live gas pipe
- A detailed commercial appraisal

3.3 Case Study Example (Element 1 and 2):

Condition based projects are often necessary for mains with high levels of joint leakage.

[redacted]

The mains diameters are 18" and 24" and are located in a built up area where the potential for gas ingress is high. The only current viable option currently is to replace the 2 mains over a 600 metre length, at an estimated cost of £500k.

There may still be the requirement to replace the mains due to pipe barrel risk, however in this example, the leakage history indicates that joints have been the only recorded mode of failure.

This [redacted] represents a typical example of a large diameter project submitted to the Condition Review Group where this new system could provide the means of enabling us to meet our Pipelines Safety Regulation (PSR) obligations at a significantly reduced cost, compared with traditional remediation methods.

The first of the modular robots addresses the leakage issues relating to the joints in metallic gas distribution systems. The module will perform two functions, utilising both mechanical seal and repair methods to manage leaking joints and returning maximum environmental, customer and financial benefits.

3.4 Benefits of Element 1 and 2:

The first Element will facilitate the creation of a universal platform on which to base each of the specific method solutions, rather then pursuing siloed solutions for each problem. This releases an economy of scale recognised in the suite modules that will be developed and reduces the general operating costs of the units for the gas distribution network operators. Typical benefits of pursuing this approach are:

- A universal launch/retrieval system and method
- Unification of the control and support systems on which the modules operate, allowing a plug and play solution
- Minimal unique parts allowing greater production at reduced cost
- Reduced specialist training requirements, reducing unit costs

The specific benefits of each of the modules to be developed to run from this platform are described below.

Due to changing engineering methodology and the time frame in which the GDNs have evolved, various jointing methods and systems have been developed and accepted as fit for purpose or 'standard' on the metallic gas distribution systems. These range from CI lead yarn joints, Spun CI elastomeric joints and on to screwed or mechanical joints.

In total, GDNs have been allowed £685.6m over the next eight years for repair activity resulting from gas escapes. The repair of leaking joints represents the majority (typically 80 to 85%) of our activity in this area.

3.4.1 Environmental Benefits:

The development and delivery of this module will bring multiple environmental benefits which include:

- The reduction of leakage and gas emissions to mirror mains replacement
- Reduced excavation and reinstatement requirements in the highway
- Reduced gas main replacement activity

3.4.2 Customer Benefits:

- Reduced excavation requirements in the highway which will reduce costs and minimise disruption to road users
- Reduced gas mains repairs as a result of fewer public reported gas escapes
- Reduced gas main replacement activity

For further benefits, see social calculator in Section 8.5.

[redacted]

- [redacted]
- [redacted]

3.5 Case Study Example (Element 3):

In metallic networks, the pipe wall itself is a common failure mode. This can occur through various mechanisms depending on which metal the pipe is made from and what environmental factors are affecting it.

The metallic gas distribution system is primarily constructed of four metals, CI, Spun Iron (SI), DI and ST. ST mains within low pressure (LP) distribution networks are generally unprotected. ST is the primary metallic material for service pipes connecting the mains supply to the customer's meter. It is also used for higher pressure transmission systems, which are outside of this scope.

Generally three mechanisms can act on a pipe (or pipe wall) to allow gas to leak for the system; corrosion, fracture due to stress and joint failure. Pipes made from ST and DI are susceptible to through wall corrosion and are generally replaced on the grounds of condition. For CI pipes though, the primary mechanism for failure is joints, however the highest risk posed is through fracture, which is the primary determinant of risk with the Mains Risk Prioritisation System (MRPS) model.

The MRPS model has been adopted as a common risk model by all GB distribution networks and is the recognised basis for replacement programmes.

Under RIIO, there is an opportunity to explore alternative methods of risk reduction for tier 2 and 3 mains, and our development of robotics to measure stress, strain, defects and/or corrosion in pipe walls will allow alternative risk removal techniques to be applied, realising a broad range of benefits. Further details of pipe failure modes are provided in Appendix E.

Tier 2 and 3 gas mains are less prone to fracture than tier 1, we believe that through effective assessment of the pipe using the sensor technologies we intend to develop, we will be able to remediate rather than replace as a means of risk management. We believe this will account for at least 55% of pipes surveyed based on the assessment of previous pipe failure modes and risk methodology as detailed in Appendix E.

For tier 1 pipes, which are more prone to fracture, replacement is the only option at this time.

3.6 Benefits of Element 3:

3.6.1 Environmental Benefits:

- The reduction of leakage and gas emissions
  - Not all leakage from a distribution network will get reported as a public reported escape (PRE). Using its suite of sensors this module will detect all leaking joints and fractures which can then be remediated.
- Proactively identifying fracture failures before they happen.
  - Currently, one of the inputs for the prioritisation of mains replacement in the risk model is the recording of a fracture, and therefore a leak. By surveying the prioritised mains before replacing them we can target the ones shown at greatest risk from fracture based on empirical data, rather than statistical analysis.

3.6.2 Customer Benefits:

- Reduced excavation and reinstatement requirements in the highway will reduce costs and minimise disruption to road users.
- Accelerated removal of actual risk from the distribution system.
  - By surveying the tier two and tier three mains first, rather than just replacing them through the top down output of the risk model, an objective assessment of risk can be obtained. This allows prioritised replacement of at risk mains and the remediation of those not at imminent risk of fracture.

[redacted]

3.7 Case Study Example (Element 4):

The replacement of gas distribution pipe requires the excavation of trenches, into which the pipe is laid. However, a technique known as pipe insertion provides a means for the installation of distribution pipe with reduced excavation, resources, permitry and reinstatement costs. Pipe insertion is the process of inserting a smaller pipe into an existing, larger one. It currently provides a means for gas companies to cost effectively replace large sections of main.

Pipe insertion can be further broken down into two commonly applied methods, dead insertion and live insertion. For dead insertion a pipe is temporarily disconnected from the existing gas distribution network. Typically, an excavation is made at suitable access points on the existing gas main. A cut out of an excavated section of main is created and a new PE pipe is pulled or pushed into the section of existing main. In order to eliminate the need to excavate over each service an in situ means of connecting newly inserted PE pipe to service lines is needed.

Within the context of Element 4 we intend to develop a module capable of remotely reconnecting service lines to inserted pipe without the need to perform excavation over each of the connection points.

3.8 Benefits of Element 4:

3.8.1 Environmental Benefits:

- Reduced excavation and reinstatement requirements.
  - The breaking up and excavation of the existing driveways, pathways and highways and the replacement of it with new material during reinstatement of the excavation produces significant waste. This is multiplied for each customer service pipe that

Project Business Case continued

requires replacement to the new mains supply. By utilising this new methodology we will reduce the requirement to excavate.

3.8.2 Customer Benefits:

- Reduced excavation and reinstatement requirements in the highway, pathway and driveways of our customers' homes.
  - Excavations are a visible and disruptive element of our service work. This module will greatly reduce the requirement to excavate which we believe is of great importance to our customers.

[redacted]

Under the Final Proposals for RIIO-GD1, the IQI provides for efficiency savings made against expected expenditure during the price control to be shared with the relevant GDNs customers. For SGN customers in our Scottish and Southern licence areas, 36% of savings on total expenditure are returned to customers, via a reduction in allowed revenue. [redacted]

[redacted]

Section 4: Evaluation Criteria

This section should be between 8 and 10 pages.

This section identifies how the Project performs against each of the evaluation criteria described in the NIC Governance document:

a) Accelerates the development of a low carbon energy sector and/or delivers environmental benefits whilst having the potential to deliver net financial benefits to future and/or existing Customers:

This criterion has been broken down in four subsections as per the Full submission Guidance Document.

i) Contribution to the Governments current strategy for reducing greenhouse gas emissions, as per the document entitled "the Carbon Plan" published by DECC:

The Government's Carbon plan sets the UK's progress towards and framework for meeting carbon targets. Currently, GHG emissions caused by leakage from the UK's gas network are, although relatively low in terms of units of energy lost, the most significant source of GHG emissions from the UK network, far greater than our operational emissions. We see an enduring role for the gas network, transporting many sources of new unconventional and low-carbon gas whilst being utilised for different purposes including innovative heating solutions and transport. Reducing leakage and cutting GHG emissions from the network is a very important aspect of increasing our sustainability and we hope that this project will help us towards this goal.

ii) Network capacity released by the method:

The following table presents the benefits of retaining capacity and removing replacement requirements via use of the robotic technology introduced through this project. The larger diameter pipes within a distribution network tend to be arterial mains, therefore reducing pressure drop in these network sections through avoided replacement (by insertion of a smaller pipe), will support greater insertion activity in the smaller diameter ranges. This effect will be network specific.

Table 1 - Summary of Replacement Project Analysis

[redacted]	[redacted]	**Pressure Loss (mbar)**	
		Replacement	Robotic Solution
[redacted]	[redacted]	57	14
[redacted]	[redacted]	10	7

iii) The expected environmental benefits the Project can deliver to Customers:

One of the challenges of developing alternative risk management strategies for distribution pipelines, is the requirement to meet environmental emissions reduction targets. Mains replacement activity contributes significantly to this, so it is important that alternative strategies mirror the reductions in emissions delivered through mains replacement. The robotic solution proposed is designed to meet this objective, but furthermore, we have targeted an increase in speed of operation (20% faster) as part of the design criteria. This will influence design decisions for the development of the robotic solution.

Using this 20% target we can speculate an additional benefit in terms of CO2e reduction. In order to calculate this benefit, we have assumed a 3 month lag following successful project completion. We believe, assuming the project development is successful, that SGN can ramp up to full rollout of this technique within 12 months, and the other GDN's within 24 months following this lag. Based on the potential value of this project, we feel this is a realistic rollout period. See Appendix G for further details.

At present the total leakage across all UK distribution networks is approximately 4.56Mtonnes of CO2e per annum. If pipe remediation through robotics is successful then leakage can and will be prevented. As an example, if full remediation of 1km of a 24" CI gas pipe within a 30mbar network was achieved, the saving in gas emissions would be 5.55 tonnes of Natural gas or 116.5 tonnes of CO2e per annum.

It is essential that any new risk management method mirrors the leakage reduction of full replacement activity in order to achieve the CO2e outputs.

All GDNs are engaged in a multi-million pound mains replacement programme. This project will demonstrate the viability of remediating some of these mains rather than replacing them, accelerating leakage reduction as well as removing the cost, disruption and environmental impact of the unnecessary replacement.

It should be noted that the UK gas networks represents the most efficient energy distribution network available.
If the target remediation of 55% is met and this can be achieved 20% faster, elements 2 and 3 will combine to release a saving of 3513 tonnes CO2e for SGN. Allowing for a phased rollout out to the other networks, this would represent a saving of 12657 tonnes CO2e for the GB GDNs as a whole.

It should be noted that rollout period will be very much network dependent. Each network will have their own contractual obligations and rates for replacement activity. For the purposes of analysis, we have assumed that rollout is achievable within two years.

A secondary benefit realised as a consequence of using the module developed in element 2/3 would be the reduction in the use of replacement polyethylene pipe. This would realise savings in emissions of 215 tonnes of CO2e per year or 1,290 tonnes of CO2e over the remainder of the period. If applied to all the other GDNs as is the intention, then the GB benefit would be somewhere in the order of 5160 tonnes of CO2e.

The final environmental benefit, applicable to all the modules developed as part of the project concerns the reduction in the need to excavate. Although this is harder to accurately quantify, it represent a reduction in the quantity of material excavated. During normal mains replacement insertion activity we would expect to open two excavations for every one hundred metres of pipe being inserted. The new method would only require one excavation per 300 metres and its location can be strategically selected to minimise disruption. This represents a saving of 6:1 in the tonnage of material excavated, 4% of which would be sent to landfill and 7% of which would be replaced with virgin aggregate.

[redacted]

[redacted]

[redacted]

[redacted]

b) Provides value for money to gas Customers:

The development of this robotic technology has the potential to fundamentally change the way in which the routine activities involved with securing the supply of gas through the distribution system. Starting the shift away from external management of the infrastructure to an internal approach is only now possible though recent advances in precision manufacturing techniques being used in robotic technology and offers multiple customer and environmental benefits as well as reducing the operating costs of the activities.

We believe the time is right to advance the industry understanding of the use of internally deployed robotics that will allow us to counter the often disruptive nature of our routine GDN activities on our customers. At first glance, the cost and scale appear significant, but in the context of the benefits that will be realised actually represent a sound industry changing investment.

The Project utilises a tried and tested project management methodology with the scope and Project Plan clearly defined up front with four main elements:

1. Element 1 and 2 - Develop Modular Robotic Inspection & Repair Platform
2. Element 3 - Robotic Visual & Non-Visual Inspection
3. Element 4 - Live Asset Replacement

Each of these Elements has then been broken down in to a set of pre determined tasks that influence the realistic but challenging project timescales. As shown in the project plan (Appendix H) a total of 18 go/no go Stage Gates have been proposed. These are situated at critical dates in the Project and allow SGN to put the Project on hold and revise its status or terminate the Project if they believe that it will fail to deliver its outputs. Technical descriptions of what should be completed at each go/no go stage gate are detailed in Appendix I and as shown in Section 9 a number of these stage gates set out our proposed Successful Delivery Reward Criteria (SDRC),

In addition, the project plan also sets out the project payment milestones for ULC Robotics for each element (see Appendix I for detailed summary of project cost breakdown).

At the heart of the project engineering is the consideration for the capability of the robotics to be developed. A feasibility study was undertaken to assess a range of companies and products in the market and ULC Robotics were identified as being at the forefront of pipeline robotics. They are the only specialised pipeline robotics company with successful and demonstrable experience of robotic solutions in the world. Until now this SME has been solely based in North America, primarily the USA.

The Project is designed to reduce leakage and failure of GDNs through inspection, repair and replacement of assets from inside the gas main using robotic techniques. These are high cost areas for GDNs, which justify the scale of the Project proposed.

The field of robotics is highly specialised. ULC Robotics has been selected for their unique experience and competence in this area to support this Project and many of the concepts and ideas has contributed to the development of the Project requirements and proposal. The prices submitted within the Project have been benchmarked against previous work and based on projected daily rates.

Additional suppliers will be required to support Elements 3 and 4 of our project. Specifically, technologies including microwave, acoustics, radiography, magnetic flux leakage, pulsed eddy current, and ultrasonics, will all be researched and analysed for use in performing in situ integrity assessment of the pipe wall. This will include the detection of corrosion, wall loss, cracking, pitting and locating of unknown features. This aspect will be subject to competitive process and an estimated cost has been included in the funding requested.

Further support will also be required by PE pipe and manufacturing suppliers to develop either electro fusion, compression, or push fit fittings for application in the annulus of the pipe by the robotic solution. This has been estimated as part of the funding assessment, but will be subject to our internal competitive process.

[redacted]

There are aspects of the Project that will require external technical assurance, such as an ATEX analysis, review of the selected repair, inspection and replacement methods. We plan to use suppliers on our technical services agreement, who have been through a recent procurement event at the beginning of this year.

A procurement event was completed to support this and a number of UK based industry expert suppliers were included. Innovation delivery was a key factor used as part of the assessment process. In total, there were 80 applicants and from this a total of 26 were short listed as potential suppliers. Through further rigorous review, the final award was made to 8 suppliers, all providing good evidence of their capability in supporting projects at this level.

c) Gener ates kn owledge th at can be shared amongst all relevant Network Licensees:

As laid out in the Project Plan, while progressing each element of the project we will be capturing and demonstrating learning. A learning dissemination table is detailed in Appendix J.

If the project is successful, it is our intention to immediately implement the use of the first production modules based on these prototypes and the other gas distribution network owners will also have full and equal access to this technology to do the same.

The prototypes at the end of the project will belong to SGN, but with an unrestricted licence for ULC Robotics to commercialise in GB, with no royalty due from any other GB GDN to utilise under a commercial agreement.

In addition, it is proposed that the GDNs will have first refusal up to one month in advance, subject to a first come first serve basis. Where more than one network wishes to use the robotic solution, it will be offered in sequence or subject to agreement.

As a means of rollout across all GDNs a free demonstration of a 300m section will be offered upon successful completion by ULC Robotics, this is a benefit in kind. This is intended to share knowledge, assuage engineering concerns and engage with other distribution networks.
In terms of maintenance and operation, ULC Robotics will perform required maintenance to ensure ready for deployment within a month for a period of a year following completion of the Project without additional cost.

d) Is innovati ve (i.e. not busi ness as us ual) and h as an u nproven bu siness cas e where the innovati on risk warrants a limited Devel opment or Demonstrati on

Evaluation Criteria continued

Project to demonstrate its effectiveness:

The Project seeks solutions to industry challenges from the field of cutting edge robotics. Due to the novelty of the robotics application, the project has particular technical challenges, specifically the engineering and operational aspects that require to be controlled in order to operate complex electronics in a live gas environment. It is not feasible for such a technology to be developed to an operational standard without support and operational field trialling from a gas distribution network. Although some robotic solutions exist in the market they rarely perform more than one specific function and are limited in terms of adaptability regarding the sizes of infrastructure they can operate in. This Project aims to provide an integrated and consistent modular solution to the common problems the gas distribution networks face when undertaking mains management activities.

e) Involvement of other partners and external funding:

There are two key Project participants; ULC Robotics and SGN.

ULC Robotics specialises in developing unique solutions for energy industry technical challenges; from the creation of simple tools to complex electromechanical systems.
ULC Robotics has a proven track record of success in robotics and routinely executes multiple complex robotics research and development projects simultaneously. They have expertise in project management, mechanical engineering, electrical engineering, sensor development and application, programming, user interface development as well as manufacturing, assembly and testing. ULC Robotics has unique experience in the commercial deployment of live gas pipeline robotics are considered the ideal partner to commercialise and deploy the technologies developed under the Project.

Additional suppliers will be sought at various stages of the project. The cost for this aspect has been estimated as part of the funding assessment, but will be subject to a competitive process.

ULC Robotics are currently working with us to develop a Network Innovation Allowance (NIA) project to field trial and demonstrate their cast iron joint sealing robot (CISBOT), an existing ULC Robotics commercial product. This will be a precursor to this project and the learning from it will be utilised.

Further to a period of comprehensive stakeholder engagement we have set out an innovation strategy to do a number of things:

- Improve the way in which we work to be more efficient, more customer focussed, less disruptive while carrying out road works and reduce our carbon footprint
- Support entry into the network from renewable sources of gas and support the low carbon economy
- Open up competition in gas distribution through provision of alternative entry points

To support our innovation strategy, we adopt both a proactive and reactive approach to idea generation. We run a suggestions scheme, called Ignite (Ignitescheme@sgn.co.uk), for our staff, our project partners, suppliers and anyone else who wishes to make a suggestion, offer a new product or share an idea. We are also proactive in seeking new innovations and project partners, through our industry watch; our external memberships with greater access to SMEs; and most successfully through challenging our ever increasing array of project partners to come up with solutions to our industry issues.

Evaluation Criteria continued

This proposal from ULC Robotics is a good example of this proactive approach in action. We provided detailed problem statements and definitions, to address which, they have proposed this project. Our problem statements are available externally on both the Energy Innovation Centre (EIC) and Energy Network Associations (ENA) websites and will soon be introduced on to our own external website.

We continually prioritise the ideas and develop projects for both the NIA and NIC based on their scale, feasibility, potential to add value to the UK gas consumer and support our outputs under RIIO GD1. The project proposals are subject to a challenge and review at our Innovation Board, which reports to our Executive. Having followed this process, we believe the robotics project to be of significant scale and potential to be considered under the NIC.

f) Relevance and Timing:

The relevance and timing of this project is all the more pertinent given where we are in RIIO, at the beginning of the GD1 price control. The project offers a multitude of benefits to our customers, efficiency and cost to the gas distribution network owners and also environmentally at a time when the government is actively seeking industry solutions and participation in reducing and controlling CO_2e emissions. The project is designed to deliver environmental benefits to UK gas customers through:

- The accelerated reduction of leakage and gas emissions
- Reduced excavation requirements in the highway
- Reduced gas mains repairs as a result of less public reported gas escapes
- Reduced gas main replacement activity

The Government's Carbon plan sets the UK's progress towards and framework for meeting carbon targets. Currently, GHG emissions caused by leakage from the GB's gas network are, although relatively low in terms of units of energy lost, the most significant source of GHG emissions from the GB network, far greater than our operational emissions.

We see an enduring role for the gas network, transporting many sources of new unconventional and low-carbon gas whilst being utilised for different purposes including innovative heating solutions and transport. Reducing leakage and cutting GHG emissions from the network is a very important aspect of increasing our sustainability and we hope that this project will help us, and the other gas distribution network owners, towards this goal.

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Section 5: Knowledge dissemination

This section should be between 3 and 5 pages.

☐ Please cross the box if the Network Licensee does not intend to conform to the default IPR requirements.

5.1 Learning Dissemination

The main outputs of this Project are the technical and engineering knowledge gained in using new methods to assess and remediate the existing natural gas network. It may also support any future directive or ordinance in this field.

Therefore it is essential that learning opportunities generated by this project are successfully disseminated for GB GDNs, the wider gas community, national and international standards bodies, academia, local authorities and other key stakeholders such as the ENA, Department of Energy and Climate Change (DECC), Institute of Gas Engineers and Managers (IGEM) and Ofgem. Learning will be coordinated through the Project in such a way to ensure that all knowledge generated is disseminated effectively and that, if successful, the trial can be translated to business-as-usual solutions – a table detailing the plan can be found in Appendix J.

We have already gained positive interest regarding the project from the other gas distribution owners during the regular Gas Innovation Governance Group (GIGG) meetings.

In order to ensure that learning is effectively disseminated, a specific workstream, lead by SGN has been established for this purpose: Workstream 4 'Learning Dissemination'. The learning dissemination will focus on both internal and external learning and knowledge dissemination activities. See Appendix J.

5.1.1 Target Audience

The target audience for dissemination activities will include both internal and external parties. The audience is anticipated to include but not be limited to:

- All our employees
- GB GDNs;
- The Energy Networks Association (ENA);
- Ofgem;
- DECC;
- IGEM;
- Academic Institutions;
- Local Authorities;
- Local Communities;
- Relevant Trade Associations

5.1.2 Internal Dissemination

Sharing knowledge with all our employees is considered a vital activity of all innovation projects to ensure the ongoing engagement of staff so that the outcomes of the project are adopted for future application. We will be adopting a similar approach to knowledge dissemination for this Project to help build awareness and knowledge of the Project around our business. Methods for internal dissemination will include, but not limited to, the following:

Knowledge dissemination continued

- Project briefing presentations for all employees at Project start and end using our *teamtalk* briefing session.
- An article outlining the Project will be produced for our in-house newspaper 'SGN*mail'.*
- An article outlining the Project will be produced for our in-house intranet site 'SGNnet'.
- Training key members of staff before, during and after the Project.
- Inclusion of our graduate trainees in Project delivery as part of their accredited training scheme.
- Identifying Project champions and points of contact within each business area that can be kept updated of developments to ensure customer experience is effectively managed.
- An annual internal innovation and technology conference.
- Knowledge transfer 'in' to the Project for previous projects.
- Operational workshops.

The development of this technology along with the new methods and techniques to use it is likely to require new working procedures to be developed and further training of staff to be conducted. We will use the expertise of the Project members to contribute to the training of Project staff. This will complement our existing in-house training team and facilities which we already have in SGN.

This Project has strong links to a number of business directorates including Operations, Customer Service and Network through our Innovation Board. Principal points of contact are established within this body to ensure all information on the Project is exchanged to manage the internal process as well as for learning dissemination.

In addition to our Innovation Board, we will also be identifying Project champions from each of the other business areas who will act as ambassadors and lead engagement within their business unit. This will involve providing updates, *teamtalks* and making other presentations as appropriate to keep staff informed of developments.

Recently we have started planning an annual innovation and technology conference for our staff attend to find out about the various developments which are ongoing across business. This will be ideal forum to raise knowledge and awareness of the Project. A broad range of staff will be in attendance.

We believe that this broad range of activities will provide comprehensive sharing of the learning from this Project, and that the learning will be embedded into day to day practices. Many of these processes for internal dissemination are building upon existing activities and experiences from other innovation projects.

We have planned to undertake a workshop with the operational and design staff who are engaged with these projects. We recognise that over and above the wide variety of material available in relation to this project, some of the less tangible learning is best shared in a workshop environment where people can talk about their experiences. This event has already been agreed to be undertaken prior to the commencement of the Project. We will also be looking to undertake a similar activity with other GDNs where we believe there to be merit.

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Knowledge dissemination continued

5.1.3 External Dissemination

We are intending to build upon our successful dissemination approach already used for all our innovation projects. For this Project, this will include, but not limited to, the following:

- Project presentations at learned bodies such as IGEM and the Pipeline Industries Guild throughout the project life cycle to share lessons learned
- Updating of the NIC portal website which will provide access for any interested party to understand more about the Project.
- Articles outlining the project and its progress will be produced for our external website site 'www.sgn.co.uk' at various key stages.
- An article with be produced for the monthly IGEM magazine 'Gas International'.
- Innovation workshops.
- The NIC and other industry conferences.
- Six monthly progress reports to Ofgem.
- Influencing the updating of policies and standards.
- Partner dissemination.
- Engagement with media and trade press.
- Engagement with the local authorities.

The Project will identify areas of existing technical and regulatory standards which are impacted by the trials or where the implications of a GB wide roll-out will have such an impact. These areas will be documented in reports and presented to other GDNs.

From the experience of undertaking this Project, key learning points will be fed into the relevant national policies and standards to ensure all parties can benefit. One of the principal learning points which will help with the dissemination will be the recommendations to use the new technology, methods and techniques as standard.

5.1.4 Knowledge Dissemination Plan

A knowledge dissemination plan is detailed in Appendix J. The goal of this dissemination plan is to ensure accessibility to, and dissemination of, the project results and methods. The knowledge dissemination plan details the format and timescales of the internal and external dissemination modes. We would wish for this plan to work both ways, gaining thoughts and ideas back in as well as knowledge and information flowing out.

5.2 IPR

We have an agreement in principle where both parties are fully committed to the default IPR position.

At this stage, we do not know what specific forms of IPR will be created and consequently require registration, if any. As part of the design process, detailed prior art review is necessary and will be dependent on the solution pursued.

It is proposed if and where IPR is to be registered, that it will be done by ULC Robotics, following transfer of any foreground IPR created by SGN.

Upon successful completion of the Project, royalties would be due from ULC Robotics (either from direct utilisation or licensing), if the project is rolled out. These will be paid to SGN, subject to an evaluation of their true commercial value, on either a per unit basis (e.g. per

Knowledge dissemination continued

unit manufactured and utilised), or an annual basis. The final arrangements will be determined at a later stage in the project, but will be designed so as to ensure the best value for the GB gas customer.

Income from royalties, minus any costs incurred in maintaining and managing IPR, would be returned to customers in proportion to their funding. SGN would retain the remaining portion (equivalent to our funding contribution) as profit. For this project, this would be 10%. SGN would calculate and declare this Returned NIC Royalty income in our regulatory returns on an annual basis.

Under the provisions within the contract between both parties, ULC Robotics will be required to comply with the NIC governance document. ULC Robotics will grant to the Network Licensees and the Parties: an irrevocable, perpetual, world-wide, non-exclusive royalty-free right and licence to use, access, copy, maintain, modify, enhance and create derivative works of any Relevant Foreground IPR (including any Relevant Background IPR contained therein) within their network system.

A key section of the NIC governance relates to Relevant Foreground IPR. Under the NIC document, Relevant Foreground IPRs are defined as Foreground IPRs that other Licensees will need to utilise in order to implement the Methods (the proposed way of solving a Problem (the obstacle or issue that needs to be resolved in order to facilitate the low carbon future and/or provide some environmental benefit to customers)) developed in the Project.

Network Licensees will only have the right to use Relevant Foreground IPRs within their network royalty free. They cannot sell or grant sub licences to Relevant Foreground IPRs.

Where access to a participant's Background IPR is required to undertake the project, the participant shall grant a non-exclusive licence to this background IPR (Relevant Background IPR) to the other participants, solely for the purposes of the project during the term of the project. The Network Licencees will also be granted a licence for any Background IPR required to utilitise any Relevant Foreground IPR for which they receive a licence.

5.3 Commercialisation

It is anticipated that there will be four ways the technology could be rolled out following the completion of development and commercialisation. A full commercial appraisal and recommendations will be made as part of the Project.

Knowledge dissemination continued

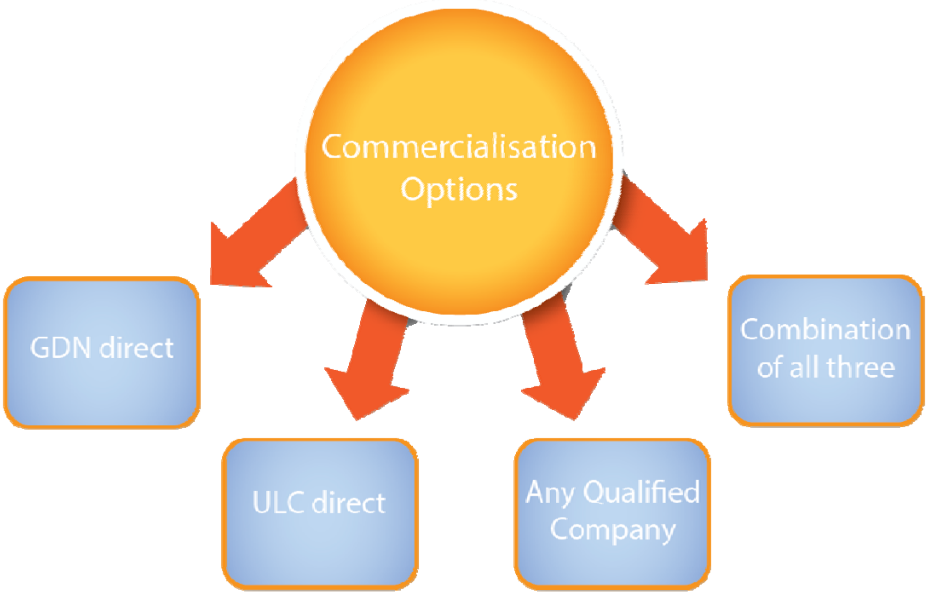

Figure 5 - Commercialisation Options for Roll Out

5.3.2 Example Option 1 – ULC Robotics Direct

ULC Robotics performs the work as a service to all distribution network operators in the UK. A target price per metre has been determined which yields positive costs benefit for gas customers. This target unit pricing will be used during the development process to guide critical design and operational decisions. Royalties will be paid by ULC Robotics to SGN. ULC Robotics will provide non-exclusive licenses to perform the service along with training, maintenance and spares to any qualified company or network operator in the UK under a separate licensing agreement.

Example Option 2 – GDN direct

Distribution Networks Perform the service directly within their own networks utilising their own resources. No licensing fee is due to ULC Robotics. ULC Robotics will provide an optional maintenance, spares and repair service to each distribution network under a separate service agreement. ULC Robotics will provide training and operational support as necessary under this service agreement. ULC Robotics will provide non-exclusive licenses to perform the service along with training, maintenance and spares to any qualified company or network operator in the UK under a separate licensing agreement.

Example Option 3 – Any Qualified company

ULC Robotics will provide non-exclusive licenses to perform the service along with training, maintenance and spares to any qualified company or network operator in the UK under a separate licensing agreement.

Example Opion 4 – Any combination of the first 3 options

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Section 6: Project Readiness

This section should be between 5 and 8 pages.

[redacted]

[redacted]

6.1 Introducti on:

We are confident of the readiness of this project due to the preparation that has taken place pre-proposal, having already initiated an IFI project in 2011 that was linked to the early developments of robotic technology introduced by ULC Robotics. In addition, we have taken encouragement following the Initial Screening Process (ISP) and the interest made known by the other GDNs. Furthermore, we are also currently in the process of registering a smaller scale NIA project with ULC Robotics to evaluate their existing robotic commercial product. Through applying proven project management methods, effective planning and engaging with our experienced project participants we have a high degree of confidence of delivery and success.

This section will provide evidence of why the Project can start in a timely manner, how the costs and benefits have been estimated and measures in place to minimise the cost of overruns or shortfalls in direct benefits. Furthermore, this section will explain the verification process for information provided, how the Project Plan would still deliver learning if take up is lower than anticipated and the processes in place to suspend the project if necessary. This is explained in more detailed under the following headings:

- Project plan
- Programme management and governance
- Project team
- Procurement
- Risk mitigation and contingency strategy
- Key performance indicators
- Quality assurance
- Stakeholder engagement
- Previous studies
- Accuracy if project costs and benefits
- Verification process
- Project learning (if take up is lower than anticipated)

6.2 Project Plan:

The Project plan sets out the best approach and timescales that the project team has determined to bring the highest likelihood of success. The Plan identifies the 4 main Project Elements, including additional work tasks broken down under each. This detailed Project plan can be found in Appendix H. The plan will be revised an updated again before the start of the Project.

6.3 Programme Management and Governance:

This Project will employ the standard programme management and governance approach used by SGN as described in our Project Management Procedures. The Project governance

Project Readiness continued

structure will ensure that the Project meets the delivery criteria and milestones identified. Ultimate Project direction will come from the Project Director, Angus McIntosh, Innovation & New technology (SGN). Key decisions and sign off will however be managed by a Project Steering Group, consisting of key representatives from both SGN and ULC Robotics. The Steering Group will have access to the day to day running of the Project enabling them to make key informed decisions as to the strategic direction of the Project.

The Project Manager shall maintain the planning system and monitor the progress of the project and be responsible for updating the accepted programme on a regular basis. Coordination meetings will be held to maintain during the design and construction phases a coordinated approach between all parties throughout all phases of the project.

Protocols shall be put in place by the Project Team to ensure regular contacts are established through a meeting schedule and that information is shared between all parties throughout the duration of the project. As a minimum, the following meetings shall be held:

- Pre-start meeting
- SGN / participant meetings
- Progress meetings
- Construction meetings
- Commercial meetings
- Quality meetings
- Health, safety and environmental meetings

6.4 Project Team:

The project team's organisation structure, showing lines of reporting can be found in Appendix K.

One of the key criteria for building a robust Project Plan was in the selection of the relevant project participants and the forming of a competent project team. Our preferred participants were identified after an undertaking review of skill sets required and competence levels. ULC Robotics provides a highly skilled, specialised workforce.

As part of the proposal, SGN have ensured that the Project Team is in a position where all our members can commence Project work come the 6th January 2014, are aligned to the specific project deliverables and are able to commit to and meet their scope of work and defined outputs. The work schedules have been developed together with ULC Robotics to ensure the Project will start in a timely manner as detailed in the project plan.

6.5 Procurement:

SGN's procurement of services and operational equipment and materials will be carried out in accordance with SGN's standard Procurement Procedures.

Following the initial site investigations and preliminary works, the Project Manager will procure the equipment and materials to undertake the field testing. At this point, all long lead items / critical items will be identified to ensure this does not influence the proposed Project Plan. All equipment, spares and materials will be documented within an Equipment/Materials Control Register which will be maintained throughout the duration of the Project to record and track the following detail:

- Description of equipment, material and specification to be purchased against;
- Identifies suppliers;
- Quantities required;
- Programme delivery dates, order by date, and expected lead times; and
- Outstanding information e.g. sufficient information to prevent procurement;

The Equipment/Material Control Register will be updated on a regular basis by the Procurement Manager. Equipment and materials will be procured at site level by the Project Manager in consultation with the Procurement Manager who will be responsible for the placement of large orders.

Regular review meetings shall be held to coordinate material delivery dates, highlight any special requirements e.g. unloading arrangements and establish material storage requirements.

6.6 Risk Mitigation and Contingency Strategy:

Hazard and Risk Assessments of network mains will be undertaken by Asset Management before any on site operational activities take place, using recognised Hazard Identification (HAZID) and Hazard Operability Study (HAZOP) methodology. This is recommended in order to assess the condition of the network prior to inserting the robotic solution into a live gas environment. Such risk assessments will consider the historical data behind each individual pipe and environmental factors.

Embedded within our project management methodology is the capability to manage risks and issues. This project will adopt the existing risk management process currently in operation within SGN.

The Risk and Issues Model employed considers risks and issues that are business-as-normal and those specifically related to the project all of which will be articulated in a common format. Appendix I outlines the risks that have been identified prior to the start of the project and the corresponding contingencies put in place. Within the risks model, likelihood and consequences will each be given a score from 1 to 5, and the resulting product of these two ratings used to score and rank the risks on the project. The model has been used and refined for many years and has been found to be both robust and recognised as an exemplar approach.

The risk register will be used by the Project Manager, Project Director, ULC Robotics and Project Steering Group to continually review Project risks, their mitigating action(s) and controls, and to ensure that risks are managed in priority order. The risk model describes the Methodology for determining an `uncontrolled' risk score. However, if control measures are applied, aimed at reducing the hazard and/or mitigating the risk, it should be possible to produce a `controlled' risk score that is lower than the `uncontrolled' risk.

The risk register will be re-visited in greater detail prior to Project start and further problematic or opportunistic areas together with risks identified will be analysed and

Project Readiness continued

mitigation measures agreed and implemented.

Also in place is a risk escalation process which documents how certain risk types are escalated up through the Project team. The governance processes to be operated across the Project Participants, will regularly review risks and issues and either remove these if agreed mitigation has occurred and/or bring new issues or risks to the attention of the Project Steering Group. The Group will agree management actions, which may lead to the Project being halted until such time as sufficient mitigation has occurred to enable on-going management of the risk or issue, or to halt the Project and defer further commitment until agreement has been reached with Ofgem on how to proceed.

Mitigation and contingency management will form a key part of the risk strategy. When a risk is raised the Project team will be responsible for creating a mitigation action that can be brought into play should the risk be realised.

During the Project, the method of identifying hazards and controlling the risks will be by performing Risk Assessments by competent and experienced persons, both across SGN and ULC Robotics who will implement the relevant control measures if necessary. Activities will also be controlled by issuing Method Statements for any operation as required. The assessment shall be subject to ongoing review and shall be reissued to take into account any changes in circumstances or new hazards.
Over and above the foregoing and prior to the start of the Project, we will facilitate a necessary HAZID meeting to ensure we fulfil our duty to manage and mitigate identified and foreseeable risks encountered during the works and those identified during the planning phase.

6.7 Stakeholder Engagement:

Throughout the bid preparation process we will discuss and plan our stakeholder engagement strategy for the project in much the same way as we would in conventional business as usual repair and replacement activity. See typical stakeholder communication material in Appendix M.

6.8 Key Performance Indicators:

We shall develop Key Performance Indicators (KPIs) as a mechanism to identify critical measurements and to capture performance information in these specific areas on site:

- Health and Safety
- Environment
- Delivery

The detail of these KPIs shall be communicated to all Project personnel and external consultants at the project induction meeting.

It is envisaged that a reporting system will need to be implemented to ensure the required statistical data is captured. This will enable an updated project Monthly Report to be compiled and circulated to all relevant participants.

6.9 Quality Assurance:

We are fully committed to achieving high standards with regard to engineering, safety, health and environment. Throughout this Project we will adopt a strict quality control procedure in accordance with our existing Safety Management Framework (SMF) which enshrines our approach to managing our activities safely. It also protects and enhances our reputation by defining the standards we will apply in relation to how we manage risks, the engineering of our assets, protection of the public, the well-being of our workforce and contractors, and the protection of the environment.

All necessary equipment and materials for operational activities will be ordered to the required specification and the Procurement Manager and Project Manager will be responsible for obtaining and collating all quality assurance documentation.

All on site activities, including Non Routine Operations (NRO) will be undertaken by competent engineers and all documentation appropriately logged by the Programme Manager in the Project folder.

SGN and where applicable ULC Robotics will carry out visual inspection of all equipment materials at the point of receipt into the storage areas during unloading in accordance with SGN procedures.

6.10 Previous Studies:

While the gas industry worldwide are gradually waking up to the potential for robotics to improve transmission and distribution operations, GB will take some warming up to the concept and at present seem happy to view it as a long-term trend that will have a gradual rather than a sudden effect. However, we understand the importance and focus in relation to safety, environmental impact, cost efficiency and increased production and believe that the potential for a more extensive use of robotic technology is evident and imminent.

The most significant challenge that ULC Robotics have faced in selling their technology to the gas industry is the difficulty in engagement with the GDN due to the complexity of the technology, but the proven resilience and performance standard assuages many concerns in this regard. In November 2011 we internally approved an IFI project to develop an innovative solution for the repair of leaking lead yarn joints within our cast iron population. This was the first time we began working alongside ULC Robotics and their CISBOT technology. The aim of this project was to insert CISBOT technology directly into 6”-12” diameter cast iron mains to seal leaking joints with an anaerobic sealant, without disrupting service, and with minimal excavation. Whilst this project did not progress we learned a great deal about the feasibility of the technology and the capabilities of ULC Robotics.

Having explored early developments introduced by ULC Robotics and understood the level of experience they had with regards to robotic technology, a detailed problem definition was provided. ULC Robotics have proposed a more advanced CISBOT commercial product that would potentially aid us in delivering our future outputs. This technology is referred to as large CISBOT and has already sealed more than 3000 cast iron joints for Con Edison and gas companies throughout the Northeast of America. It uses the same anaerobic sealant that has been used throughout the UK gas industry for over 15 years. However, the most significant advantage is that the method employed has allowed the repair process to be remediated and offers a 50 year extension to asset life, as tested and verified by Cornell University.

We are looking to carry out an assessment of this commercial product separately under the

Project Readiness continued

NIA mechanism and trial the large CISBOT technology on a large diameter main on our network. Whilst proven in the USA it is currently limited in its capability for GB application to straight lengths of pipe with lead yarn joints. This project is designed to develop a more comprehensive robotic solution to distribution mains management focusing on the GB gas distribution network needs.

In addition to the previous studies that have taken place with ULC Robotics, we are also in the process of finalising another transitional IFI to NIA project with Synthotech Limited. The project entitled; SynthoTrax I-Seal Robots (Technical Feasibility Study), project reference NIA_SGN0003 commenced in January 2013 under IFI and is nearing completion under NIA. The initial phase of this project was funded from SGN's IFI in 2012/13 (£52,920). The total outstanding expenditure is expected to be £17,332, of which 90% is allowable NIA expenditure.

This technical project explores the feasibility of expanding the capability of a robotic platform; originally developed by Synthotech in 2009, which provided an inspection system for 18" to 48" diameter gas mains and a laser scanning system for 355mm to 630mm polyethylene gas mains operating at pressures up to 2bar.

This new platform is referred to as SynthoTrax and its initial prototype does have similarities in terms of application to that already designed by ULC Robotics, as both seek to operate on a live network and seal leaking joints on larger diameter gas pipes internally, reducing the need for excavations to repair joints.

However, the objectives of the NIA project are different to the NIC submission as the purpose is to carry out a feasibility study to investigate the potential to extend the capability of the prototype SynthoTrax architecture to enable remote internal joint sealing of gas pipes, whereas the ULC Robotics technology has already be tried and tested in the US.

Furthermore, this study aims to provide some information that can be utilised throughout the NIC project, including a global assessment review of the technology available for each of the individual system components:

- Access Fitting
- Access System
- In-pipe robotic platform
- Sealant Application System
- In-pipe CCTV
- External Support Systems

As this NIA project moves towards successful completion it has already been agreed that the learning from this project will be disseminated amongst the other Network Licensees in a clearly defined report. Yet more importantly will form a fundamental basis for US SGN to work from when progressing this Project as the study will provide an assessment of the associated cost of developing current technologies available to meet the specification provided and also offer a cost comparison against current repair techniques.

Project Readiness continued

6.11 Accuracy of Project Costs and Benefits:

The Project costs have been calculated using input from ULC Robotics and a finance resource from SGN.

This is a highly complex and technically challenging project. The potential financial benefits if successful are compelling, however this is an unproven technology, therefore we will continuously review the probability of success and any changes to the financial benefits.

The overall budget will be managed by a Finance Manager embedded in the Project team. They will be responsible for managing all costs and constructing and delivering the reporting requirements as part of the Project.

SGN will run a robust financial tracking and reporting system in line with our current internal policies and frameworks. As per the Ofgem requirements the Project finances will be held in a separate Project Bank Account which will meet the following requirements:

- Show all transactions relating to (and only to) the Project;
- Be capable of supplying a real time statement (of transactions and current balance) at any time;
- Accrue expenditures when a payment is authorized (and subsequently reconciled with the actual bank account);
- Accrue payments from the moment the receipt is advised to the bank (and then subsequently reconciled with the actual bank account);
- Calculate a daily total; and
- Calculate interest on the daily total according to the rules applicable to the account within which the funds are actually held.

SGN will engage with our financial auditors, to alert them of their potential responsibilities should this Project be awarded the funding.

6.12 Verification Process:

Throughout the whole process SGN has carried out a strict internal verification process. The process firstly started with NIC project suggestions being shortlisted at Novembers 2012 Innovation Board, in anticipation that the bill would be passed through Parliament to allow the NIC to take place this year. This Board is made up of the Heads of each function across SGN and its purpose is to engage in delivering Innovation throughout SGN and provide the overall executive level control and guidance required. Furthermore, it:

- Decides on innovation areas to pursue in order to significantly reduce SGN's operating costs and promote effective working and management of risk.
- Spreads innovation throughout the Company.
- Supports evaluation of ideas and suggestions.
- Ensures Innovation projects are being properly progressed.
- Ensures any "best practice" is spread across SGN as standard practice.
- Removes any blockages or barriers to implementation.
- Supports implementation and tracking of initiative effectiveness.

The Board meet on a monthly basis initially to review progress against the budget and plan, support major deliverables and provide input to risk and issue management. Particular

Project Readiness continued

importance will be placed on managing the key dependencies between the different business streams to minimise the delays.

Following recommendations at the Board meeting this Project was identified and it was agreed by all members that this would significant value to network licensees throughout GB. The next step was to present a proposal paper to the investment committee, which consists of Directors and provides Executive sponsor.

Following approval the initial screening submission was undertaken with support from members of the Innovation Board. The Executive were also informed of developments fortnightly and following the success of the initial screening process the executive agreed to provide additional resources from out with the Innovation department to support and manage the expectations of the Final Submission.

To ensure the final submission was to the required standard a steering group was created consisting of a variety of experiences and competencies across SGN. Each member of the group had a specific role to play and weekly meetings took place to ensure that all data and supporting information was provided. In addition, weekly teleconference meetings have taken place throughout the year between SGN and ULC Robotics to ensure that not only all technical information is shared but also to finalise all contractual documentation in support of the Project being successful. Our Regulation team have also been involved throughout the whole process with frequent discussions and guidance provided to ensure full compliance with the governance criteria.

6.13 Project learning if take-up is lower than anticipated:

Regardless if the take-up from the other Network Licensees is lower than anticipated there will still be sufficient scope to use the learning generated from this Project in the future if they wish. From our perspective we believe that this will not influence the outcome of the Project and the cost benefit targets set will still largely be achieved, along with learning and improvement in the following areas:

- Robotic technology that has been field trialed and tested and commercially available.
- Demonstration and analysis of new approach and assessment of risk reduction methodology and risk management.
- Proven or disproved leakage reduction mechanism.
- Detailed understanding of robotic capability.
- Detailed sensor capability and combination review.
- New methodology for launch, operation and retrieval of robotic solutions.
- Commercial appraisal of robotic methods.

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Section 7: Regulatory issues

This section should be between 1 and 3 pages.

☐ Please cross the box if the Project may require any derogations, consents or changes to the regulatory arrangements.

This Project does not require derogation, licence consent, licence exemption or a change to the current regulatory arrangements in order to execute it. If the Project is successful, however, we will look to raise a Uniform Network Code (UNC) modification through the Shrinkage forum in accordance with our licence condition special condition(s) 1F; Part E; 1F.17 & 1F.18 in order to reflect changes to remediated pipe.

Section 8: Customer impacts

This section should be between 2 and 4 pages.

8.1 Customer Interactions:

At SGN we pride ourselves on our customer focus. Our philosophy of putting the customer first will be at the heart of this Project.

Our customer's requirements are based around safety, reliability, annual running cost and efficiency. As part of our commitment to providing the highest quality of service, we will keep our customers informed and updated throughout the duration of this Project, deal with any issues fully and resolve them quickly, and always listen to our customers and understand there needs.

8.2 Custo mer Impact:

The Project will impact on customers within the demonstration projects for asset replacement only. The impact will be positive as we will be field trialling on a project where we are intending to replace the asset anyway and the method proposed is designed to be less disruptive than the current method.

Any failure of the system would require us to revert back to known techniques with no additional disruption to the customer.

We will work within and meet our internal obligations to our customers as well as all our obligations to the guaranteed standards of service (GSOS) as laid out by the regulator.

8.3 Customer Engagement Plan:

Part of this Project will involve interaction with our customers and the Project will comply with the conditions relating to the customer engagement and data protection act as set out in NIC Governance Document. Examples of flyers we may design for the Project are given in Appendix M.

SGN shall submit to Ofgem, at least two months prior initiating any form of customer engagement, a final and more detailed Customer Engagement Plan of how we will engage with, or impact upon, relevant customers as part of the Project.

The final Customer Engagement Plan will include:

- a communications strategy which sets out inter alia:
  - any proposed interaction with a customer or proposed interruption to the supply of any customer for the purposes of the Project, and how the Customer will be notified in advance;
  - on-going communications with the customers involved in the Project; and
  - arrangements for responding to queries or complaints relating to the Project from relevant customers;
- Information on the Priority Services Customers who will be involved in the Project and how they will be appropriately treated (including providing information to any person acting on behalf of a Priority Services Customer in accordance with condition 37 of the Gas Supply Licence, where applicable);
- Details of any safety information that may be relevant to the Project; and
- Details of how any consent that may be required as part of the Project will be

obtained.

SGN shall publish the plan and make it readily available on its website.

8.3 Managing Customer Enquiries:

Looking after our customers is a key value for SGN, and this philosophy will of course be applied to this Project. For this reason a number of communication channels have been selected to ensure that the management of customer questions/queries is responsive, confidential and convenient.

Customers will be able to ask questions or raise queries related to the Project using the following channels:

- ***Telephone*** – SGN operates a customer enquiry service that is continuously staffed and can be contacted 24 hours a day/7 days a week on 0845 070 1432.
- ***SMS*** - For customers wishing to receive a call back service, an SMS can be sent to dedicated number, this will ensure an SGN representative will call the customer back as soon as possible.
- ***Project Webpage*** - The Project webpage will be the main source of information for the Project for our stakeholders and customers. All aspects of the Project will be hosted on this site, including all customer focused information (e.g. field trial locations, customer pamphlets, contact details, FAQs etc) will be uploaded on the site and available to download.
- ***Written Correspondence*** - Customers will be able to contact the Project team by sending a letter to a dedicated address.
- ***Email*** – *O ur c*ustomers can contact the Project team at a dedicated project email address which will be set up.
- ***Social Media –*** We regularly update our Facebook and Twitter page to inform customers about forthcoming project and progress of existing projects. Our in-house communications will utilise these channels of communication to engage with our customers
- **You Tu be –** We plan to create a You Tube video to let customers see and understand what we are aiming to achieve. We have found You Tube to be a successful communication for past Projects we have undertaken.

8.4 Customer Incentives:

The Project will impact on all customers within the field trial locations. A comprehensive period of stakeholder engagement will be carried out, with local authorities, schools, businesses and community groups. However, due to the minimal level of disruption there are no incentives built into this Project for our customers.

8.5 Social Costs Calculations:

Social cost calculations were based on "A Web-Based Social Cost Calculator for Utility Construction Projects" by John C. Matthews and Erez N. Allouche of Louisiana Tech University. In this paper, the authors outline a method for estimating the social costs of construction projects, including costs due to traffic delays, pedestrian delays, increased carbon emissions, and other costs. There are no accepted social cost calculators, however in discussions with Southwark Council it was agreed this methodology was most plausible.

Information from the [redacted] project was used to estimate the social cost which would be avoided if the robotic system outlined in this proposal were used rather than conventional methods. The work [redacted] was estimated at 192 days of construction to replace 609m of 24" diameter main. [redacted] Council kindly provided traffic and pedestrian data for the road in question and we married with data from our planned works to calculate the social cost.

Traffic delay time in seconds (T_D) is given by the equation below, requiring inputs for green signal time (g), traffic cycle time (c), lane group saturation (X), number of affected hours per day (H), and lane group capacity (u). The delay times for peak and off-peak hours, passenger vehicles and heavy goods vehicles, are each calculated separately.

$$T_D = \frac{\frac{c}{2}\left(1-\frac{g}{c}\right)^2}{1-\left(\min(1,X)\frac{g}{c}\right)} + 900H\left[(X-1)+\sqrt{(X-1)^2+\frac{4X}{uH}}\right]$$

The social cost of traffic disruption (C_{TDP}) is given by the equation below, requiring inputs for delay time (T_D), peak vehicle traffic for both passenger vehicles and heavy goods vehicles (v_{pv}, v_{hv}), estimated hourly rate per passenger vehicle and heavy goods vehicle (HR_{PV}, HR_{HV}), number of affected hours per day (H), and number of construction days (D). The delay costs for peak and off peak hours are calculated separately.

$$C_{TDP} = T_D\,[(v_{PV}HR_{PV}) + (v_{HV}HR_{HV})]\,H\,D$$

The social cost of pedestrian delays (C_{PD}) is given by the equation below, requiring inputs for the number of affected pedestrians (P), the time needed to navigate around construction (T_{PD}), the number of construction days (D), and the estimated average hourly wage (HR_{PD}).

$$C_{PD} = T_{PD}\,HR_{PD}\,D\,P$$

The social cost of increased carbon emissions (C_{AP}) is given by the following equation, requiring inputs for the number of additional tonnes of CO2 emitted (C_{EIN}) and the cost per tonne of CO2 (C_{CO2}).

$$C_{AP} = C_{EIN}\,C_{CO2}$$

The following inputs provided by SGN were used in the equations to calculate social costs based on data collected [redacted]

Section 8: Customer Impacts continued

Table 2 – Social Cost Calculations

Traffic Delays	
Annual average daily traffic (vehicles per day)	5348
Length of time for construction (days)	192
Peak traffic hours affected by construction (hours/day)	6
Off peak traffic hours affected by construction (hours/day)	6
Heavy vehicle traffic as % of total traffic	0.5
Traffic signal green time (seconds)	30
Traffic signal cycle time (seconds)	120
Pedestrian Delays	
Average wage for pedestrians (£/hour)	21
Estimated daily pedestrian traffic (pedestrians)	4100
Time needed to navigate around construction zone (seconds)	120
Carbon emissions	
Tonnes CO2 produced	91
Cost of CO2 emissions (£/tonne)	17

Additionally, reduction factors were applied to lower the calculated costs and provide conservatism to the estimates. The calculated social costs for performing this excavation using conventional methods are shown below:

Table 3 – Social Cost Calculations

Conventional Excavations -192 days	
Cost Due to Traffic Delays	£120,771.84
Cost Due to Pedestrian Delays	£13,776.00
Cost Due to Increased CO2	£1,547.00
Total Increased Social Cost	**£136,094.84**

[redacted]

[redacted]

[redacted]	
[redacted]	[redacted]
[redacted]	
[redacted]	[redacted]

[redacted]

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Section 9: Successful Delivery Reward Criteria

This section should be between 2 and 5 pages.

This section sets out our proposed Successful Delivery Reward Criteria (SDRC), each under a subsection labelled 9.1 to 9.8.

Our SDRC are genuine actions linked to the Go/No Go Stage Gate outputs of the Project with a realistic and challenging deadline. In the following subsections we set out some of the criterion then clearly state the evidence we propose Ofgem should use to assess performance against the criterion. For further information on the criterion see Appendix I.

9.1 Development of Conceptual Designs (Element 1 & 2) by 28th March 2014:

- Research and conceptual design will have been performed into methods of repairing Weco seals and mechanical joints with a robotic system.
- Various tools and methods for repair will be considered, with judgment criteria based on effectiveness, ease of deployment, technical feasibility and cost in line with the target price.
- A detailed technical report outlining these findings and suggestions will be delivered by ULC Robotics to SGN.
- SGN will have reviewed the proposed repair method, carried out a risk assessment and gap analysis against the identified performance specifications in order to determine what the off site and on site testing success criteria will be.
- For the robotic platform, the design will have included consideration of pipe loading, wall press vs free weight, size requirements for no-blow vertical launching, wheel torque, traction, power transmission, pneumatics, electronics, form factor, maneuverability in the pipe, travel distance, and the ability to negotiate bends as desired. An estimation of a variance against the target price will have been carried out.
- Provided the method identified has the potential to be deemed an 'interim' repair as defined within SGN/PR/EM/74 part B, and the high level performance specifications are feasible the project will progress.

9.1.1 Evidence:

- Delivery of technical report.
- Approval and sign off by the Project Director that the report defines the outputs required in Elements 1 and 2.
- All specifications, designs, risk assessments and supporting documentation to be documented in Project file.

9.2 Development of Conceptual Design (Element 4) by 28th March 2014:

1. Research and conceptual design will have been performed into methods of performing no-dig service replacement with a robotic system.
2. Various tools and methods will be considered, with judgment criteria based on effectiveness, ease of deployment, technical feasibility and cost in line with the target price. ULC Robotics will have drawn upon its past experience performing field service work related to gas services and will have referred to performance specifications provided by SGN.
3. Considerations for the robot design will have included size requirements for

maneuvering inside the pipe or annular space, form factor, drive system and power transmission, pneumatic systems, electronic power requirements, tapping and fitting tools to be carried by the robot, service line testing, and travel distance.

4. A report outlining these findings and suggestions will be delivered by ULC Robotics to SGN.
5. SGN will review the proposed replacement method, carry out a risk assessment and gap analysis against the identified specifications (for example relevant sections of GIS/LPL22) in order to determine what the off site and on site testing success criteria will be. This will include an independent assessment by one of SGN's technical service providers.
6. Provided the method identified has the potential to be deemed an acceptable means of no-dig service replacement, the project will progress.

9.2.1 Evidence:

- Delivery of technical report that looks to provide a means of robotic no-dig service replacement.
- Approval and sign off by Project Director depending on the outputs of the report.
- All specifications, designs and supporting documentation to be documented in the Project file.

9.3 Source Vendor for Sensor (Element 3) by 27th June 2014:

- ULC Robotics will have drawn on previous experience with researching and deploying sensors for pipe wall analysis for this task, and used the outline of performance requirements provided by SGN for guidance.
- After identifying an appropriate sensor technology, or combination of sensors for evaluating pipeline structural integrity, SGN will have confirmed the suitability of the sensor technology outputs as an indicator of pipe condition that can inform pipe risk.
- Following a suitability assessment an appropriate vendor will have been identified to provide the sensor at best price and within budget. ULC Robotics will have discussed lead times and manufacturing capabilities with the vendor related to specific components that may pose a concern. Once all of the requirements are satisfied, ULC Robotics will place a purchase order with the sensor manufacturer.
- If no suitable sensor technology is identified that has the potential to inform pipe risk, following the SGN and independent assessment, this element of the Project will be terminated.
- SGN will engage with the HSE and other stakeholders to keep informed as to the identified method and its potential to inform risk management.
- If successful, SGN will progress this Project forward.

9.3.1 Evidence:

- Sensor technology evaluation accepted by Project Director.
- Project plan will be revised to incorporate lead times and manufacturing capabilities.
- All purchase orders will be documented in Project file and controlled by ULC Robotics.
- All invoices and transactions documented in Project file and controlled by Finance

Successful Delivery Reward Criteria continued

Manager.

- All discussions with the HSE will be documented in Project file i.e. minutes of meetings or email correspondence.

9.4 Configuration Testing with Robotic Platform (Element 3) by 3rd July 2015:

- The sensor module will have been integrated with the robotic platform developed under Element 1 and 2.
- The assembled robot will have been tested to ensure there are no problems controlling the system or acquiring sensor data.
- The sensor package will have been tested to determine if all components function as designed when integrated into the modular robotic platform.
- The robotic platform with the sensor module will have been deployed via the launch tube into the test pipe to determine if there are any issues with launching, travelling, or retrieval. Testing will have determined if the sensor module can operate in the pipe as part of the modular robotic platform and provide sensor data in the operational configuration without major issues. The combined system will have been tested through the full range of motion to test the full capability of the system.
- Minor modifications to improve form, fit, or function will have been incorporated at this stage.
  A report on the success of configuration testing will have been be delivered by ULC Robotics to SGN.
- If there are any difficulties with the configuration tests, ULC Robotics will provide recommendations for engineering work needed to solve the problem. SGN will review against the performance specification (for example, maneuverability, speed) to confirm before determining if the project is to progress forward.

9.4.1 Evidence:

- All relevant testing documentation will be readily available in the Project file.
- The Project Director will review and sign off the configuration report prior to progressing.

9.5 Tapping & Fitting Tool Validation (Element 4) by 5th June 2015:

- The tools used for tapping holes in the PE main and installing PE fittings will have been tested at ULC Robotics both in the test pipe and on the work bench. ULC Robotics will have selected a vendor capable of producing custom fittings and flexible service replacement tubing for this Project.
- The robot will have been inserted into the test pipe and will connect new PE services to the main line test pipe. Testing will have been used to demonstrate accurately locating the services, precisely tapping the holes, and placing the fitting securely. This process will have been repeated multiple times to ensure a robust, repeatable process is in place with predictable and reliable results.
- Any improvements noted during testing will have been incorporated until a robust, field-ready process is developed.

Successful Delivery Reward Criteria continued

- ULC Robotics will deliver a report summarizing the results of this testing to SGN. If any problems are identified during testing, ULC Robotics will make recommendations for engineering work needed to solve the problem.

9.5.1 Evidence:

- Test report will be approved and signed off by Project Director.
- All test data and demonstrations will be stored in the Project file.

9.6 Launch Robot (Element 1 & 2) by 9th October 2015:

- The entire system, including the robot, launch tube, and required support equipment, will have been shipped to the UK from ULC Robotics New York facilities.
- SGN will have selected sites suitable for deployment of the robot and prepare the necessary opening notices, traffic management, excavations, mains drilling and valve installation.
- All of the components will have been unpacked and tested to ensure they are functioning properly prior to being deployed at SGN sites.
- After following all safety procedures in accordance with SGN's Safety Management Framework and Safe Control of operations permitry prepared, registered and authorized by SGN, the launch tube will have been mounted and the robot deployed in the main.
- Provided the launch is successful, the Project will progress and robotic inspection and sealing operations will commence.

9.6.1 Evidence:

- Shipping sign off and delivery documentation available in Project file.
- All Network Planning analysis and designs to be documented in Project file.
- Method statement and approvals available in Project file.
- Photos will be taken during the launch both externally and internally. These will be filed in the Project folder.
- GDNs invited to site to witness launch of robot into main.

9.7 Launch Robot (Element 3) by 9th October 2015:

- The entire system, including the robot, launch tube, and required support equipment, will have been shipped to the UK from ULC Robotics New York facilities.
- SGN will have selected sites suitable for deployment of the robot and prepare opening notices, traffic management, excavations, mains drilling and valve installation.
- ULC Robotics team of engineers and robot operators will have arrived in the UK and prepared the equipment for operations. All of the components will have been unpacked and tested to ensure they are functioning properly prior to being deployed at SGN sites.
- After following all safety procedures, in accordance with SGN's Safety Management Framework and Safe Control of operations permitry prepared, registered and

Successful Delivery Reward Criteria continued

authorized by SGN, the launch tube will have been mounted and the robot will be deployed in the main. Operational or logistical issues may delay the actual date of launching.

- The completion of this stage gate will have been measured by the successful deployment of the robot in the main. If any problems are identified during deployment, ULC Robotics will make recommendations for engineering work needed to solve the problem.
- SGN will have made a decision on whether to proceed to the next stage.

9.7.1 Evidence:

- Shipping sign off and delivery documentation available in Project file.
- All Network Planning analysis and designs to be documented in Project file.
- Method statement and approvals available in Project file.
- Photos will be taken during the launch both externally and internally. These will be filed in the Project folder.
- GDNs invited to site to witness launch of robot into main.

9.8 Launch Robot (Element 4) by 9th October 2015:

- The entire system, including the robot and required support equipment, will have been shipped to the UK from ULC Robotics New York facilities.
- SGN will have selected sites suitable for deployment of the robot and prepared the necessary excavations.
- All of the components will have been unpacked and tested to ensure they are functioning properly prior to being deployed at SGN sites.
- After following all safety procedures, the robot will have been deployed in the main.
- Operational or logistical issues have the potential to delay the actual date of launching; the completion of this stage gate should be measured by the successful deployment of the robot in the main.
- If any problems are identified during deployment, ULC Robotics will have to make recommendations for engineering work needed to solve the problem. At any point SGN will have the option to stop the project.
- The project will progress when SGN are satisfied that the robot has been safely launched into the main.

9.8.1 Evidence:

- Shipping sign off and delivery documentation available in the Project file.
- All site location information, including photos and analysis will be made available in the Project file.
- Method statements and approvals available in Project file.
- Photos will be taken during the launch both externally and internally. These will be filed in the project folder.
- GDNs invited to site to witness launch of robot into main.

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Section 10: List of Appendices

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Appendix B – **About SGN and ULC Robotics**
This appendi x contai ns i nformation about each of the companies involved in this project.

Appendix C - **Project Conceptual Drawings and Detailed Descriptions**
This appendix illustrates the pr oject conceptual drawings and provides a detailed description of the process.

Appendix D - **Pipe Specificati on, Industr y an d British Standar ds (Abridged)**
This appendix illustrates the abridged pipe specifications and British standards to support the developm ent of the robotic platforms for all elements.

[redacted]

Appendix G - **CO2e/Leakage Savings**
This appen dix sh ows specu lative savings based on CO2e and leakage.

Appendix H - **Project Plan**
This appendix sh ows our det ailed project programme in Microsoft Project which identifies key stages and milestones for the project

Appendix I – **Go/No Go Sta ge Gates, Pa yment Mil estones, and c ost breakdown, linked to technical outputs**
This appendix shows the projects proposed go/no-go s tage gates for each ele ment of the project, including technical descriptions of each.

Appendix J - **Knowledge Dissemination Plan**
This appendi x shows what, ho w, w hen and to who m we wi ll disseminate the learning generated form this Project

Appendix K – **Project Team Organograms**
This appendix shows our suggested project team structure

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Appendix M – **Typical Stakeholder Communication Examples**

This appen dix iden tifies ex amples of typical stakeholder communication material previously undertaken by SGN

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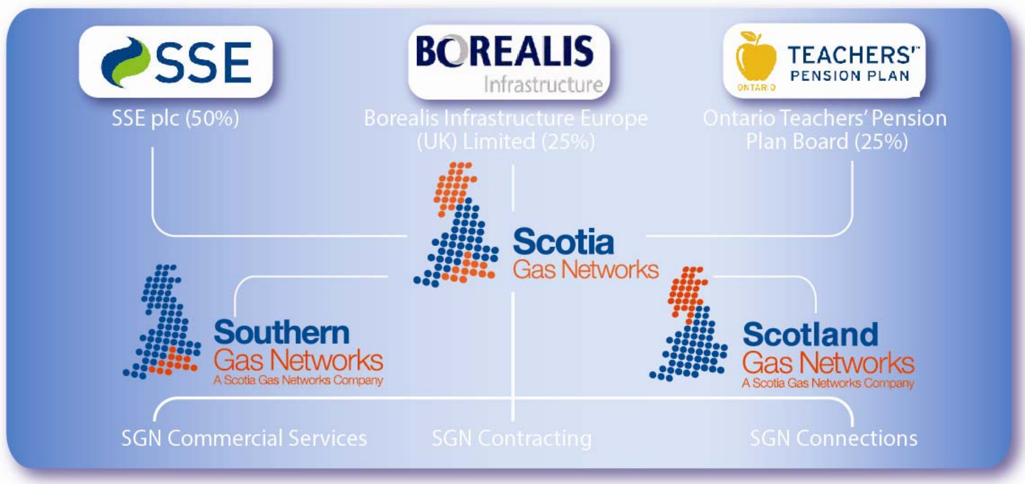
Appendix B – About SGN and ULC Robotics

SGN operates two of the UK's largest gas networks through 74,000km of gas mains and services. Scotland is served by Scotland Gas Networks and Southern Gas Networks encompasses the south and south-east of England. We provide a safe and secure supply of natural gas to 5.8 million customers and are the second largest gas distribution company in the UK.

Formed in June 2005, we have three shareholders who are the UK-based SSE plc (50%) and two Canadian pension funds : Borealis Infrastructure Management Inc (25%) and Ontario Teacher's Pension Plan Board (25%).

By actively engaging with and helping our customers, our environment and our communities, and by demonstrating the highest standards of safety, reliability and efficiency, we aim to become the UK's leading gas network operator.

Our people take pride in making a real difference, continuously improving and innovating. We are committed to delivering excellent customer service in all areas of our business and aim to be the leading operator of gas distribution networks in the UK.



ULC Robotics is a pipleine robotics energy service, research and development organisation. Their aim is to work closely with their customers to develop novel solutions to their infrastructure operations and maintance needs.

Based in New York, USA ULC Robotics thrives on creating and implementing a range of devices from simple tools to complex electromaechanical systems and robotics. Their staff includes highly experienced field operations personnel, mechanical and electrical engineers, automation specialists and master machinists and technicians.

At ULC Robotics their values are based around the partnership built with their customers and the capability to produce value. They believe customer relationships are built on integrity, innovation, value and safety, these are the underlying principles that they ULC Robotics deliver.

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Appendix C – Project Conceptual Drawings and Detailed Descriptions

Element 1

Robot Deployment

Figure 6 shows a street-level view showing the deployment of the modular robotic platform developed for elements 1, 2 and 3. Under this concept, the robot is able to travel along the pipe up to 150 meters in either direction from the point of insertion. The vertical launch tube shown minimizes the size of the required excavation needed to perform the operation.

Figure 6 - Robot Deployment

The inserted robot has a live video feed which is directly streamed to the robots operator in the vehicle. The entire system is capable of operating without the release of any gas from the main whilst minimising the disruption which can be caused from conventional excavations, thus resulting in an overall reduction in the impact to the customers and the environment.

Launch System

Figure 7 is a conceptual cross-section explaining the proposed method of deployment for the tethered modular robot to be launched in the down a gas main using a hydraulically controlled winching system in to the vertical no-blow launch tube attached to the gas main.

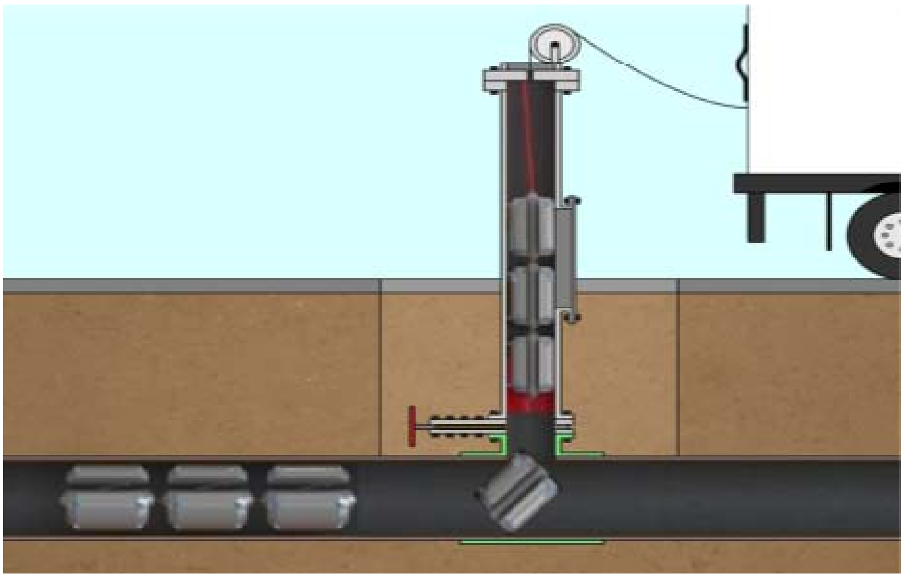

Figure 7 - Launch Tube

Expand to fit

The expanding modules at the front and the back would have powered wheels to drive the robot along the pipe. A camera and lighting system mounted in the forward module would provide the operator with live video images of the interior of the pipe. The module in the middle is a conceptual joint repair module.

The tethered robotic system is controlled and monitored by an operator in a vehicle. After the robot has been inserted into the gas main it will then expand to fit the inner diameter of the pipe as required, as shown in Figure 8.

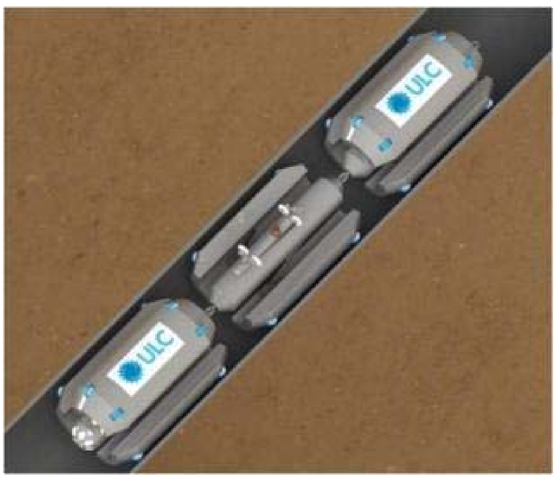

Figure 8 – Expanding to Fit Main

The ability to expand allows this system to operate in a variety of pipe diameters. The ability to expand will allow the robot to launch into a small tap hole and to operate in a variety of pipe diameters.

The expanding modules at the front and the back have powered wheels to drive the robot along the pipe. A camera and lighting system mounted in the forward module would provide the operator with live video images of the interior of the pipe. The module in the middle is the joint repair module. (See Element 2)

Repair Module

Figure 9 is conceptual drawing of the repair module developed for element 2. After locating a joint that requires a repair, the repair module is positioned and a tool is deployed to seal the joint. The process involves an expanding sealant being injected directly in to the joint; the secondary conceptual repair method would be the deploying a mechanical seal at the joint.

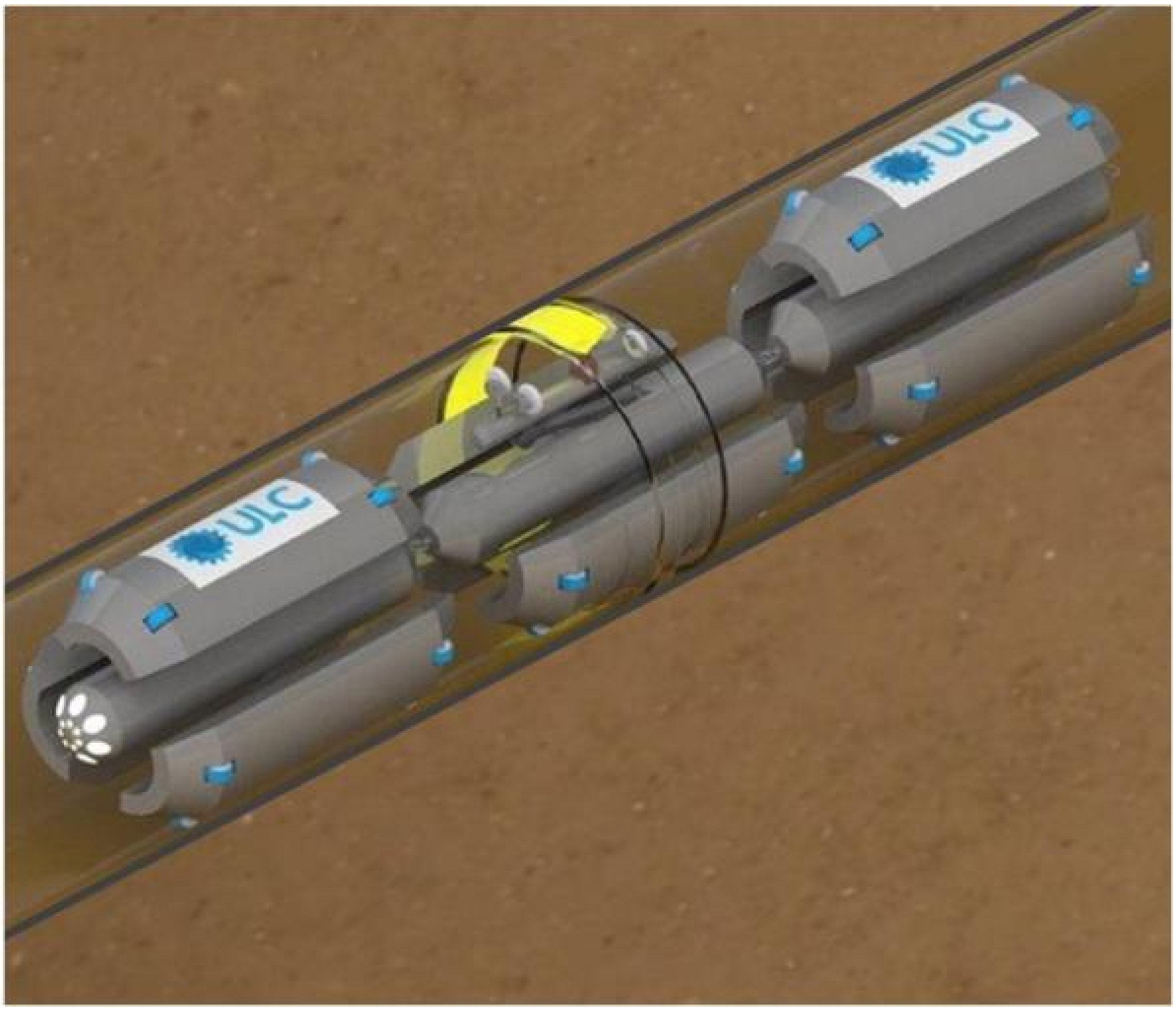

Figure 9 – Repair Module

After completing the first sealing operation, the robot continues along the main, locating the next joint and repeats the joint sealing operation. Using the robotic platform and launch tube described in element 1, multiple joints could be inspected and repaired from a single insertion point, eliminating the need for costly and disruptive excavations at each joint.

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Element 3

Sensor Module

Figure 10 is a conceptual drawing of the modular robot developed for elements 1 & 2 with the sensor module developed for element 3. This module shown in the middle could be installed on the same robot and deployed for different applications.

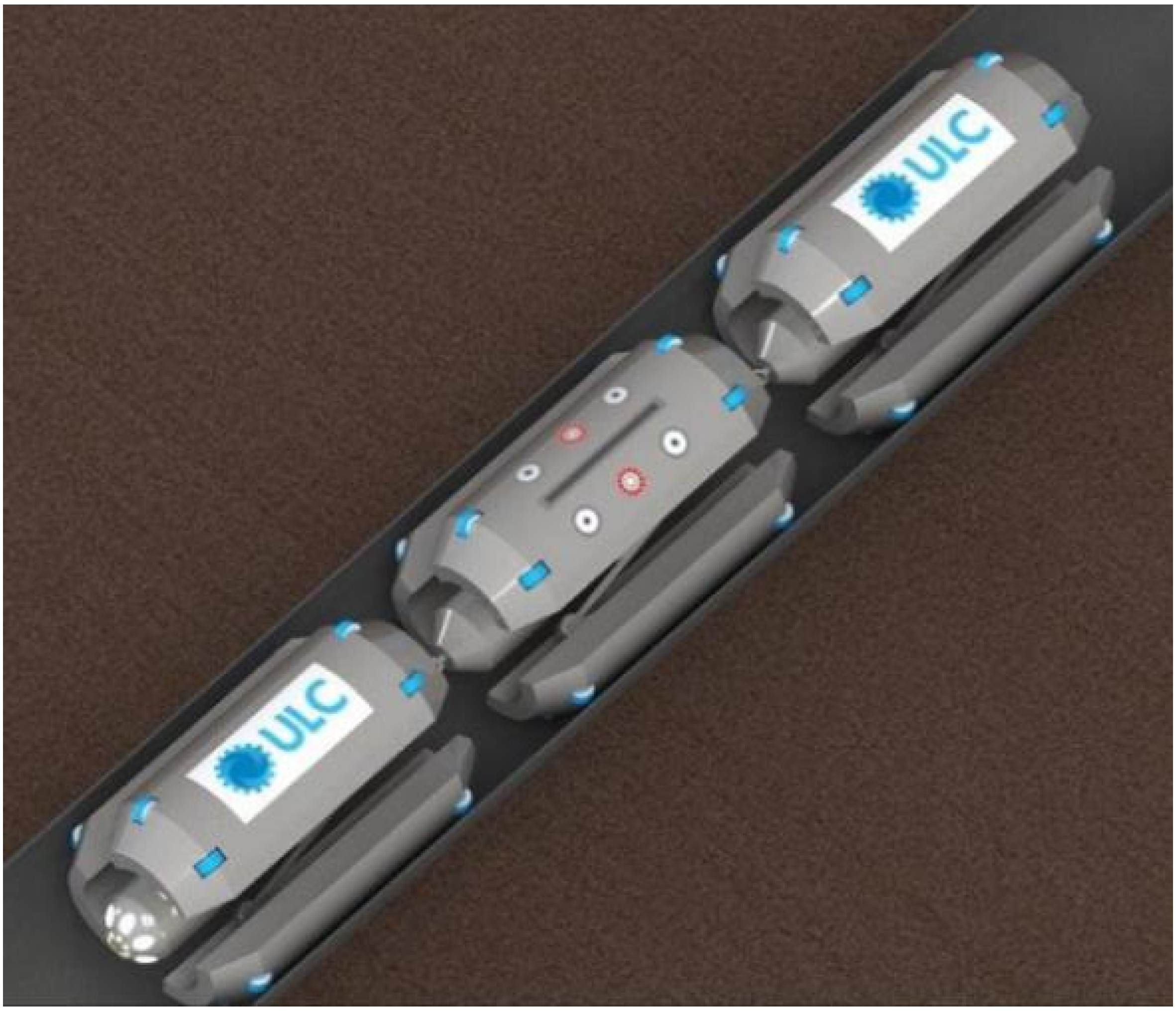

Figure 10 – Sensor Module

The sensor module added on to the robot would carry instruments capable of measuring wall thickness, detecting corrosion, cracks, pipe stress data and potentially other types of data. The robot is designed to travel along the inside of the pipe to assess its structural integrity from a single insertion point, again minimising the disruption from excavations.

Service Excavations

Figure 11 below is a plan view of a traditional 'insertion' replacement operation. Each home is connected to the gas main via a small diameter service pipe leading from the main to the customers Emergency Control Valve. To insert a replacement PE pipe inside the existing gas main, large excavations are created along the main, as shown below.

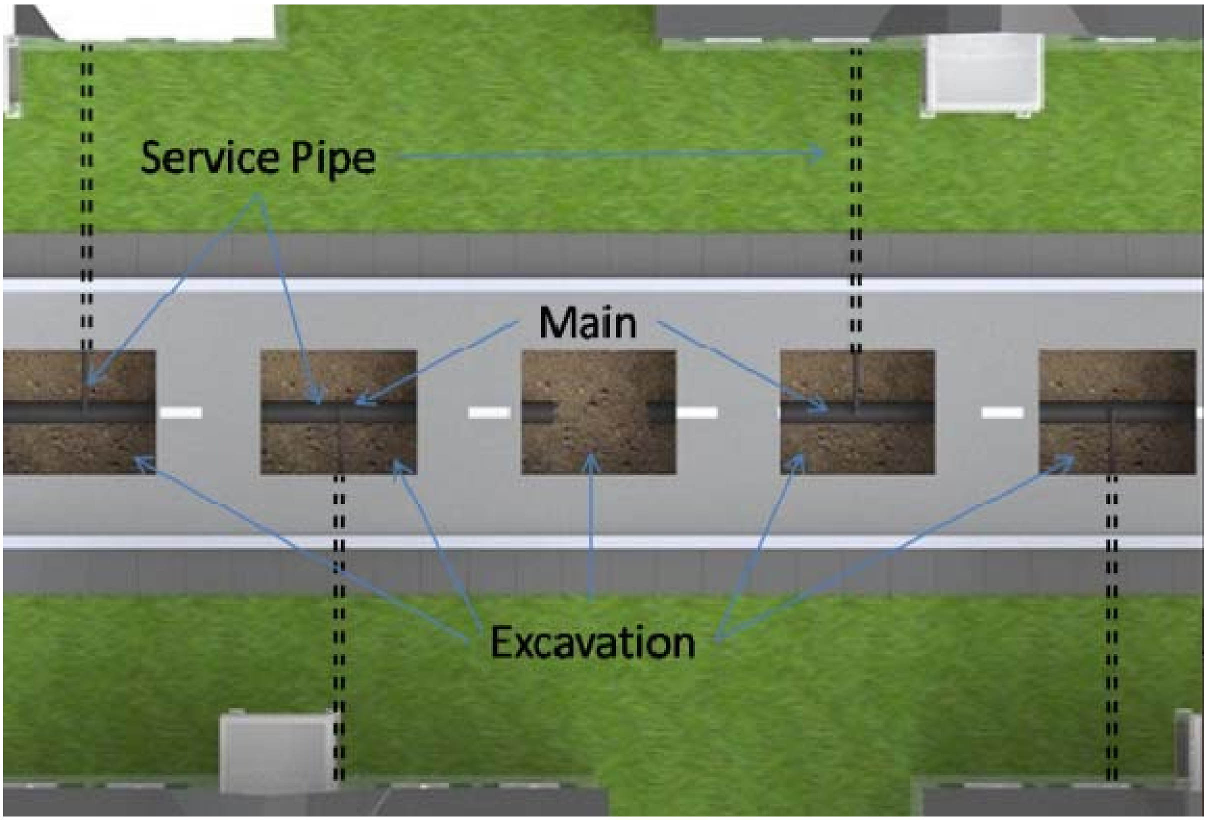

Figure 11 – Service Excavations Plan View

The replacement PE main is inserted in the carrier main from one of these excavations. To connect new PE service pipe using traditional methods, additional excavations have to be created at each service connection point.

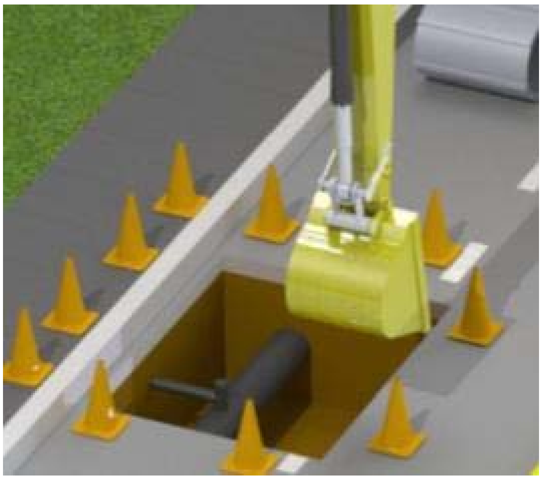

Figure 12 shows a 'street-level' view of a traditional service replacement operation. An excavation is required at each of the services connection point to the main to insert a new PE service into the existing service carrier pipe. This method is highly disruptive to the public and requires extensive street works.

Figure 12 – Service Connection Excavation

Service Replacement

Figure 13 shows a cross-section of PE service replacement. The new PE main is inserted into the existing gas main and a new flexible PE service pipe is inserted into the existing service pipe.

Figure 13 – Service Replacement

Both of the new PE pipes are joined at the service connection with a PE fitting. The robotic system developed for element 4 will be capable of making connections at multiple service lines from a single point of entry, (as described in section 4.1) minimizing the excavations required.

Robot Operation

Figure 14 is a conceptual drawing of the proposed robotic service replacement system developed under scope of element 4.

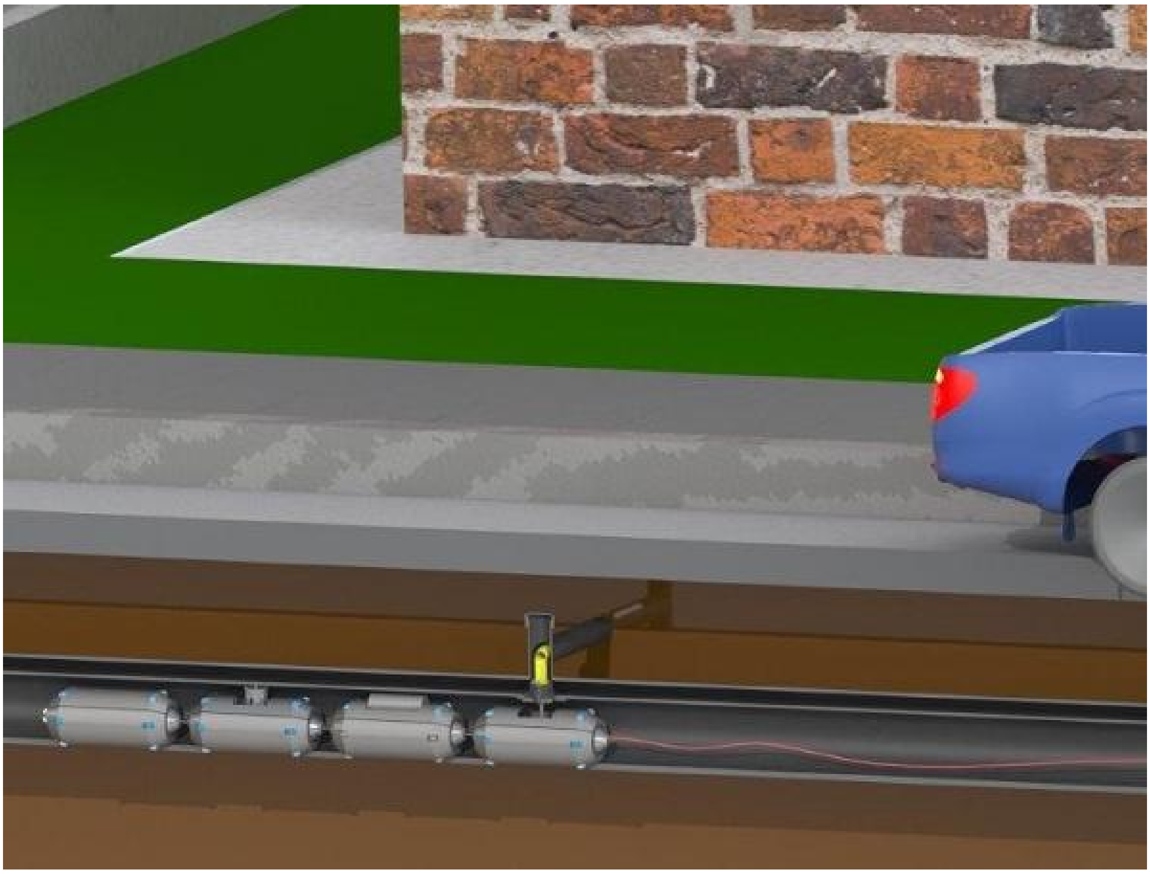

Figure 14 - Robot Operation

This shows a robot which is inserted into the replacement PE main. The robot travels along the main to each service connection. Tools carried by the robot drill a hole in the PE main, install a PE fitting, and connect the new PE service line to the main. Multiple services can be reconnected from a single insertion point using this method, eliminating the need for an excavation at each connection. As shown in the figure, this method greatly reduces the disruption to the public caused by service replacement.

Drilling, Fitting and Reconnecting

Figure 14 shows a conceptual cross-section of the robotic system developed for element 4 coving the three main steps in the operation of:

- Internally drilling the PE main,
- Inserting a PE fitting for the service reconnection,
- Reconnecting the service.

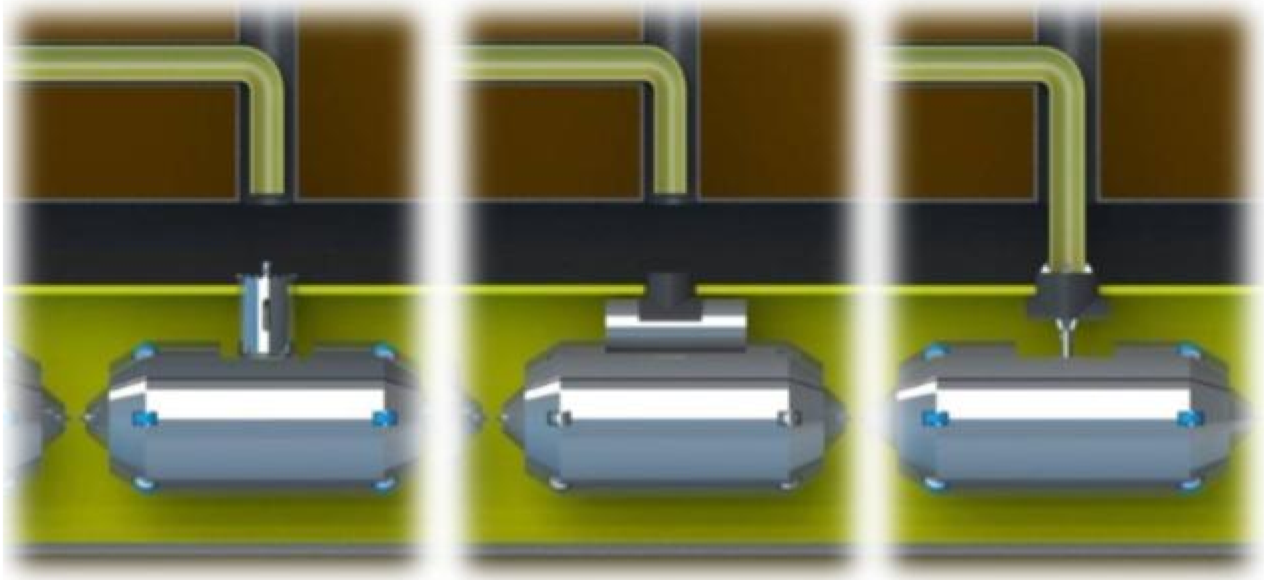

Figure 15 - Drilling, Fitting and Reconnecting

The Drilling Process involves the robot travelling along the newly inserted PE main to the service connection point location. The drilling or cutting tool is then deployed to make a small hole in to the new PE main in preparation for service reconnection.

A new PE fitting is installed by the robot in the new hole that was cut in the main. The PE fitting can be electrically welded to the main from the inside.

The new PE service is inserted from the customer side and connected to the newly installed PE fitting. A tool on the robot could be used to position the new service line and insert it securely to the PE fitting. The new PE service connection would then be pressure tested to ensure its integrity before the gas supply is restored.

Following off site testing, minor modifications will be performed to prepare the system for field testing.

Once off site testing has been performed, the system will be packed and crated in preparation for shipping to the UK.

Field testing will be performed at sites provided by SGN and will determine:

- Engineering and Planning steps necessary prior to deployment
- Maximum Travel Distance and Ability to Remotely Reconnect Service Lines
- Impact On Customers
- Ability for system to operate and remotely install service connection on newly inserted PE pipelines
- Deployment Methodology
- Modifications prior to system commercialization
- Estimated Unit Pricing for Commercial Work Performed

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Appendix D– Pipe Specifications, Industry and British Standards (Abridged)

Table 5 – Pipe Specifications

Cast Iron (Pit or Spun)	Steel	Ductile
Pre 1917 pipe manufacturers proprietary standards - note it is considered most standards had become broadly similar by 1903 and subsequent BS 78 represented a rationalisation of the proprietary standards	BS 534 Steel pipes, fittings and specials for water, gas and sewage	S20 (July 1969) British Gas Corporation Engineering Research Station Specification for DI cast in metal moulds July 1969
BS 78:1917 Cast Iron Pipes for Water, Gas and Sewerage	BS 3601:1962 Steel pipes and tubes for pressure purposes, Carbon Steel: Ordinary duties	BS 4772:1971 Specification for ductile iron pipes and fittings
BS 78:1938 Cast Iron Pipes for Water, Gas and Sewerage	BS 3601:1987 Specification for carbon steel pipes and tubes with specified room temperature properties for pressure purposes	BS 4772:1980 Specification for ductile iron pipes and fittings
BS 78-1:1962 Specification for cast iron spigot and socket pipes and fittings. Pipes	BS 3601:1974 Specification for steel pipes and tubes for pressure purposes: carbon steel with specified room temperature properties	BS 4772:1988 Specification for ductile iron pipes and fittings
BS 2035:1966 Specification for cast iron flanged pipes and flanged fittings		BS EN 969:1996, Ductile iron pipes, fittings, accessories and their joints for gas pipelines. Requirements and test methods.
BS 1211:1945 Specification for centrifugally cast (spun) iron pressure pipes for water, gas and sewerage		BS EN 969:2009, Ductile iron pipes, fittings, accessories and their joints for gas pipelines. Requirements and test methods.
BS 1211:1958 Specification for centrifugally cast (spun) iron pressure pipes for water, gas and sewerage		
BS 4622:1970 Specification for grey iron pipes and fittings		

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Table 6 - Industry and British Standards (Abridged)

Type	Standard	Element				Requirment					
		One	Two	Three	Four	Joint Seal Test	Joint Stress Test	Service Pressure Test	Electrofuse Test	Compression Fitting Test	Drilling Check
	ATEX 137 workplace directive 99/92/EC, Minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres.	●	●	●	●						
ATEX	ATEX 95 equipment directive 94/9/EC, Equipment and protective systems intended for use in potentially explosive atmospheres;	●	●	●	●				Element 4		Element 4
British Standard	BS EN 682:2002, Elastomeric seals - Materials requirements for seals used in pipes and fittings carrying gas and hydrocarbon fluids		●			Element 2	Element 2				
Gas Industry Standard	GIS/ECE1, Specification for electrofusion control boxes.				●				Element 4		
Gas Industry Standard	GIS/F10:2006, Specification for ancillary fittings used for the live insertion of gas mains operating at pressures equal to or less than 75 mbar.				●				Element 4		
Gas Industry Standard	GIS/F16:2006, Specification for in-pipe close fit lined pipe service fittings				●					Element 4	
Gas Industry Standard	GIS/LC14:2009, Specification for annular gap sealants				●	Element 2					
Gas Industry Standard	GIS/LC8 Part 3:2006, Specification for methods of repairing leaking ferrous gas mains. Part 3 - Internal sealing methods		●			Element 2	Element 2				
Gas Industry Standard	GIS/PL2-1, Specification for polyethylene pipes and fittings for natural gas and suitable manufactured gas; Part 1: General and polyethylene compounds for use in polyethylene pipes and fittings				●				Element 4	Element 4	
Gas Industry Standard	GIS/PL2-2, Specification for polyethylene pipes and fittings for natural gas and suitable manufactured gas; Part 2: Pipes for use at pressures up to 5.5 bar.				●			Element 4			
Gas Industry Standard	GIS/PL2-3, Specification for polyethylene pipes and fittings for natural gas and suitable manufactured gas; Part 3: Butt fusion machines and ancillary equipment.				●				Element 4		
Gas Industry Standard	GIS/PL2-4, Specification for polyethylene pipes and fittings for natural gas and suitable manufactured gas; Part 4: Fusion fittings with integral heating element(s).				●				Element 4		
Gas Industry Standard	GIS/PL2-5, Specification for polyethylene pipes and fittings for natural gas and suitable manufactured gas; Part 5: Electrofusion ancillary tooling.				●				Element 4		
Gas Industry Standard	GIS/TE/E1.9:2006, Specification for LIve Mains Abandonment Equipment for LP Mains				●						
Gas Industry Standard	GIS/TE/P6.3:2007, Specification for equipment used in testing gas mains and gas services with operating pressures not greater than 7 bar				●			Element 4	Element 4	Element 4	
IGEM	IGE/TD/3 - Distribution Mains		●	●	●	Element 2	Element 2				
IGEM	IGE/TD/4 - Gas Services		●	●	●			Element 4	Element 4	Element 4	Element 4
SGN Procedure	SGN/PR/EM/74-B, Work Procedure for Locating and Repairing Gas Escapes on the Network Operating At Pressures Not Exceeding 7 bar - Part B - Repair Techniques		●			Element 2	Element 2				

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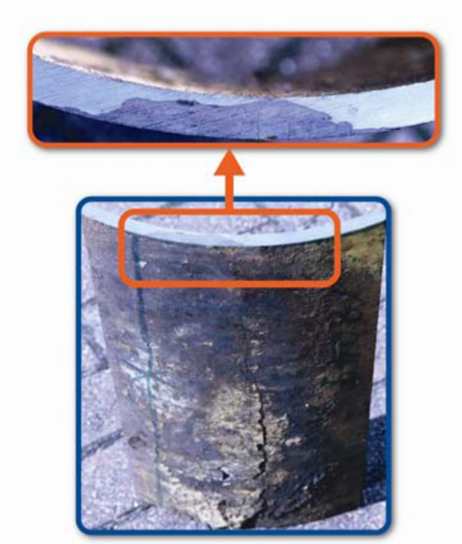

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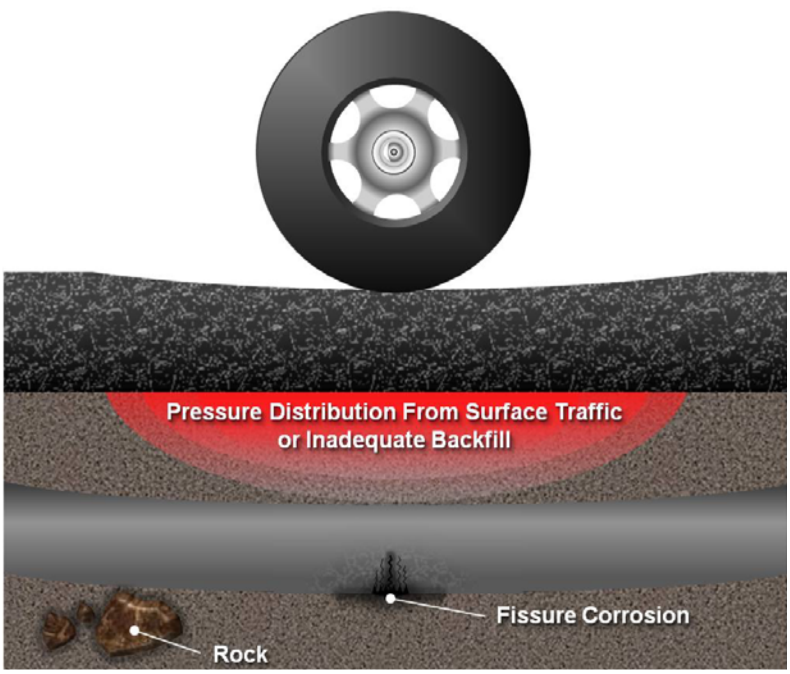

Figure 17 – Exaggerated Example of Pipe Under Stress

Sensor(s) Module to Inform Risk

The sensor/s module that will be employed will seek to identify characteristics in the pipe that would inform risk. Its design or selection will not be limited to the above features and will consider pipe ovality, wall thickness, visual inspection and others.

A variety of sensors will also be researched and tested to determine if the integrity of the lead and jute seals on Cast Iron joints can be determined remotely from within the pipe.

Other information collected by sensors could include:

- Identification and measurement of corrosion levels using visual and non-visual sensing devices
- Measurement of key in pipe features using video measurement software
- Measurements of the circumferential and axial extent of damage along the pipe wall using laser measurement. Combined with wall thickness measurements this information could be used to generate a 3D "map" of the pipe's inner surface.
- Determination of low points in pipe using onboard accelerometers

The development of robotics technology in terms of iron and steel distribution gas mains has the potential to inform industry pipe risk models and to identify, down to individual pipe length, where local factors exist that will influence decisions on remediation action and remediation methods to reduce on a prioritised basis the associated societal and individual risk.

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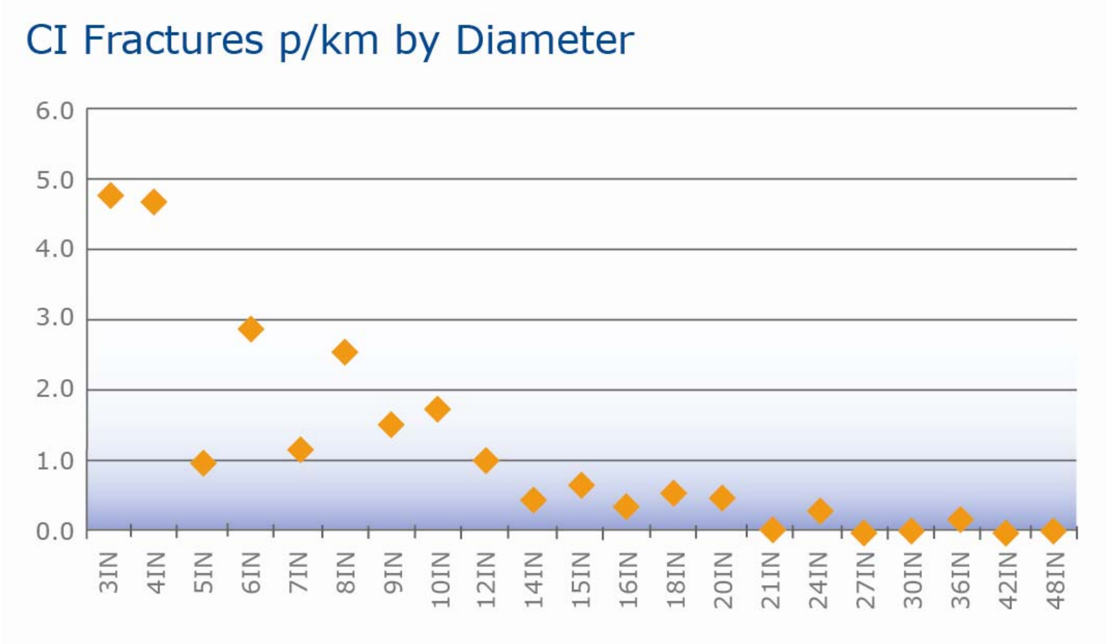

Figure 18 – CI Fractures p/km by Diameter

Conversely there is a higher incidence of joint failure per/km in the larger diameters within tiers 2 and 3 (see figure 19). This is an indication that larger pipes are less prone to fracture failure than smaller diameters (tier 1).

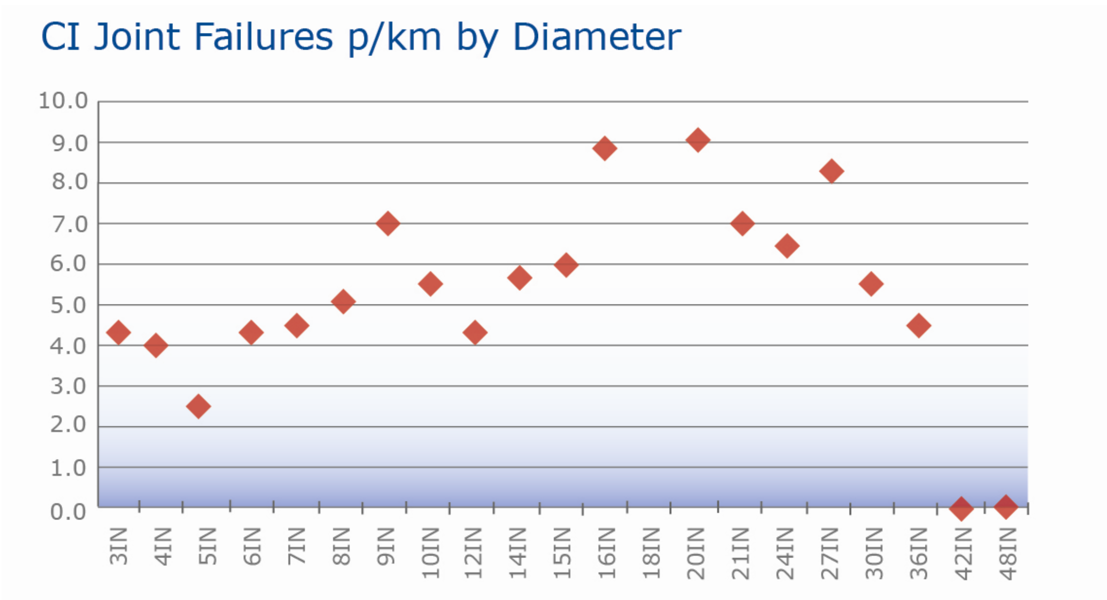

Figure 19 – CI Joint Failures p/km by Diameter

It is also evident through limited review of interference damage reports, such as the one identified at Clairilaw Farm in Hawick (RP1411 above), that certain pipes are in excellent condition. Other failure reports indicate that points of failure have been highly localised, due to poor backfill reinstatement practices or specific traffic loading stresses.

Despite development over a number of years current risk models are limited in that we do not have a capability to physically examine buried distribution mains to assess pipe condition without involving considerable expenditure and distribution to the public. Even where using excavation it is generally only practicable to access parts of a pipeline rather expose it in full. Robotics potentially provide a means of assessing pipeline condition without incurring such cost or disruption but identifying factors which may exist and increase the risk of pipe failure.

At present our industry risk models (see figure 20 below) consider the previous fracture/ corrosion history of a pipe unit together with the background fracture/corrosion rates of pipes in the locus but not other factors which increase the probability of pipe failure/leakage or influence potential failure mode.

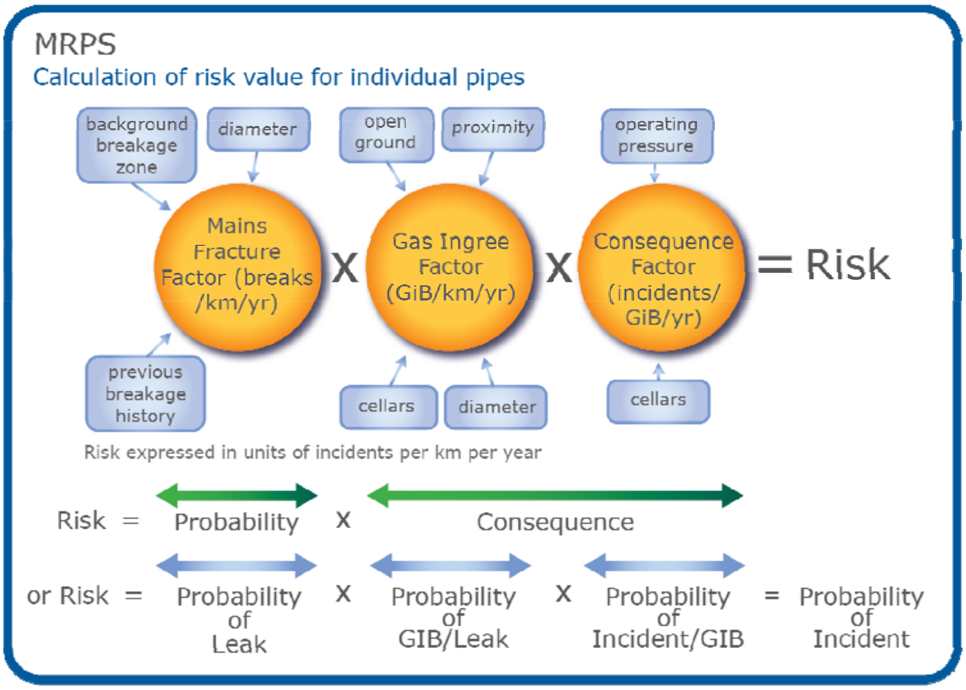

Figure 20 – MRPS Calculation Model

Advantica (now GL Noble Denton) developed the risk assessment model between 1997 and 1999, in order to assist in prioritising gas mains for replacement and optimising risk replacement in the gas distribution system. The Mains Risk Prioritisation Scheme (MRPS) is dependant on the material of the gas mains. Three models have been created taking into account the material of the mains, the Cast Iron Risk Model, the Ductile Iron Risk Model and the Steel Risk Model. These models have been developed using data from the entire UK network.

The models were originally implemented by Transco in 2000 and have undergone several updates since then.

The MRPS enables distribution mains to be ranked in order of decreasing risk, thus the risk on each mains unit can be quantified and an optimal replacement strategy implemented.

Most serious incidents arising from gas main leakage relate to gas pipe fractures and corrosion events rather than joint leakage. Failure modes are well documented and relate to pipe corrosion, pipe loading, pipe defects and indeed human factors particularly associated with pipe construction and third party interference. Often it is a combination of factors that lead to corrosion blowout, circumferential or longitudinal stress cracking in an individual pipe or pipeline.

It is hoped that this project can lead to the utilisation of robotics to provide useful data on physical pipe condition and be used to minimise future pipeline failures by enabling targeted action to be prioritised. By determining pipe stresses, corrosion, wall thickness, pipe inclination, cracks and other pipe defects and damage it is hoped that future remediation can be targeted more efficiently to those pipes more likely to fail through pipe corrosion and fracture, in addition to addressing issues surrounding joint leakage etc. This is most likely to be of assistance when considering larger diameter mains, which are less prone to in fracture, but none the less when failures occur often produce significant emergencies.

It is not considered that this proposal on its own will establish fitness for purpose criteria in terms of asset integrity for legacy pipelines, some of which were constructed predating recognised UK pipe standards being established. Nevertheless, this may be one of the outcomes of the project.

A collaborative project between all the GDNs is about to commence under NIA to review fitness-for- purpose of cast iron pipelines. The outputs of this project will feed in to this assessment.

It is hoped that the project will be able to demonstrate use of this technology and identify situations and establish criteria that would trigger action - be it in terms of increased monitoring or physical remediation or pipe replacement for pipes identified at being of high risk.

It is not expected that the MRPS risk assessment process would be applied , as it is currently to confirm the determination of pipes identified at higher risk based on internal inspection findings. It is more likely that additional physical condition information will allow a better informed assessment of the probability and consequence of pipe fracture/ corrosion, than those used the current risk model in situations where inspection exceptions to the norm are identified. The basic principles of our risk models would however be applied.

It is hoped that information in terms of the knowledge gained from this project and other work in this area will when shared and lead in improved industry pipe risk models and risk management techniques. Therefore it has been conservatively assumed that 55% of pipes in the tier 2 and tier 3 categories will require remediation as a means of risk management, rather than replacement. This is the basis for the assumptions within the CBA, but an indication of the accuracy of these assumptions will be borne out of the project. If conversely, the information gathered identifies that more pipe lines require replacement than currently planned, this would also be a highly valuable output from the project.

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Appendix G – CO2e/Leakage Savings

The following assumptions have been made:

- 20% increase in speed of rosk management and relative increase in year
- No carry forward from 2021
- 3 month lag following successful project completion
- Ramp up in SGN work to full capacity within 12 months
- Ramp up in GB work in full capacity within 24 months
- GB networks assumed (based on 4 x SGN)

Leakage Reduction

Total leakage to be removed (CO2e) through risk removal under RIIO for Scotland and Southern

Network	*Tier*	*CI*	*DI*	*SI*	***Total***
Southern	*T2*	14791.2	151.3	875.5	**15818.0**
Scotland	*T2*	7505.9	99.8	746.0	**8351.7**
Southern	*T3*	5509.0	56.4	326.1	**5891.4**
Scotland	*T3*	2251.8	30.0	223.8	**2505.5**
Total	**-**	**30057.8**	**337.4**	**2171.3**	**32566.6**

Approximate CO2e Required Reduction Per Year of Period

CI	*DI*	*SI*	***Total***
3757.2	42.2	271.4	4070.8

Target Remediation time saving over Replacement = 20%

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Reduction CO2e Per Quarter over Phased Implementation Period - SGN

			Project				
Fin. Year	Quarter (end)	Base	Rep CI	Rem CI	Other	**Total**	**Saving**
2015/16	4	20354.1					
2016/17	1	19336.4	810.2	155.0	78.4	1043.5	25.8
2016/17	2	18318.7	681.0	310.0	78.4	1069.4	51.7
2016/17	3	17301.0	551.8	465.0	78.4	1095.2	77.5
2016/17	4	16283.3	422.7	619.9	78.4	1121.0	103.3
2016/17	**Total**		**2465.7**	**1549.9**	**313.6**	**4329.1**	**258.3**

Potential phased remediation ramp up Percentages - SGN

Fin. Year	Quarter	Rep CI	Rem CI
2016/17	1	86.3%	13.8%
2016/17	2	72.5%	27.5%
2016/17	3	58.8%	41.3%
2016/17	4	45.0%	55.0%

Potential SGN CO2e Reduction Over PCR Period

			Project				
Fin. Year	Year (end)	Base	Rep CI	Rem CI	Other	**Total**	**Saving**
2012/13	0	32566.6				32566.6	**0.0**
2013/14	1	28495.8				28495.8	**0.0**
2014/15	2	24424.9				24424.9	**0.0**
2015/16	3	20354.1	9228.7	9557.5	1568.0	20354.1	**0.0**
2016/17	4	16283.3	6763.0	8007.6	1254.4	16025.0	**258.3**
2017/18	5	12212.5	5072.3	5527.8	940.8	11540.9	**671.6**
2018/19	6	8141.6	3381.5	3048.1	627.2	7056.7	**1084.9**
2019/20	7	4070.8	1690.8	568.3	313.6	2572.6	**1498.2**
2020/21	8	0.0	0.0	0.0	0.0	0.0	**0.0**
				Total Saving Over Period:			**3513.0**

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Reduction in CO2e Per Quarter over Phased Implementation Period - GB (not including SGN)

			Project				
Fin. Year	Quater (end)	Base	Rep CI	Rem CI	Other	**Total**	**Saving**
2015/16	4	61062.3					
2016/17	1	58009.2	2624.2	232.5	235.2	3091.9	38.7
2016/17	2	54956.1	2430.5	465.0	235.2	3130.6	77.5
2016/17	3	51903.0	2236.7	697.4	235.2	3169.4	116.2
2016/17	4	48849.9	2043.0	929.9	235.2	3208.1	155.0
2017/18	1	45796.8	1849.3	1162.4	235.2	3246.8	193.7
2017/18	2	42743.6	1655.5	1394.9	235.2	3285.6	232.5
2017/18	3	39690.5	1461.8	1627.4	235.2	3324.3	271.2
2017/18	4	36637.4	1268.1	1859.8	235.2	3363.1	310.0
2016/17	**Total**		**9334.4**	**2324.8**	**940.8**	**12599.9**	**387.5**
2017/18	**Total**		**6234.7**	**6044.4**	**940.8**	**13219.9**	**1007.4**

Potential Phased remediation ramp up

Percentages - GB (not including SGN)

Year	Quarter	Rep CI	Rem CI
2016/17	1	93.1%	6.9%
2016/17	2	86.3%	13.8%
2016/17	3	79.4%	20.6%
2016/17	4	72.5%	27.5%
2017/18	1	65.6%	34.4%
2017/18	2	58.8%	41.3%
2017/18	3	51.9%	48.1%
2017/18	4	45.0%	55.0%

Potential GB CO2e Reduction Over PCR Period

Fin. Year	Year (end)	Base	**Saving**
2012/13	0	130266.3	**0.0**
2013/14	1	113983.0	**0.0**
2014/15	2	97699.8	**0.0**
2015/16	3	81416.5	**0.0**
2016/17	4	65133.2	**645.8**
2017/18	5	48849.9	**1679.0**
2018/19	6	32566.6	**4339.6**
2019/20	7	16283.3	**5992.8**
2020/21	8	0.0	**0.0**
Total Saving Over Period:			**12657.2**

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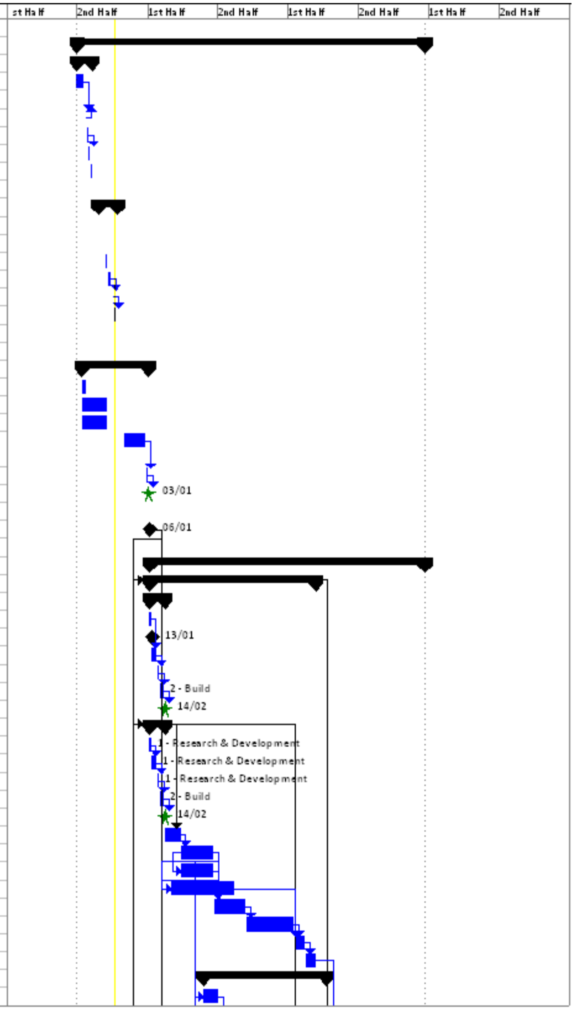
Appendix H – Project Plan

ID	Task Name	Duration	Start	Finish
1				
2	NIC SGN_GN_01 Proposal - SGN	646 days?	Mon 01/07/13	Mon 21/12/15
3	Initial Bid Submission	30 days?	Mon 01/07/13	Fri 09/08/13
4	Complete 1st Draft	15 days?	Mon 01/07/13	Fri 19/07/13
5	Executive Sign Off	1 day?	Mon 29/07/13	Mon 29/07/13
6	Review 1st Draft	1 day?	Fri 26/07/13	Fri 26/07/13
7	Revise 1st Draft	3 days?	Mon 29/07/13	Wed 31/07/13
8	Prepare Bid Folders	1 day?	Fri 02/08/13	Fri 02/08/13
9	Submit bid to OFGEM	1 day?	Fri 09/08/13	Fri 09/08/13
10				
11	Bid Resubmission	36 days?	Mon 26/08/13	Mon 14/10/13
12	Bilateral Meetings	1 day?	Mon 26/08/13	Mon 26/08/13
13	Consultants Meetings	1 day?	Mon 02/09/13	Mon 02/09/13
14	Further Billaterals	1 day?	Mon 16/09/13	Mon 16/09/13
15	Revise Bids	5 days?	Mon 23/09/13	Fri 27/09/13
16	Review Bid	1 day?	Fri 04/10/13	Fri 04/10/13
17	Prepare Bid Folders	2 days?	Mon 07/10/13	Tue 08/10/13
18	Resubmit to OFGEM	1 day?	Mon 14/10/13	Mon 14/10/13
19				
20	Project Preparation	125 days	Mon 15/07/13	Fri 03/01/14
21	Generate Detailed Project Plan	10 days	Mon 15/07/13	Fri 26/07/13
22	Assess Staffing Needs and Hire Dedicated Project Staff	46 days	Mon 15/07/13	Mon 16/09/13
23	Procure Project Specific Equipment - Computers, Office Equipment	46 days	Mon 15/07/13	Mon 16/09/13
24	Establish Project Reporting Structure and Timetable between Project Team Partners	41 days	Fri 01/11/13	Fri 27/12/13
25	Create Project Reporting Structure & Timetable Documents	4 days	Mon 30/12/13	Thu 02/01/14
26	Publish Project Reporting Structure Document	1 day	Fri 03/01/14	Fri 03/01/14
27				
28	Project Start Date	0 days	Mon 06/01/14	Mon 06/01/14
29				
30	Project Element 1 & 2 - Develop Modular Robotic Inspection & Repair Platform	511 days?	Mon 06/01/14	Mon 21/12/15
31	Task 1 - Develop Robotic Platform	310 days	Mon 06/01/14	Fri 13/03/15
32	Electrical Specification Document Development	30 days	Mon 06/01/14	Fri 14/02/14
33	Establish detailed specifications of scenarios for use of systems on Gas Network	5 days	Mon 06/01/14	Fri 10/01/14
34	*Delivery of High Level, Preliminary Specification Document By ULC To SGN*	0 days	Mon 13/01/14	Mon 13/01/14
35	Match Network Specifications to Robotic high Level design requirements	10 days	Mon 13/01/14	Fri 24/01/14
36	SGN confirm with ULCR specification match	5 days	Mon 27/01/14	Fri 31/01/14
37	Obtain Stage 1 approval for scenario specifications	9 days	Mon 03/02/14	Thu 13/02/14
38	Publish Element 1 & 2 Electrical Stage 1 Scenario Specification Approval Certificate	1 day	Fri 14/02/14	Fri 14/02/14
39	Mechanical Specification Document Development	30 days	Mon 06/01/14	Fri 14/02/14
40	Establish detailed specifications of scenarios for use of systems on Gas Network	5 days	Mon 06/01/14	Fri 10/01/14
41	Match Network Specifications to Robotic high Level design requirements	10 days	Mon 13/01/14	Fri 24/01/14
42	SGN confirm with ULCR specification match	5 days	Mon 27/01/14	Fri 31/01/14
43	Obtain Stage 1 approval for scenario specifications	9 days	Mon 03/02/14	Thu 13/02/14
44	Publish Element 1 & 2 Mechanical Stage 1 Scenario Specification Approval Certificate	1 day	Fri 14/02/14	Fri 14/02/14
45	*SDRC 9.1 - Development of Conceptual Designs*	30 days	Mon 17/02/14	Fri 28/03/14
46	*Initial 3D Design of Transport Platform*	60 days	Mon 31/03/14	Fri 20/06/14
47	Initial 3D Design of Repair Module	60 days	Mon 31/03/14	Fri 20/06/14
48	Selection and Procurement of Motors, Gears, & Bearings for Propulsion System	120 days	Mon 03/03/14	Fri 15/08/14
49	*Creation of Detailed Fabrication and Manufacturing Documentation (Robotic Platform)*	60 days	Mon 23/06/14	Fri 12/09/14
50	*Initial Parts Fabrication*	90 days	Mon 15/09/14	Fri 16/01/15
51	*Robotic Platform and Joint Repair Module Assembly*	20 days	Mon 19/01/15	Fri 13/02/15
52	*Robotic Platform and Joint Repair Module Preliminary Functional Test*	20 days	Mon 16/02/15	Fri 13/03/15
53	Task 2 - Launch System Development	230 days	Mon 26/05/14	Fri 10/04/15
54	*Mechanical Specification Document Development (Launch Tube)*	30 days	Mon 26/05/14	Fri 04/07/14



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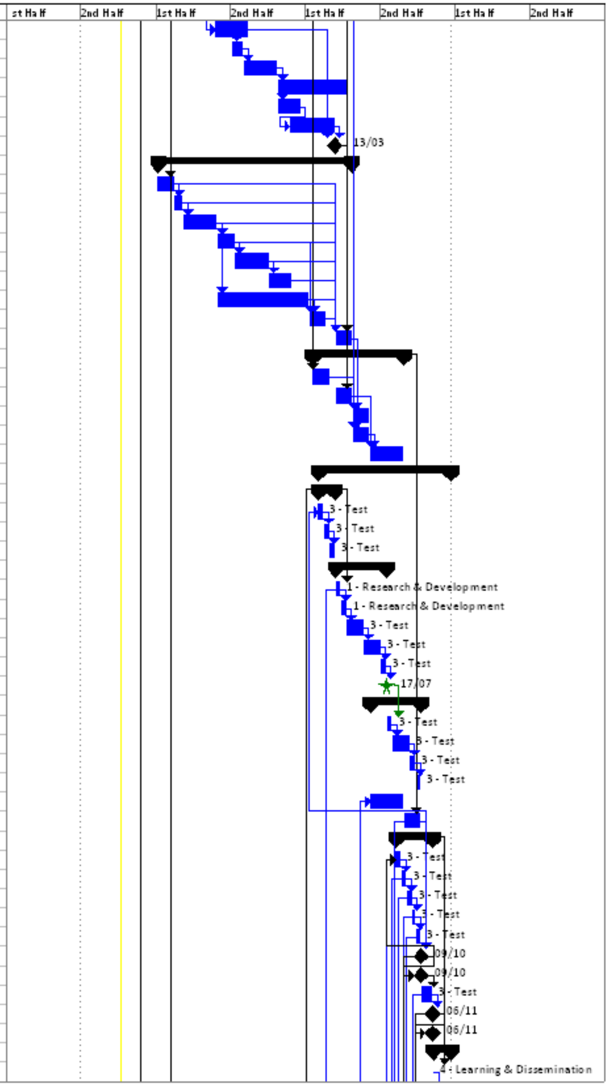
ID	Task Name	Duration	Start	Finish
55	Electrical Design, Fabrication and Assembly	60 days	Mon 26/05/14	Fri 15/08/14
56	*Development of Conceptual Designs (Launch Tube)*	20 days	Mon 07/07/14	Fri 01/08/14
57	*3D Design of Mechanical Components (Launch Tube)*	60 days	Mon 04/08/14	Fri 24/10/14
58	Selection and Procurement of Motors, Gears, & Bearings for Launch System	120 days	Mon 27/10/14	Fri 10/04/15
59	*Creation of Detailed Fabrication and Manufacturing Documentation (Launch Tube)*	40 days	Mon 27/10/14	Fri 19/12/14
60	Parts Fabrication and Assembly	80 days	Mon 24/11/14	Fri 13/03/15
61	Launch System Prototype Complete	0 days	Fri 13/03/15	Fri 13/03/15
62	**Task 3 - Support & Control System Development**	**340 days**	**Mon 06/01/14**	**Fri 24/04/15**
63	Electrical Specification Document Development	30 days	Mon 06/01/14	Fri 14/02/14
64	Electrical and Software System Block Diagram Development	15 days	Mon 17/02/14	Fri 07/03/14
65	*Initial Electrical Schematic Design and Parts Selection*	60 days	Mon 10/03/14	Fri 30/05/14
66	Circuit Card Layout and Fabrication	30 days	Mon 02/06/14	Fri 11/07/14
67	Microprocessor Firmware Programming	60 days	Mon 14/07/14	Fri 03/10/14
68	*User Interface and Control System Design and Programming*	40 days	Mon 06/10/14	Fri 28/11/14
69	Tether Design and Procurement	160 days	Mon 02/06/14	Fri 09/01/15
70	Bench Testing of Electrical System	30 days	Mon 12/01/15	Fri 20/02/15
71	Integration Of Electrical System into Mechanical Prototype	30 days	Mon 16/03/15	Fri 24/04/15
72	**Task 4 - Off Site Testing and Modifications**	**160 days**	**Mon 19/01/15**	**Fri 28/08/15**
73	Fabricate Mock Test Environment at ULC Shop	30 days	Mon 19/01/15	Fri 27/02/15
74	*Launch System Testing*	30 days	Mon 16/03/15	Fri 24/04/15
75	*Robotic Platform Launch, Retrieval and Travel Testing*	30 days	Mon 27/04/15	Fri 05/06/15
76	*Seal Repair Tool Testing*	30 days	Mon 27/04/15	Fri 05/06/15
77	Incorporate Improvements Discovered During Testing	60 days	Mon 08/06/15	Fri 28/08/15
78	**Task 5 - Field Testing**	**231 days?**	**Mon 02/02/15**	**Mon 21/12/15**
79	**Site Selection and Planning**	**30 days**	**Mon 02/02/15**	**Fri 13/03/15**
80	Identify Potential live mains suitable for trial on SGN network	10 days	Mon 02/02/15	Fri 13/02/15
81	Network Analysis/Mains Replacement Design/Contingency Planning	10 days	Mon 16/02/15	Fri 27/02/15
82	Highways Authority liaison and road opening notices	10 days	Mon 02/03/15	Fri 13/03/15
83	**Complete Technical Assurance Statement and Risk Assessment**	**90 days**	**Mon 16/03/15**	**Fri 17/07/15**
84	Establish and approve G/23 Field Trial requirements	10 days	Mon 16/03/15	Fri 27/03/15
85	Hazard and Risk Analysis of Network mains by Asset Management	10 days	Mon 30/03/15	Fri 10/04/15
86	Electrical safety and Compliance	30 days	Mon 13/04/15	Fri 22/05/15
87	Site Management and CDM Requirements	30 days	Mon 25/05/15	Fri 03/07/15
88	Obtain Stage 2 approval for Technical Assurance	9 days	Mon 06/07/15	Thu 16/07/15
89	Publish Element 1 & 2 Stage 2 Technical Assurance Approval Certificate	1 day	Fri 17/07/15	Fri 17/07/15
90	**Pre Site Preparation**	**90 days**	**Mon 08/06/15**	**Fri 09/10/15**
91	Site specific risk assessment	10 days	Mon 20/07/15	Fri 31/07/15
92	Drilling and Assessment of Network Impact	30 days	Mon 03/08/15	Fri 11/09/15
93	Design Anchorage for launch tube / site specific civils	10 days	Mon 14/09/15	Fri 25/09/15
94	Prepare excavations in accordance with SGN's SMF/traffic management procedures	10 days	Mon 28/09/15	Fri 09/10/15
95	*Procure Spares and Materials for Field Testing*	60 days	Mon 08/06/15	Fri 28/08/15
96	Pack and Ship System to the UK	30 days	Mon 31/08/15	Fri 09/10/15
97	*Perform 20 days Field Testing*	**65 days**	**Mon 10/08/15**	**Fri 06/11/15**
98	Prepare and authorise NRO's and PTW's under SCO	10 days	Mon 10/08/15	Fri 21/08/15
99	CDM Site Management	10 days	Mon 24/08/15	Fri 04/09/15
100	Prepare drillings for pre-deployment inspection / specialist contractor	10 days	Mon 07/09/15	Fri 18/09/15
101	Carry out pre-deployment inspection using CCTV	5 days	Mon 21/09/15	Fri 25/09/15
102	Prepare drillings / specialist contractors	10 days	Mon 28/09/15	Fri 09/10/15
103	Mount Launch Tube on Valve at Site	0 days	Fri 09/10/15	Fri 09/10/15
104	*SDRC 9.6 - Launch Robot*	0 days	Fri 09/10/15	Fri 09/10/15
105	Support deployment of robotic solution	20 days	Mon 12/10/15	Fri 06/11/15
106	Retrieve Robot	0 days	Fri 06/11/15	Fri 06/11/15
107	Reinstate	0 days	Fri 06/11/15	Fri 06/11/15
108	**Generate Final Report**	**31 days?**	**Mon 09/11/15**	**Mon 21/12/15**
109	Report on Field Trial against Success Criteria	1 day?	Mon 09/11/15	Mon 09/11/15



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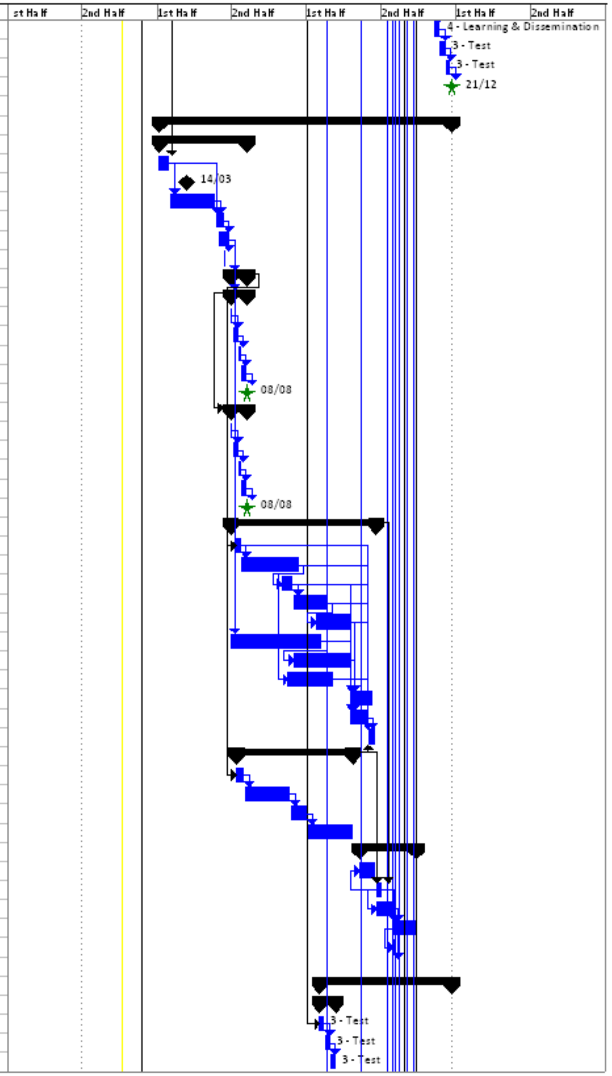
ID	Task Name	Duration	Start	Finish
110	ULCR generate final report	10 days	Tue 10/11/15	Mon 23/11/15
111	Update Technical Assurance Report	10 days	Tue 24/11/15	Mon 07/12/15
112	Obtain Stage 3 Internal Approval	9 days	Tue 08/12/15	Fri 18/12/15
113	Publish Element 1 & 2 Stage 3 Committee Approval Document	1 day	Mon 21/12/15	Mon 21/12/15
114				
115	**Project Element 3 - Robotic Visual & Non-Visual Inspection**	**511 days?**	**Mon 06/01/14**	**Mon 21/12/15**
116	**Task 1 - Research Sensor Requirements & Capabilities**	**155 days**	**Mon 06/01/14**	**Fri 08/08/14**
117	Develop Sensor Specifications and Data Requirements	20 days	Mon 06/01/14	Fri 31/01/14
118	Interim Report on Sensor Research	0 days	Fri 14/03/14	Fri 14/03/14
119	Research Existing Technology and Generate Report (w/Sensor Recommendations)	80 days	Mon 03/02/14	Fri 23/05/14
120	Approval from SGN to Proceed With Sensor Selected	15 days	Mon 26/05/14	Fri 13/06/14
121	SDRC 9.3 - Source Vendor for Sensor	20 days	Mon 02/06/14	Fri 27/06/14
122	Engagement with HSE	1 day	Mon 16/06/14	Mon 16/06/14
123	Sensor Module Specification Document Development	30 days	Mon 30/06/14	Fri 08/08/14
124	**Electrical Specification Document Development**	**30 days**	**Mon 30/06/14**	**Fri 08/08/14**
125	Establish detailed specifications of scenarios for use of systems on Gas Network	5 days	Mon 30/06/14	Fri 04/07/14
126	Match Network Specifications to Robotic high Level design requirements	10 days	Mon 07/07/14	Fri 18/07/14
127	SGN confirm with ULCR specification match	5 days	Mon 21/07/14	Fri 25/07/14
128	Obtain Stage 1 approval for scenario specifications	9 days	Mon 28/07/14	Thu 07/08/14
129	Publish Element 3 Electrical Stage 1 Scenario Specification Approval Certificate	1 day	Fri 08/08/14	Fri 08/08/14
130	**Mechanical Specification Document Development**	**30 days**	**Mon 30/06/14**	**Fri 08/08/14**
131	Establish detailed specifications of scenarios for use of systems on Gas Network	5 days	Mon 30/06/14	Fri 04/07/14
132	Match Network Specifications to Robotic high Level design requirements	10 days	Mon 07/07/14	Fri 18/07/14
133	SGN confirm with ULCR specification match	5 days	Mon 21/07/14	Fri 25/07/14
134	Obtain Stage 1 approval for scenario specifications	9 days	Mon 28/07/14	Thu 07/08/14
135	Publish Element 3 Mechanical Stage 1 Scenario Specification Approval Certificate	1 day	Fri 08/08/14	Fri 08/08/14
136	**Task 2 - Design Sensor Module Electronics**	**255 days**	**Mon 30/06/14**	**Fri 19/06/15**
137	Electrical and Software System Block Diagram Development	10 days	Mon 14/07/14	Fri 25/07/14
138	Initial Electrical Schematic Design and Parts Selection	100 days	Mon 28/07/14	Fri 12/12/14
139	Circuit Card Layout and Fabrication	20 days	Mon 03/11/14	Fri 28/11/14
140	Microprocessor Firmware Programming	60 days	Mon 01/12/14	Fri 20/02/15
141	User Interface and Control System Design and Programming	60 days	Mon 26/01/15	Fri 17/04/15
142	Procurement & Testing of Sensor Package	160 days	Mon 30/06/14	Fri 06/02/15
143	Develop, Procure, and Test Data Acquisition System	100 days	Mon 01/12/14	Fri 17/04/15
144	Design and Procure Tether	80 days	Mon 17/11/14	Fri 06/03/15
145	Integrate and Test Tether With Sensor/Data Acquisition System	40 days	Mon 20/04/15	Fri 12/06/15
146	Bench Testing of Electrical System	30 days	Mon 20/04/15	Fri 29/05/15
147	Integration Of Electrical System & Sensor into Modular Package for Deployment	15 days	Mon 01/06/15	Fri 19/06/15
148	**Task 3 - Design Sensor Module Hardware**	**205 days**	**Mon 14/07/14**	**Fri 24/04/15**
149	Development of Conceptual Designs	15 days	Mon 14/07/14	Fri 01/08/14
150	Initial 3D Design of Mechanical Components	80 days	Mon 04/08/14	Fri 21/11/14
151	Creation of Detailed Fabrication and Manufacturing Documentation	30 days	Mon 24/11/14	Fri 02/01/15
152	Initial Parts Fabrication and Assembly	80 days	Mon 05/01/15	Fri 24/04/15
153	**Task 4 - Off Site Testing & Modifications**	**100 days**	**Mon 11/05/15**	**Fri 25/09/15**
154	Fabricate Mock Test Environment at ULC Shop	30 days	Mon 11/05/15	Fri 19/06/15
155	SDRC 9.4 - Configuration Testing with Robotic Platform	10 days	Mon 22/06/15	Fri 03/07/15
156	Sensor Data Validation	30 days	Mon 22/06/15	Fri 31/07/15
157	Incorporate Improvements Discovered During Testing	40 days	Mon 03/08/15	Fri 25/09/15
158	Develop Test Plan for the Field	5 days	Mon 03/08/15	Fri 07/08/15
159	HSE Engagement	1 day	Mon 03/08/15	Mon 03/08/15
160	**Task 5 - Field Testing - (Concurrent with Element 1&2 Field Test)**	**231 days?**	**Mon 02/02/15**	**Mon 21/12/15**
161	**Site Selection and Planning**	**30 days**	**Mon 02/02/15**	**Fri 13/03/15**
162	Identify Potential live mains suitable for trial on SGN network	10 days	Mon 02/02/15	Fri 13/02/15
163	Network Analysis/Mains Replacement Design/Contingency Planning	10 days	Mon 16/02/15	Fri 27/02/15
164	Highways Authority liaison and road opening notices	10 days	Mon 02/03/15	Fri 13/03/15



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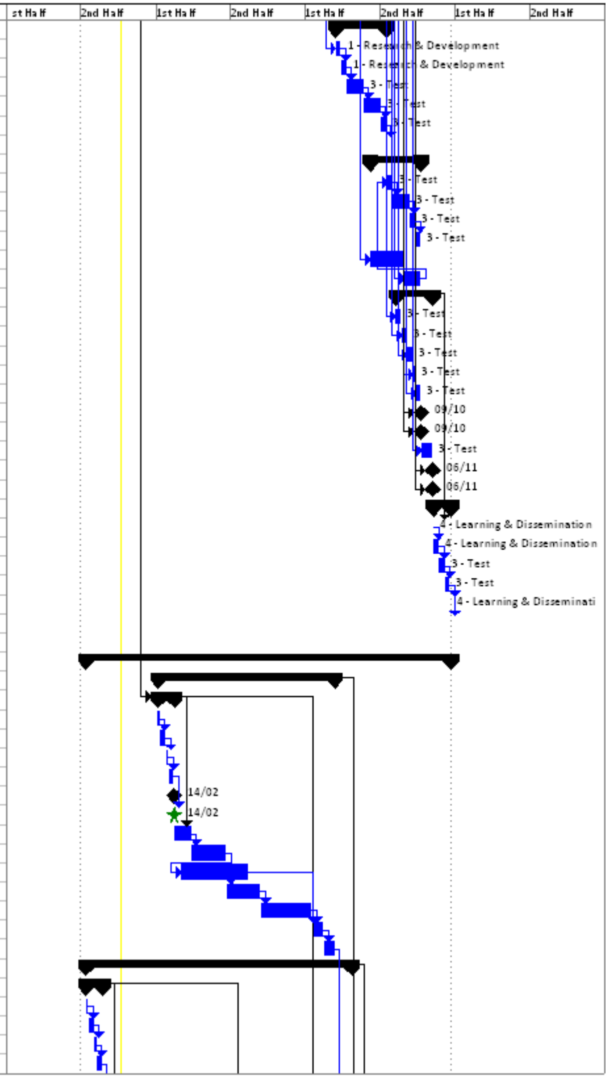
ID	Task Name	Duration	Start	Finish
165	**Complete Technical Assurance Statement and Risk Assessment**	**90 days**	**Mon 16/03/15**	**Fri 17/07/15**
166	Establish and approve G/23 Field Trial requirements	10 days	Mon 16/03/15	Fri 27/03/15
167	Hazard and Risk Analysis of Network mains by Asset Management	10 days	Mon 30/03/15	Fri 10/04/15
168	Electrical safety and Compliance	30 days	Mon 13/04/15	Fri 22/05/15
169	Site Management and CDM Requirements	30 days	Mon 25/05/15	Fri 03/07/15
170	Obtain Stage 2 approval for Technical Assurance	9 days	Mon 06/07/15	Thu 16/07/15
171	Publish Element 3 Stage 2 Technical Assurance Approval Certificate	1 day	Fri 17/07/15	Fri 17/07/15
172	**Pre Site Preparation**	**90 days**	**Mon 08/06/15**	**Fri 09/10/15**
173	Site specific risk assessment	10 days	Mon 20/07/15	Fri 31/07/15
174	Drilling and Assessment of Network Impact	30 days	Mon 03/08/15	Fri 11/09/15
175	Design Anchorage for launch tube / site specific civils	10 days	Mon 14/09/15	Fri 25/09/15
176	Prepare excavations in accordance with SGN's SMF/traffic management procedures	10 days	Mon 28/09/15	Fri 09/10/15
177	Procure Spares and Materials for Field Testing	60 days	Mon 08/06/15	Fri 28/08/15
178	Pack and Ship System to the UK	30 days	Mon 31/08/15	Fri 09/10/15
179	*Perform 20 days Field Testing*	**65 days**	**Mon 10/08/15**	**Fri 06/11/15**
180	Prepare and authorise NRO's and PTW's under SCO	10 days	Mon 10/08/15	Fri 21/08/15
181	CDM Site Management	10 days	Mon 24/08/15	Fri 04/09/15
182	Prepare drillings for pre-deployment inspection / specialist contractor	10 days	Mon 07/09/15	Fri 18/09/15
183	Carry out pre-deployment inspection using CCTV	5 days	Mon 21/09/15	Fri 25/09/15
184	Prepare drillings / specialist contractors	10 days	Mon 28/09/15	Fri 09/10/15
185	Mount Launch Tube on Valve at Site	0 days	Fri 09/10/15	Fri 09/10/15
186	*SDRC 9.7 - Launch Robot*	0 days	Fri 09/10/15	Fri 09/10/15
187	Support deployment of robotic solution	20 days	Mon 12/10/15	Fri 06/11/15
188	Retrieve Robot	0 days	Fri 06/11/15	Fri 06/11/15
189	Reinstate	0 days	Fri 06/11/15	Fri 06/11/15
190	**Generate Final Report**	**31 days?**	**Mon 09/11/15**	**Mon 21/12/15**
191	Report on Field Trial against Success Criteria	1 day?	Mon 09/11/15	Mon 09/11/15
192	*ULCR generate final report*	10 days	Tue 10/11/15	Mon 23/11/15
193	Update Technical Assurance Report	10 days	Tue 24/11/15	Mon 07/12/15
194	Obtain Stage 3 Internal Approval	9 days	Tue 08/12/15	Fri 18/12/15
195	Publish Element 3 Stage 3 Committee Approval Document	1 day	Mon 21/12/15	Mon 21/12/15
196	HSE Engagament	1 day	Mon 21/12/15	Mon 21/12/15
197				
198	**Project Element 4 - Live Asset Replacement**	**636 days?**	**Mon 15/07/13**	**Mon 21/12/15**
199	**Task 1 - Robot Body Development**	**310 days**	**Mon 06/01/14**	**Fri 13/03/15**
200	**Mechanical Specification Document Development**	**30 days**	**Mon 06/01/14**	**Fri 14/02/14**
201	Establish detailed specifications of scenarios for use of systems on Gas Network	5 days	Mon 06/01/14	Fri 10/01/14
202	Match Network Specifications to Robotic high Level design requirements	10 days	Mon 13/01/14	Fri 24/01/14
203	SGN confirm with ULCR specification match	5 days	Mon 27/01/14	Fri 31/01/14
204	Obtain Stage 1 approval for scenario specifications	9 days	Mon 03/02/14	Thu 13/02/14
205	*Delivery of High Level, Preliminary Specification Document By ULC To SGN*	0 days	Fri 14/02/14	Fri 14/02/14
206	Publish Element 4 Mechanical Stage 1 Scenario Specification Approval Certificate	1 day	Fri 14/02/14	Fri 14/02/14
207	***SDRC 9.2 - Development of Conceptual Designs***	30 days	Mon 17/02/14	Fri 28/03/14
208	*Initial 3D Design of Mechanical Components*	*60 days*	*Mon 31/03/14*	*Fri 20/06/14*
209	*Selection and Procurement of Motors, Gears and Bearings*	120 days	Mon 03/03/14	Fri 15/08/14
210	*Creation of Detailed Fabrication and Manufacturing Documentation*	60 days	Mon 23/06/14	Fri 12/09/14
211	*Initial Parts Fabrication*	90 days	Mon 15/09/14	Fri 16/01/15
212	*Robot Assembly*	20 days	Mon 19/01/15	Fri 13/02/15
213	***Robot Preliminary Functional Test***	20 days	Mon 16/02/15	Fri 13/03/15
214	**Task 2 - Develop Support & Control System**	**465 days**	**Mon 15/07/13**	**Fri 24/04/15**
215	**Electrical Specification Document Development**	**30 days**	**Mon 15/07/13**	**Fri 23/08/13**
216	Establish detailed specifications of scenarios for use of systems on Gas Network	5 days	Mon 15/07/13	Fri 19/07/13
217	Match Network Specifications to Robotic high Level design requirements	10 days	Mon 22/07/13	Fri 02/08/13
218	SGN confirm with ULCR specification match	5 days	Mon 05/08/13	Fri 09/08/13
219	Obtain Stage 1 approval for scenario specifications	9 days	Mon 12/08/13	Thu 22/08/13



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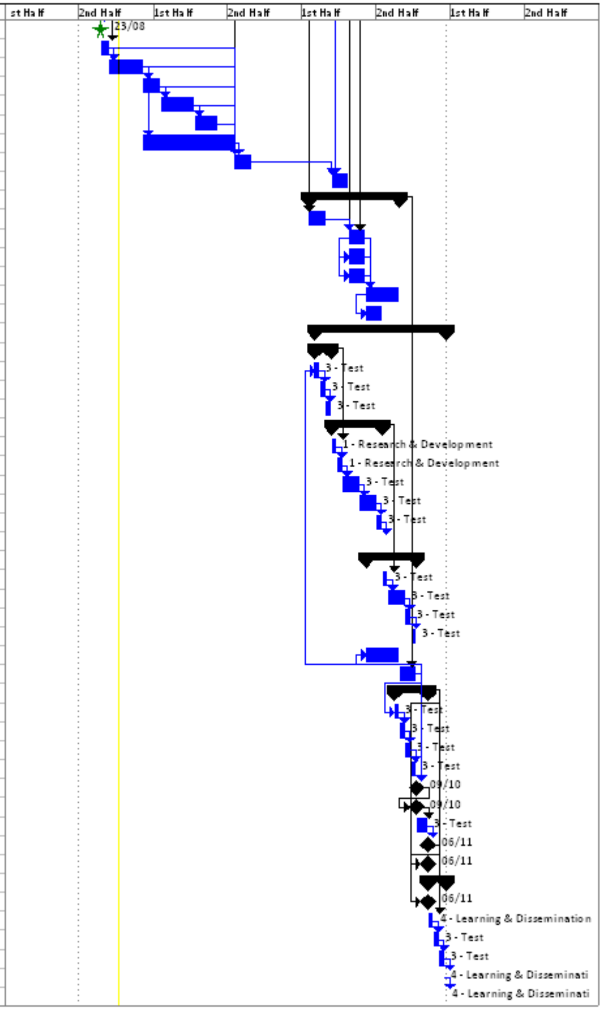
ID	Task Name	Duration	Start	Finish
220	Publish Element 4 Mechanical Stage 1 Scenario Specification Approval Certificate	1 day	Fri 23/08/13	Fri 23/08/13
221	Electrical and Software System Block Diagram Development	15 days	Mon 26/08/13	Fri 13/09/13
222	*Initial Electrical Schematic Design and Parts Selection*	*60 days*	*Mon 16/09/13*	*Fri 06/12/13*
223	*Circuit Card Layout and Fabrication*	30 days	Mon 09/12/13	Fri 17/01/14
224	*Microprocessor Firmware Programming*	60 days	Mon 20/01/14	Fri 11/04/14
225	*User Interface and Control System Design and Programming*	40 days	Mon 14/04/14	Fri 06/06/14
226	Tether Design and Procurement	160 days	Mon 09/12/13	Fri 18/07/14
227	Bench Testing of Electrical System	30 days	Mon 21/07/14	Fri 29/08/14
228	*Integration Of Electrical System into Mechanical Prototype*	30 days	Mon 16/03/15	Fri 24/04/15
229	**Task 3 - Off Site Testing**	**160 days**	**Mon 19/01/15**	**Fri 28/08/15**
230	Fabricate Mock Test Environment at ULC Shop	30 days	Mon 19/01/15	Fri 27/02/15
231	*Pipeline Travel Testing*	30 days	Mon 27/04/15	Fri 05/06/15
232	*SDRC 9.5 - Tapping & Fitting Tool Validation*	30 days	Mon 27/04/15	Fri 05/06/15
233	*Service Installation Validation*	30 days	Mon 27/04/15	Fri 05/06/15
234	*Incorporate Improvements Discovered During Testing*	60 days	Mon 08/06/15	Fri 28/08/15
235	*Develop Test Plan for the Field*	30 days	Mon 08/06/15	Fri 17/07/15
236	**Task 4 - Field Testing**	**231 days?**	**Mon 02/02/15**	**Mon 21/12/15**
237	**Site Selection and Planning**	**30 days**	**Mon 02/02/15**	**Fri 13/03/15**
238	Identify Potential live mains suitable for trial on SGN network	10 days	Mon 02/02/15	Fri 13/02/15
239	Network Analysis/Mains Replacement Design/Contingency Planning	10 days	Mon 16/02/15	Fri 27/02/15
240	Highways Authority liaison and road opening notices	10 days	Mon 02/03/15	Fri 13/03/15
241	**Complete Technical Assurance Statement and Risk Assessment**	**90 days**	**Mon 16/03/15**	**Fri 17/07/15**
242	Establish and approve G/23 Field Trial requirements	10 days	Mon 16/03/15	Fri 27/03/15
243	Hazard and Risk Analysis of Network mains by Asset Management	10 days	Mon 30/03/15	Fri 10/04/15
244	Electrical safety and Compliance	30 days	Mon 13/04/15	Fri 22/05/15
245	Site Management and CDM Requirements	30 days	Mon 25/05/15	Fri 03/07/15
246	Obtain Stage 2 approval for Technical Assurance	9 days	Mon 06/07/15	Thu 16/07/15
247	Publish Element 4 Stage 2 Technical Assurance Approval Certificate	1 day	Fri 17/07/15	Fri 17/07/15
248	**Pre Site Preparation**	**90 days**	**Mon 08/06/15**	**Fri 09/10/15**
249	Site specific risk assessment	10 days	Mon 20/07/15	Fri 31/07/15
250	Drilling and Assessment of Network Impact	30 days	Mon 03/08/15	Fri 11/09/15
251	Design Anchorage for launch tube / site specific civils	10 days	Mon 14/09/15	Fri 25/09/15
252	Prepare excavations in accordance with SGN's SMF/traffic management procedures	10 days	Mon 28/09/15	Fri 09/10/15
253	Procure Spares and Materials for Field Testing	60 days	Mon 08/06/15	Fri 28/08/15
254	Pack and Ship System to the UK	30 days	Mon 31/08/15	Fri 09/10/15
255	*Perform 20 Days of Field Testing*	**60 days**	**Mon 17/08/15**	**Fri 06/11/15**
256	Prepare and authorise NRO's and PTW's under SCO	10 days	Mon 17/08/15	Fri 28/08/15
257	CDM Site Management	10 days	Mon 31/08/15	Fri 11/09/15
258	Prepare drillings for pre-deployment inspection / specialist contractor	10 days	Mon 14/09/15	Fri 25/09/15
259	Prepare drillings / specialist contractors	10 days	Mon 28/09/15	Fri 09/10/15
260	Mount Launch Tube on Valve at Site	0 days	Fri 09/10/15	Fri 09/10/15
261	*SDRC 9.8 - Launch Robot*	0 days	Fri 09/10/15	Fri 09/10/15
262	Support deployment of robotic solution	20 days	Mon 12/10/15	Fri 06/11/15
263	Retrieve Robot	0 days	Fri 06/11/15	Fri 06/11/15
264	Reinstate	0 days	Fri 06/11/15	Fri 06/11/15
265	**Generate Final Report**	**31 days?**	**Fri 06/11/15**	**Mon 21/12/15**
266	Report on Field Trial against Success Criteria	0 days	Fri 06/11/15	Fri 06/11/15
267	*ULCR generate final report*	10 days	Mon 09/11/15	Fri 20/11/15
268	Update Technical Assurance Report	10 days	Mon 23/11/15	Fri 04/12/15
269	Obtain Stage 3 Internal Approval	9 days	Mon 07/12/15	Thu 17/12/15
270	Publish Project Reporting Timetable Document	1 day	Fri 18/12/15	Fri 18/12/15
271	Publish Element 4 Stage 3 Committee Approval Document	1 day?	Mon 21/12/15	Mon 21/12/15



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Appendix I – Go /No Go Stage Gates, Pay ment Milestones, and cost breakdown, linked to technical outputs

Table 7 shows the projects proposed go/no-go stage gates for each element of the project. Technical descriptions of what should be completed for each go/no go stage gates are detailed below:

Table 7 – Go/No Go Stage Gates

Stage Gate	Element	Go / No-Go Stage Gates	End Date
1	Element 1 & 2	Development of Conceptual Designs	28/03/14
2	Element 1 & 2	Robotic Platform and Joint Repair Module Preliminary Functional Test	13/03/15
3	Element 1 & 2	Launch System Testing	24/04/15
4	Element 1 & 2	Robotic Platform Launch, Retrieval and Travel Testing	05/06/15
5	Element 1 & 2	Seal Repair Tool Testing	05/06/15
6	Element 1 & 2	Launch Robot	09/10/15
Stage Gate	**Element**	**Go / No-Go Stage Gates**	**End Date**
7	Element 3	Source Vendor for Sensor	27/06/14
8	Element 3	Procurement and Testing of Sensor Package	06/02/15
9	Element 3	Integrate and Test Tether With Sensor/Data Acquisition System	12/06/15
10	Element 3	Configuration Testing with Robotic Platform	03/07/15
11	Element 3	Sensor Data Validation	31/07/15
12	Element 3	Launch Robot	09/10/15
Stage Gate	**Element**	**Go / No-Go Stage Gates**	**End Date**
13	Element 4	Development of Conceptual Designs	28/03/14
14	Element 4	Robot Preliminary Functional Test	13/03/15
15	Element 4	Pipeline Travel Testing	05/06/15
16	Element 4	Tapping & Fitting Tool Validation	05/06/15
17	Element 4	Service Installation Validation	05/06/15
18	Element 4	Launch Robot	09/10/15

Those stage gates that are not SDRC outputs and included in Section 9 are detailed below:

Stage Gate 2 - Element 1 & 2 - Robotic Platform and Joint Repair Module Preliminary Functional Test (13/03/15)

1. The assembled robotic platform will have been bench tested at ULC Robotics research and development workshop. Each component of the robot, including drive systems, repair tools, electronics and pneumatic components will be tested individually to ensure that all systems function as designed. A test plan will have been developed to test the capabilities outlined in the agreed-upon mechanical specification documents. A bench model of the electronics system will have been constructed to test and control each component. Components will have been be tested in isolation or as a whole, with a focus on ensuring the system performs as planned. The system will have been powered on and monitored with a prototype of an operator's control panel. Minor modifications may be necessary as testing progresses to troubleshoot emergent problems.
2. A report detailing the components tested, the tests performed, and the results of those tests will have been delivered by ULC Robotics to SGN.
3. SGN will review against the high level performance specification criteria (for example speed and maneuverability). If any component is not functioning as planned, the report will outline the problems with that component and offer a path forward for further testing or redesign, including estimated hours to resolve the problem.
4. Following the conclusion and recommendations of the report, SGN will make a decision on whether to progress.

Stage Gate 3 - Element 1 & 2 - Launch System Testing (24/04/15)

1. The launch tube will have been assembled and tested at ULC Robotics research and development workshop to meet SGN's performance specification (this will include for example, the weight tolerances, support requirements, compatibility with GB flange fittings). The design of the launch tube will have been driven by the operational requirements of the robotic system and pipe fitting, considerations of the overall size of the robotic system, and with the aim of minimizing pit size to reduce the amount of excavation and disruption required.
2. A test pipe will have been configured for testing. It is anticipated than the test pipe will have been an actual decommissioned main representative of the pipes the robot will be designed to travel in.
3. The launch tube and valve will have been fitted on to the pipe. Valves, fittings, and any adaptor plates necessary to connect the launch tube to the pipe will have been procured in coordination with SGN. A tapping and fitting procedure to install the fittings will have been developed. All mechanical and electrical controls of the launch tube required to insert the robot into the pipe will have been tested. A typical launching procedure will have been developed and trialed to ensure all components are functioning as planned. All necessary components will have been pressure tested to ensure they are gas-tight.
4. ULC Robotics will have completed a testing report documenting the assembly and testing of the launch tube; this report will have been delivered to SGN. If any

problems are identified during testing, ULC Robotics will make recommendations for any engineering work needed to solve the problem.

5. SGN will review against the performance specification and determine whether this project can progress to the next stage.

Stage Gate 4 - Element 1 & 2 - Robotic Platform Launch, Retrieval and Travel Testing (05/06/15)

1. The assembled robotic platform will have been inserted into the launch tube and tested in the test pipe at ULC Robotics.
2. The tethered robot will have been launched and retrieved a number of times to ensure that there are no issues inserting the robot into the main. The robot will travel inside the test pipe to ensure that the mechanical, electrical and pneumatic components used to drive the robot are functioning properly. Video and sensor data will have been monitored to ensure data can be collected in the pipe as planned. The full range of motion will have been tested to ensure that the robot can maneuver as designed. The integration of the robot with the launch tube will have been assessed and any improvements required will be noted. The placement and orientation of video cameras and lights will have been assessed to provide the best possible visual inspection of the pipe.
3. The system will have been monitored and controlled by ULC Robotics experienced robot operators. ULC Robotics experience with pipeline robotics will have been drawn upon to assess the performance of the robot during in-pipe testing. Any operational issues will be noted and suggestions for improvements will be made as applicable. It is anticipated that some improvements or required modifications will be identified in testing; time has been allocated in the project plan to make those improvements.
4. ULC Robotics will have delivered a report summarising the results of this testing to SGN.
5. SGN will review against the performance specification; this will include for example, how the use of an electrical device within a gas main will be managed.
6. At this point SGN will have made a decision on whether to progress to the next stage.

Stage Gate 5 - Element 1 & 2 - Seal Repair Tool Testing (05/06/15)

1. ULC Robotics will have tested the seal repair tool in the test pipe. The test pipe fixture will have included several mechanical joints and Weco seals that would be representative of conditions found in the field.
2. The robot will have been deployed in the test pipe and the tool will have been used to perform repairs on both Weco seals and mechanical joints. ULC Robotics experienced robot operators and engineers will have performed the repairs using the robot’s remote control system.

3. A variety of different operational approaches will have been tested, depending on the type of repair mechanism selected, to determine the most effective method for performing the repair. Soap testing and pressure testing will have been performed on the joint or seal before and after the repair. The initial test will have provided a point of reference to determine how effective the sealing procedure was. If multiple techniques have been tested for sealing, pressure tests will have been used to guide selection of the most effective method. The outcome of the repair tool testing will have been a proven method of Weco seal and mechanical joint internal robotic repair which will have been proven to be comprarably effective to external sealing and encapsulation.
4. ULC Robotics will have provided a report on the tests to SGN, detailing performance against the off site success criteria identified previously. It is anticipated that some improvements or required modifications will be identified in testing; time has been allocated in the project plan to make those improvements. If there are any difficulties performing the seal repair, ULC Robotics will make recommendations for any engineering work needed to solve the problem.
5. SGN determine whether to proceed.

Stage Gate 8 - Element 3 - Procurement and Testing of Sensor Package (06/02/15)

1. The sensor package will have been evaluated at ULC Robotics research and development workshop on the workbench with material samples and in the test pipe to assess its effectiveness.
2. The sensor will have been utilised on test pipe samples to determine if it was capable of obtaining reliable data. Testing will have focused on ensuring that the sensor performs as planned under real-world conditions as well as in the laboratory. It is anticipated that some improvements or required modifications will have been identified in testing. Any form factor, performance, or operational concerns will have been noted, and ULC Robotics will have worked closely with the sensor vendor to troubleshoot any emergent issues.
3. ULC Robotics will provide SGN with a report outlining the tests performed and the results of those tests, including reliability, issues affecting performance, and precision and accuracy of data. The report will have indicated ULC Robotics opinion of the sensor technology and its suitability to provide pipeline integrity data.
4. SGN will confirm suitability of the sensor technology outputs as an indicator of pipe condition that can inform pipe risk. This will include an independent assessment by one of SGN's technical service providers. If testing does not produce reliable results as planned, further work with the sensor manufacturer or selection of an alternate manufacturer will need to take place to refine the tools.
5. If no suitable sensor technology is identified that has the potential to inform pipe risk, following the SGN and independent assessment, this element of the project will be terminated.
6. If SGN deem that satisfactory sensor technology has been identified, this project will progress.

Stage Gate 9 - Element 3 - Integrate and Test Tether with Sensor/Data Acquisition System (12/06/15)

1. The tether will have been connected to the sensor tool to provide a means of remotely testing the device. The tether will have been designed to provide a lightweight, robust, and manoeuvrable means of providing power, control, and data connections to the robot.
2. These tests will have ensured that the tether is functional and can reliably transmit data over its full length. It is anticipated that the tether will be deployed on a reel, the tether will have been tested on the reel to ensure it functions as designed when coiled as well as when uncoiled.
3. Data will have been acquired and compared to the known defects in the pipe test sections.
4. Any inaccuracies or errors in data transmitted via the tether will have been noted as items that required modification and improvement. Any mechanical issues that affect the deployment of the tether will have been noted and addressed.
5. ULC Robotics will have provided a report to SGN summarising the results of the tether testing and detailing any engineering work required to solve problems identified in testing. In the event that the tether cannot reliably function at its intended length, ULC Robotics will have performed further testing to determine the maximum operational distance of the tether and will have provided this information in the report.
6. Provided the tether is functional and can reliably transmit data over its full length then the project will progress.

Stage Gate 11 - Element 3 - Sensor Data Validation (31/07/15)

1. The sensor will have been tested on pipes and material samples with known values of wall loss or other defects that SGN would be interested in measuring as part of a pipe integrity assessment. Testing will have been used to determine the accuracy, reliability, and repeatability of the measurements.
2. Testing will have been performed under a variety of conditions to determine if there is any variability in measurements or if there are any environmental issues that affect performance. A calibration procedure may be developed to use as a reference point for the robot.
3. ULC Robotics will have provided SGN with a report summarising the findings of these tests. If there are any issues with data validation, ULC Robotics will have worked with the sensor manufacturer to determine a path forward. This report will have compared known defects to sensor measurements, quantifying the accuracy of the sensor measurement
4. SGN will have confirmed the suitability of the sensor technology outputs as an indicator of pipe condition that can inform pipe risk. This will include an independent assessment by one of SGN's technical service providers. At this point a decision will have been made on whether to progress the project.

Stage Gate 14 - Element 4 - Robot Preliminary Functional Test (13/03/15)

1. The assembled robot will have been tested at ULC Robotics research and development workshop.
2. Each component of the robot, including drive systems, service replacement tools, and pneumatic components will have been tested individually to ensure everything is working as designed. A test plan will have been developed to test the capabilities outlined in the agreed-upon mechanical specification documents. A bench model of the electronics system will have been constructed to test and control each component. Components will have been tested in isolation or as a whole, with a focus on ensuring the system will perform as planned. The system will have been powered on and monitored with a prototype of an operator's control panel. Minor modifications may be necessary as testing progresses to troubleshoot any emergent problems.
3. A report detailing the components that were tested, the tests performed, and the results of those tests will have been delivered by ULC to SGN. If any component is not functioning as planned, the report will outline the problems with that component and offer a path forward for further testing or redesign.
4. SGN will have made a decision on whether the testing delivered the proposed outputs before moving to the next stage.

Stage Gate 15 - Element 4 - Pipeline Travel Testing (05/06/15)

1. The assembled robot will have been inserted into the test pipe and tested at ULC.A mockup main including an inserted PE pipe with multiple service connections will have been constructed for testing.
2. The robot has been inserted and retrieved several times to ensure that there are no issues inserting the robot into the test pipe or annular space.
3. The robot will have travelled inside the test pipe to ensure that the mechanical components used to drive the robot are functioning properly. The full range of motion will have been tested to ensure that the robot can manoeuvre as planned. A means of precisely locating the service location and positioning the tools for tapping and fitting will have been developed and tested. Improvements to this method discovered during testing will have been incorporated with a goal of delivering accurate, field-ready locating methods.
4. ULC Robotics experienced robot operators will monitor and control the system. Any operational issues will have been noted and suggestions for improvements will have been made as applicable.
5. It is anticipated that some improvements or required modifications will have been identified during testing; time has been allocated in the project plan to make those improvements.
6. ULC Robotics will deliver a report summarising the results of this testing to SGN. If any problems are identified during testing, ULC Robotics will make recommendations for engineering work needed to solve the problem.
7. Provided the testing is completed effectively, the project will progress.

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Stage Gate 17 - Element 4 - Service Installation Validation (05/06/15)

1. The services installed by the robot on the test pipe will have been pressure tested using the robot to ensure their integrity. Notes taken by the operator and recorded video footage of the service installation will have been used to identify any issues or difficulties when the services were installed which might affect the integrity of the service connection.
2. The same standards used by UK gas networks to pressure test new services will have been applied to ensure the robotically-installed services meet all requirements.
3. If any of the services do not meet the requirements, improvements will have to be made to the tool or the process and the robot will be tested again. The process will have been refined and a detailed report will have been delivered which demonstrates how improvements have been incorporated to produce a field-ready process.
4. ULC Robotics will deliver the results of testing to SGN, who will carry out a review. This will include and independent review by one of SGN's technical service provider.
5. SGN will decide whether to proceed to the next stage.

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Appendix J – Knowledge Dissemination Plan

Table 14 - External Dissemination

Who	What	How	When
Ofgem	- Project data - Test results - Project progress	- Progress reports - Publish information on Ofgem portal - Update meetings - NIC Conference - SGN Website	- Progress report every 6 months - Comprehensive learning report after project completion - Regular updates Ofgem portal - NIC Conference dates tbc
HSE	- Project data - Sensor technology - Fit for purpose potential	- Update meetings - Progress reports - Offered technical visits	- Engagement with HSE at critical points in the project (as defined in the project plan) and as part of regular engagement
Gas Transporters	- Interested in all aspects of project learning	- NIC Conference - SGN Website - Technical visits x 3 - free 300m demo	- Regular updates on SGN website - NIC Conference dates tbc - Technical visits TBC - to be agreed with GDN's upon project completion
IGEM	- Interested in all aspects of project learning	- NIC Conference - SGN Website - Journal Paper - Paper evening presentation - IGEM Magazine article - Technical site visits	- Presentation at IGEM conference in 2014 - Results of Project to be published in IGEM magazine at end of project - Technical visit to be offered in 2014 to Young persons network
Pipeline Industries Guild	- Implications for gas production - Learning relating to transmission and distribution	- NIC Conference - SGN Website	- Regular updates on SGN website - NIC Conference dates tbc
Local Customers	- Project progress - Outcome of Project	- Twitter - Facebook - YouTube - Pamphlets	- Progress updates to be uploaded to Twitter and Facebook at regular intervals - Youtube video to be uploaded prior to start of Project - Information pamphlets will be used before and after Project to share knowledge with customers
Local and National Press	- Project success (if successful)	- Press release	- Upon any successful outcomes - You tube video for SGN website

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Table 15 - Internal Dissemination

Who	What	How	When
SGN Board of Directors	- Project outline - Project results	- Presentations to the Board - SGN Annual Report	- Presentations at the start and completion of the Project - Project outline to be submitted in 2014 Annual Report
SGN Executive	- Project outline - Project progress - Project results	- Presentation to the Executive Committee - SGN Annual Report - Progress reports - Site visits	- Presentation at the start and completion of the Project - Project outline to be submitted in 2014 Annual Report - Progress updates to be given monthly by Project Director - Site visits to be offered throughout Project
SGN Investment Committee	- Project proposal financial tracking and reporting	- Agenda item	- Monthly update
SGN Innovation Board	- Project results - Change to operating procedures	- Bi monthly project progress - Briefing notes - Presentations	- Briefing notes to be issued before start of the testing programme - Presentations throughout the Project
SGN Operational Managers	- Project results - Change to operating procedures	- Briefing notes - Presentation at Operations Committees	- Briefing notes to be issued before start of the testing programme - Presentations at the start and completion of the Project
SGN Employees	- Project results - Change to operating procedures	- Team talks - Briefing notes - Engineering Bulletins	- Team talks at key stages of the Project - Briefing notes / engineering bulletins to be issued whenever deemed necessary
All other SGN Employees	- Project outline - Project results	- SGN Mail (internal magazine) - SGNnet (intranet site)	- At the start, regular updates to the intranet and completion of the Project

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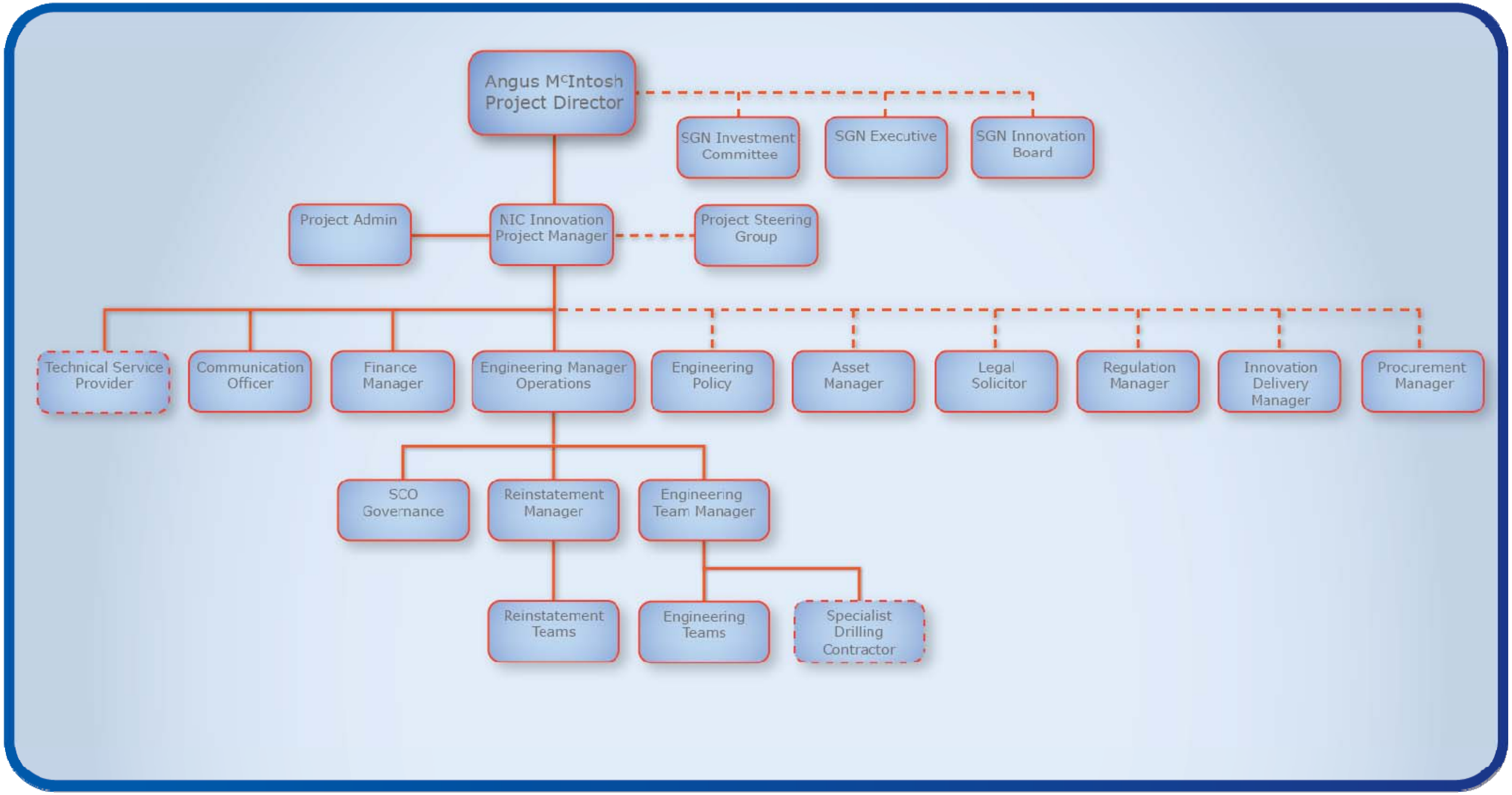
Appendix K – Project Team Organograms



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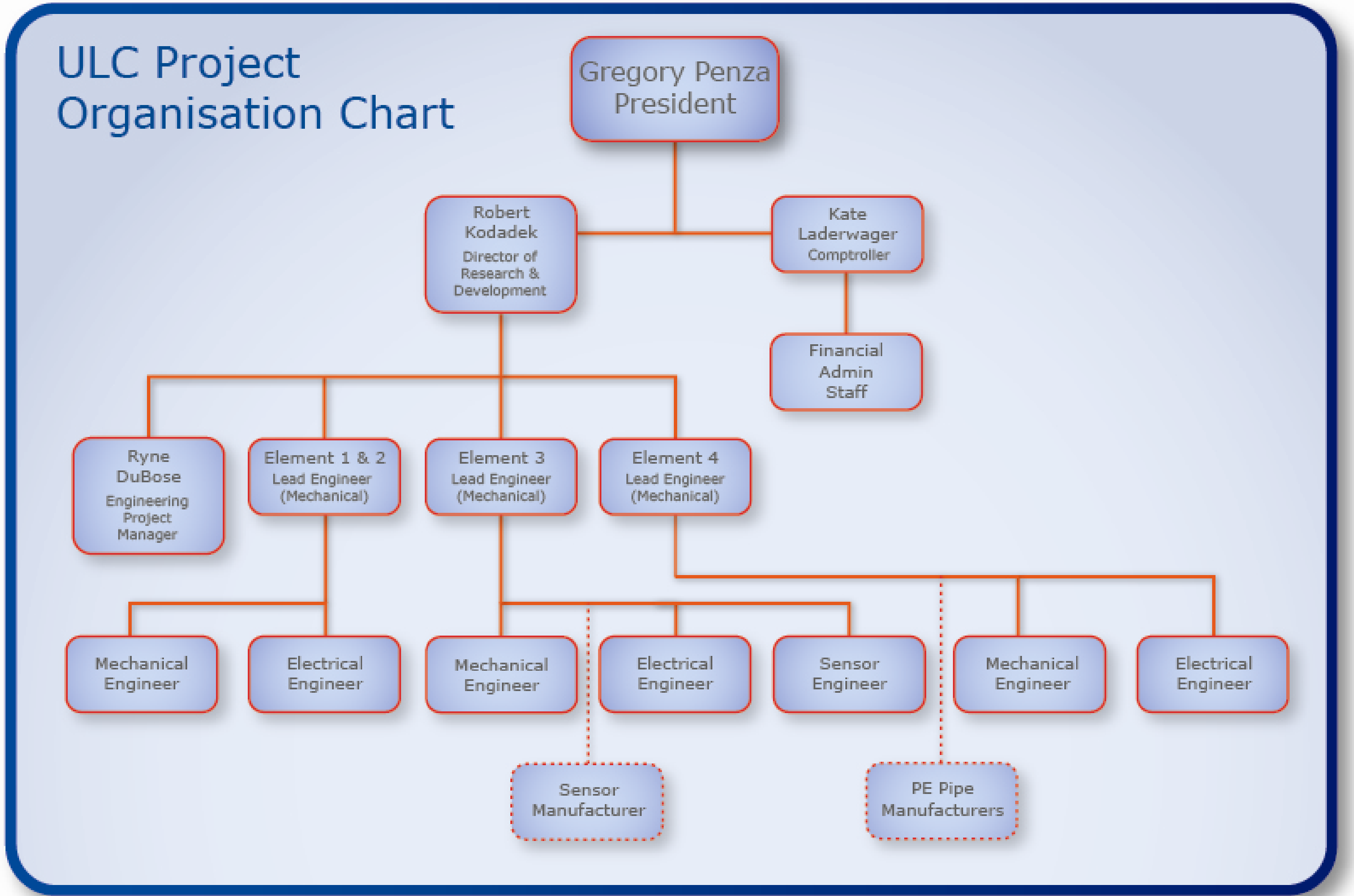

ULC Project Organisation Chart
Gregory Penza President
Robert Kodadek Director of Research & Development
Kate Laderwager Comptroller
Financial Admin Staff
Ryne DuBose Engineering Project Manager
Element 1 & 2 Lead Engineer (Mechanical)
Element 3 Lead Engineer (Mechanical)
Element 4 Lead Engineer (Mechanical)
Mechanical Engineer
Electrical Engineer
Mechanical Engineer
Electrical Engineer
Sensor Engineer
Mechanical Engineer
Electrical Engineer
Sensor Manufacturer
PE Pipe Manufacturers

[redacted]

Project Code/Version No:
SGN_GN_01/v1

Gas Network Innovation Competition Full Submission Pro-forma

Appendix M – Typical Stakeholder Communication Examples