JUNE 2015

Project GRAID Progress Report

Gas Robotic Agile Inspection Device

Gas Network Innovation Competition

1 Introduction

Project GRAID is developing innovative technology to inspect complex gas transmission underground pipework at high pressure installations.

National Grid Gas Transmission (NGGT) and its partner organisations are engaged in an exciting project that is addressing the issue of how to inspect the complex, below-ground pipework found at High Pressure Installations. The project is developing ground-breaking technology to provide the world's first robotic platform that will be able to provide real-time data on the condition of high pressure underground assets.

National Grid is collaborating with three British Small Medium Enterprises (SMEs) to develop ways to accurately assess the condition of its pipework assets that cannot currently be inspected via conventional Pipeline Inspection Gauges (PIGs). The complexity of pipework at High Pressure Installations (up to 94 Barg) presents a significant challenge for any robotic solution.

The solution being developed will enable NGGT to look inside their High Pressure Installations for the first time since their installation, in some cases dating back nearly 50 years. The current asset management strategy for this pipework relies on above ground survey techniques, and is based on good design and construction practices having been applied to these assets. If corrosion is suspected the only way to confirm this presently is through excavation, which is both financially expensive and environmentally adverse. This project will enable a proactive, risk based approach to the management, maintenance and replacement of these ageing assets.

The project highlights NGGT's commitment to delivering innovation that provides a more reliable and environmentally friendly approach to managing its assets and building value for gas consumers.

> **There are 350 kilometers of 'un-piggable' pipework in the National Transmission System**

Synthotech Ltd

Synthotech Ltd specialises in providing innovative engineering and technical services to the utility and infrastructure sectors and are designing and building the robotic platform.

Premtech Ltd

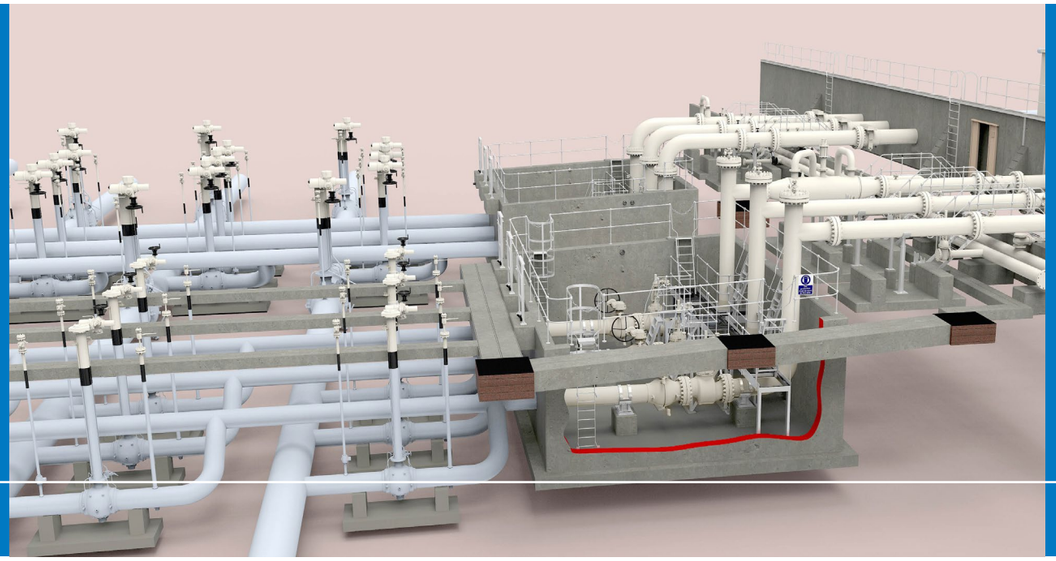
Premtech Ltd provides engineering, consultancy and design management services for on-shore pipeline and associated installation projects of various sizes. Premtech are designing the robot's launch and receive vessel, the off-line test facility and providing design consultancy services.

Pipeline Integrity Engineers Ltd

Pipeline Integrity Engineers (PIE) Ltd offers consultancy services relating to the integrity management of high pressure gas pipelines and associated installations. PIE are providing third party assurance, supporting the technical team in developing and implementing the technical strategy, and providing integrity consultancy support in translating inspection results into asset management strategies and operational procedures.

Project GRAID
Gas Robotic Agile Inspection Device

2 Executive Summary



Following the successful NIC bid and subsequent award on 24th November 2014, the project was fully mobilised in January 2015 and is progressing according to schedule. The dominant activities during this reporting period have been defining the alpha design scope for the robotic platform, conceptual designs for the launch & receive vessel and test facility, and 3D computational modelling of the sites that will be used for trials.

The first six months of the project has seen the mobilisation of the NGGT core project team and establishment of project management processes, procedures and governance structures. Work packages have been created and resourced and the project partners have started to produce initial design concepts for the various elements of the robotic platform and associated ancillaries.

The alpha design scope activity focused on four key areas of the robot's development: drive, vision, sensory, and communications systems. The alpha design scope phase highlighted the importance of effective collaboration between project partners and the challenges faced by geographically dispersed teams. The project team is working to shorten the line of communication between project partners and the NGGT staff who can provide timely asset information and react quickly to further technical questions.

A key learning point has been the identification of key personnel within NGGT who possess specialist knowledge required by project partners, and working collaboratively from the outset. For example the composition of the gas found within the Gas Network is vital for Synthotech to understand the atmospheric conditions the robot will need to operate in.

Premtech's accurate (+/- 2mm) 3D modelling of the pipework at the Bacton, Tirley and Wormington installations has provided a benefit dividend of being used for two innovation projects. The advanced techniques used to model the sites were created as part of an earlier NGGT innovation project, Building Information Modelling (BIM). These 3D maps of an installation's pipework will be used to great effect on Project GRAID as they will form part of the robot's navigation system.

The location for the test facility will be Pipelines Maintenance Centre (PMC) Ambergate which is owned by National Grid. An area of real-estate has been reserved for the test rig and PMC personnel are now involved in discussions regarding the test facility to ensure all opportunities are captured at an early stage. Project activity now focuses on the development of the robot's design and key sensory systems as well as the design and commissioning of the test facility at PMC. The test facility will be used for off-line trials in the first half of 2017. The team will also be developing Formal Process Safety Assessments in collaboration with NGGT's safety engineers.

Stakeholder engagement has continued to develop as the project gathers momentum. The project team have begun to distribute monthly newsletters and the distribution list is growing rapidly. In April the project featured as part of National Grid's innovation stand at Utilities Week Live and in early June Project GRAID was presented at the World Gas Conference in Paris. The Project Sponsor and key partners were also interviewed by BBC Radio Leicester in a feature about the benefits that Project GRAID will bring. Collaboration across the industry is taking place and several international organisations have expressed interest in contributing to the success of the project.

Further stakeholder engagement is planned over the next six months when multiple industry organisations will be approached as part of the project plan and central presentations will be delivered to raise awareness about the benefits the project will bring across a wide range of functional groups. The Stakeholder Engagement Plan will also seek out opportunities to promote science, technology, engineering and mathematics (STEM) at local schools and colleges and the project is already partnered with the University of Leeds.

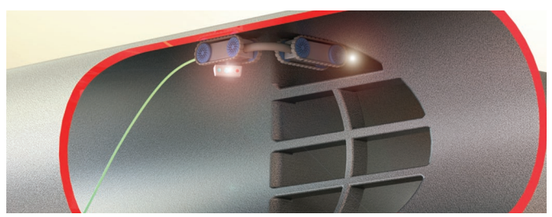
Darren Elsom - Head of Network Engineering Deputy Project Sponsor

Additional opportunities for further innovation outside of the project's scope have also been identified. The investigation into the project's design specification has produced a range of ideas and potential solutions to other asset management problems. The project team are capturing these opportunities and feeding them into the relevant business areas for further investigation.

3 Project Manager's Report

The main activities over the past six months have been the definition of the robot's design scope and exclusions, the modelling of the three trial sites, initial development of the launch and receive vessel and the design of the offline test rig.

Project GRAID is currently on schedule and within budget. The planned test site has changed from Eakring to PMC Ambergate for operational reasons. PMC are one of the potential end users of the robot when the project moves to business as usual (BAU) and so it was deemed that using their premises and expertise to assist with offline trials would help facilitate this process. When the team looked at the schedule for online trials it became apparent that it would be more efficient to use the Wormington installation instead of Hatton, planning to make use of existing maintenance schedules and minimising any potential disruption to consumers. These changes have not affected the completion of project milestones or the quality of the project's output.



The initial alpha design scope has been successfully completed which allows further concept development of the robot to take place, building towards the completion of concept modelling and prototypes by the end of Stage 1.

Premtech has surveyed the three trial sites where online trials will take place (Summer 2017). Using a combination of existing pipework design plans and advanced laser scanning techniques, they have begun to create highly accurate 3D models of these sites. This data will be used for the robot's navigation system. Premtech is also progressing with the design of the robotic platform's launch and receive vessel. Initial design drawings have been developed and discussed with the key project stakeholders within NGGT and Synthotech.

The site location for the robot test facility will be PMC Ambergate and a topographical survey has been conducted. Finalised design drawings for the test rig will be issued by the 30th June 2015. Key PMC stakeholders have been brought into meetings and workshops to ensure the design of the test facility meets safety and manufacturing standards. The project team have been holding monthly design review and co-ordination meetings as a mechanism to communicate and engage with the primary project stakeholders.

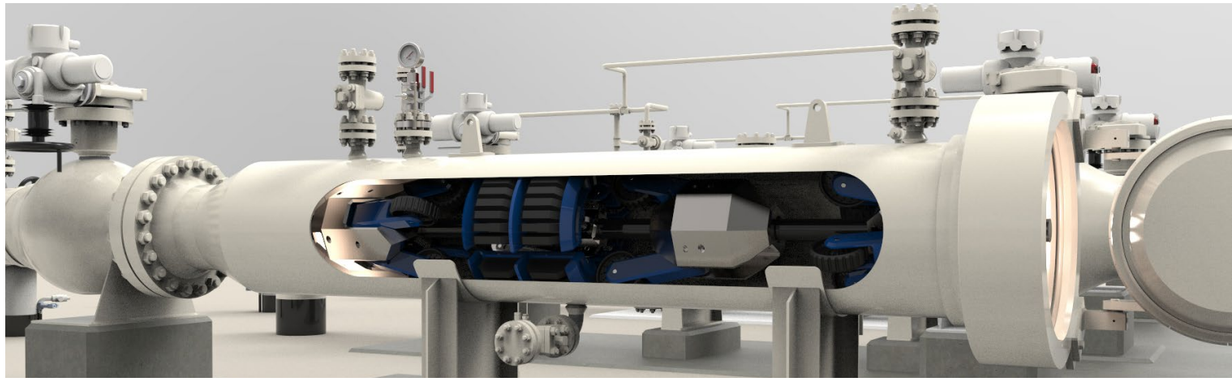
4 Business Case Update

The overall business case for carrying out the project remains unchanged and will potentially strengthen as interest builds from across the industry. There are significant benefits to having in-line (internal) inspection to complement existing external inspection methods. It will ensure that understanding of asset condition is enhanced and maintenance managed effectively. It is currently not possible to use PIG methods on pipework at High Pressure Installations due to the varying pipe geometry and high pressure.

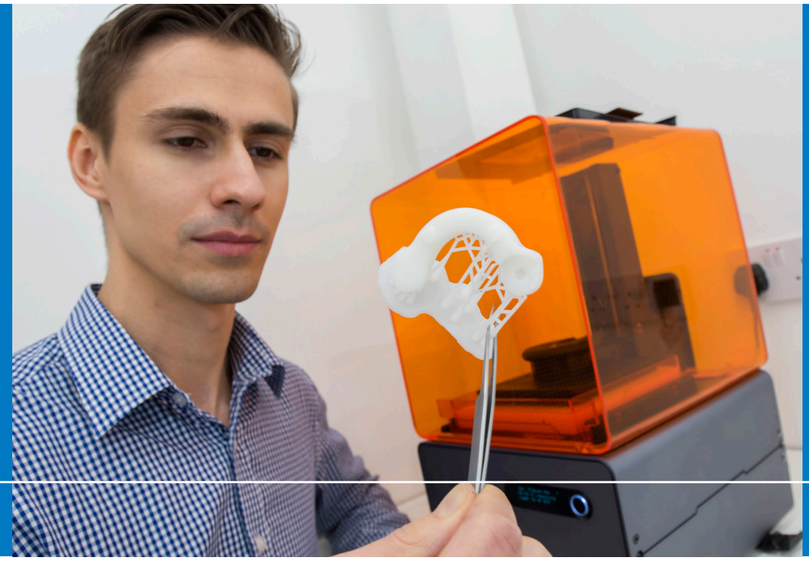
The project is developing a solution that will bridge a current capability gap, which if addressed, could reduce the likelihood of an asset failure and the consequential financial, environmental and reputational damage. An evidence-based approach to asset management will also reduce physical risk by avoiding unnecessary excavations. There are no changes to the expected financial and environmental benefits highlighted in the original NIC submission.

£$ c.£60 million savings over 20 years

2145 tonnes CO_{2e} savings per year



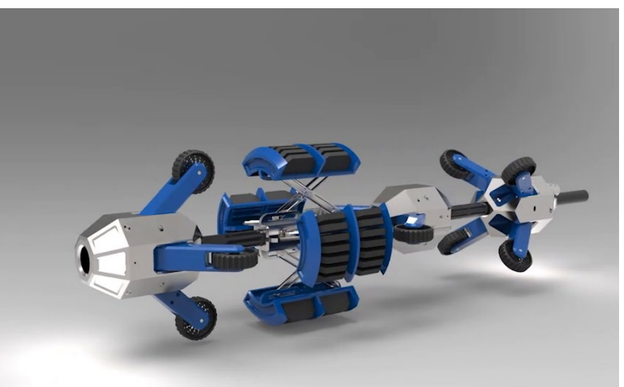
5 Progress Against Plan



The successful scoping of design has enabled the project to construct a design specification for validation, feeding the development of the alpha design concept.

Project Initiation, Mobilisation and Governance

Following the project's initiation the focus was on establishing the project team, setting up the project management systems, processes and appropriate project governance. Key members of Project GRAID's NIC bid team have remained as stakeholders ensuring that there is stability and continuity in project knowledge during the project's initiation phase. NGGT Project Management Office (PMO) has provided project assurance and monitors the project's progress against plan.



Stage 1 – Solution Development

Project GRAID is broken down into five stages with Stage 1 covering the period from the 5th January to the 30th October 2015. Stage 1 of the design process involves the development of 3D computational models by Synthotech in accordance with the initial design scope and specifications. These 3D computational models will then be printed using a technique known as 'Rapid Prototyping' that uses powders and plastic to print 3D space models. The models will then be fitted with off the shelf electrical, electronic, and pneumatics / hydraulics to provide limited functionality. These space models are used to test first principles of concept design and will be developed further during Stage 2.

Simultaneously, Premtech are designing the launch and receive vessel and test facility for offline trials, designed and appraised in accordance with relevant National Grid design codes. The test facility will be used to simulate the pipework and conditions found at High Pressure Installations in order to test the robot in a safe and controlled environment.

Work Streams Completed

During this reporting period the following work streams within Stage 1 have been completed:

- **Concept & Methodology** – Completed on the 27th February and contained 10 work packages:
  - o Preparation and issue of initial Design Assumptions Register (DAR), Lessons Learned Register and Holds & Decisions Register.
  - o Preparation and issue of initial Basis of Design Documents (BoDD) for the robot test facility and robot launch and receive vessel.
  - o Preparation and issue of initial construction information and records, site surveying and 3D modelling procedures and process maps.
  - o Preparation and issue of Concept and Methodology design document.
  - o Robot requirements assessment prior to development of concept designs.
  - o Identification of relevant standards and regulations.
  - o Robot concept of operations (operating scenarios).
  - o Global technology review. This will be ongoing throughout the project's life.
  - o Patent search. This will be ongoing throughout the project's life.
  - o Robot motion study (robot propulsion mechanisms).
- **Robot Concept Study** – Completed on the 23th April and contained 8 work packages:
  - o Initial technical questions. Three key areas include, gas environment and pipeline features, choice of sensors within the scope of the project and safety features.
  - o Robot design scope and specifications, including operating parameters (see table 1).
  - o Key systems. Definition of the robot's key sub-systems including drive, vision, sensory and control.
  - o Global technology review (continuing awareness of existing technology).
  - o Patents and IPR indemnity (continuing awareness of existing patents and potential opportunities).
  - o Standards and requirements appraisal. Deriving design requirements from relevant standards and subsequent appraisal by PIE.
  - o FMEA (failure modes and effects analysis) design mitigations. Design features that de-risk operation use of the robot.
  - o Partner engagement. Partnerships formed with organisations to collaborate on the robot's development.
- **Records & Surveys** – Completed on the 29th May and contained 4 work packages:
  - o Complete asset record gathering, including as-built drawings, reports for the 3 site locations.
  - o Completed site survey – Site 1 (Bacton).
  - o Completed site survey – Site 2 (Wormington).
  - o Completed site survey – Site 3 (Tirley).

Progress Against Plan

Stage 1 phase progress:

Work Stream	Stage 1 - Solution Development									
	Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Jul-15	Aug-15	Sep-15	Oct-15
Concept & Methodology Documents										
Records & Surveys										
Site Modelling										
Launch & Receive Vessel Design										
Replacement Asset Carbon Footprint										
Formal Process Safety Assessments										
Test Facility Design										
Robot Concept Study										
Robot Alpha Design										

Blue = Phase Complete
Green = Phase on Track

Project Technical Assurance

A technical assurance strategy is being implemented that entails independent reviewing and approving of technical reports and studies that have been conducted in 2015. Monthly design review meetings are being conducted for the purpose of sharing, reviewing and challenging the design of the offline test facility. The Concept and Methodologies Report and Alpha Specification Report, issued by Synthotech, have been subject to a detailed independent review. Further discussions have been held with Synthotech in respect to NDT resolution and robot stability. PIE have researched these areas and provided a proposal to Synthotech to conduct further assessments. An understanding is also required of the accuracy for sizing pipework features as this will input into the design of the NDT system. PIE has conducted a parametric study for Synthotech that assessed the significance of pipework feature size for different pipework diameters and wall thicknesses.

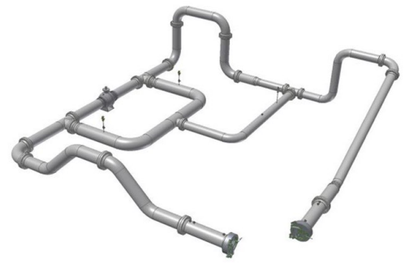
In order to ensure that the quality characteristics of the robotic platform are maintained, Synthotech has established the Subject Matter Experts Consultation Group. This is a select committee of six individuals who will meet regularly and provide the engineering team with a deeper insight and understanding of the Gas Transmission network. The group have been assembled to harness their experience across all aspects of gas transmission, from construction and design to gas quality, technology and safety management.

Specifications In Scope
100m travel distance.
0-94 Bar(G) pressure.
Two 90 degree bends.
Supply of physical and visual information.
Live operating conditions.
0-40 degrees C.
Non-supercritical phase.
1D bends or greater.
Ball valves.
0-3.5 m/s for NT.
Metal lost detection.
Existing NDT technology only.
2D cameras, lighting, flow & pressure sensors.
Location device.
Hardwired and/or wireless communications.
Umbilical power and/or battery power.
Full-bore & non full-bore robot designs.
Cable drum within launcher.
Multi-modular and/or single modular designs.
Magnetic, wall press, wheel, caterpillar track drive systems being considered.
15+ further standards compliances or deviations needing validation from PIE Ltd.

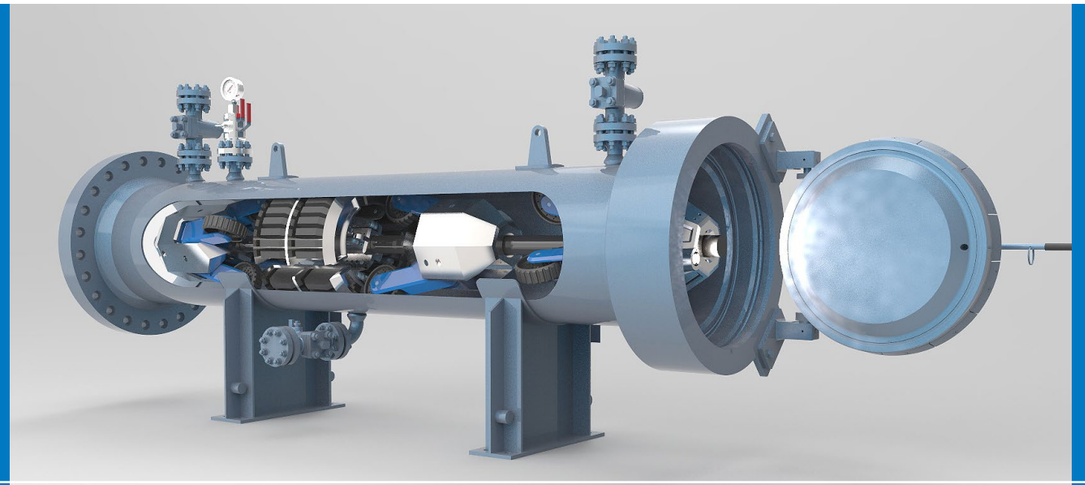
Challenges

One of the early challenges that the project faced related to communication between all the key project stakeholders in the initial stages of the project's life. As the project has progressed and requirements and objectives become more defined communication has improved and the project team is now transitioning from the 'norming' to the 'performing' phase of its development. The project communications plan has also been developed to include planned roadshow events to spread awareness and understanding of Project GRAID at key NGGT operational sites.

Detailed design of the robot by Synthotech requires an understanding of the potential environment it would experience during operation. To aid this understanding PIE has conducted a study that assesses the drag forces that are created by the pipework pressures and flows. There have also been a number of detailed discussions regarding the chemical composition of the gas, specifically in relation to pressure, temperature, blend and velocity.



Progress Against Plan



Conceptual render of the launch & receive vessel

Future Focus

The project's future focus remains on the three key areas of development: the robotic platform, the launch and receive vessel and the offline test facility.

Synthotech's key focus will be working on the robotic platform conceptual design(s), generating the required computer models and 3D prints, with a primary and alternative conceptual design(s). This will demonstrate that the robotic platform has the potential (which is a requirement of Stage 1) to achieve the objectives of travelling 100m around 2 bends, taking visual readings and wall thickness measurements in buried pipework of up to 100 Bar(G) pressure. The robot will not have to perform any of the above within Stage 1, as this is still a very early design phase, but it will need to be able to show and report that systems can be designed to achieve the requirements of the design scope.

The core project team will be working on finalising the arrangements surrounding the build of the test facility as well as developing the communications plan. The team will seek to promote Project GRAID to an assortment of industry associations with the aim of stimulating discussion and inviting collaboration.

Work Streams Ongoing

The following work streams are ongoing and on schedule for completion by the end of Stage 1:

- Site Modelling. Completion of the geo-referenced 3D models of the three online trial sites.
- Launch & Receive Vessel Design. Issue of detailed drawings and design report.
- Replacement Asset Carbon Footprint. Carbon footprint replacement reports for the trial sites.
- Formal Process Safety Assessments. Hazard identification, hazard and operability, hazards in construction.
- Test Facility Design. Issue of detailed design drawings, 3D models, engineering line drawings and material take off (MTO).
- Robot Alpha Design. Further development of key robot sub-systems, control system hardware and software. Production of three computer models, 3D print of primary and alternative prototypes. Quality reviews, R&D analysis and environmental study.

"Project GRAID will help us to really understand where best to invest our money, while keeping our network safe."

Darren Elsom
Head of Network Engineering
National Grid Gas Transmission

Pipework under construction at a High Pressure installaton.

6 Progress Against Budget

Financial Performance

The project is forecast to be delivered within its budget and is currently underspent by 3.8% of the planned cost at this point in time due to some early changes to the core project team and a reallocation of labour to a later stage of the project. Some of the labour costs assigned to operational staff were moved from Stage 1 to Stage 3 for use during field trials. As a result, between January and June less chargeable time was recorded than allocated in the budget. The increase in labour spend during Stage 3 will bring the project labour variance back to 0%. A financial summary can be found at Appendix 1.

Project to Date				
	Budget	**Actual**	**Variance**	**Variance %**
Labour	£104,582.45	£71,874.31	£32,708.14	31.3%
Equipment	£10,000	£10,752.50	(£752.50)	(7.5%)
Contractors	£722,977.44	£722,977.44	£0.00	0%
Travel & Expenses	£0.00	£0.00	£0.00	0%
	£837,559.89	**£805,604.25**	**£31,955.64**	**3.8%**

7 Bank Account

Project Bank Statements

Bank statements have been provided to Ofgem. Due to the confidential nature of the project's bank statements they have not been included in this report.

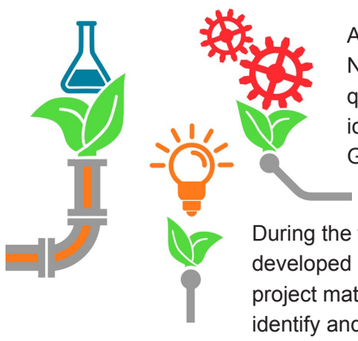
8 Successful Delivery Reward Criteria

Successful Delivery Reward Criteria

The project's first SDRC are contained within the Solution Development Stage which is due to be completed by 30th October 2015. There are no anticipated challenges in meeting the first SDRC and current progress is as follows:

SDRC	Criteria	Evidence	Progress	Date
9.1	A concept design study of robotic platform completed and scope clearly defined.	A report will be submitted by 30 October 2015 demonstrating that these measurable activities have taken place. Documentation for SDRC 9.1 uploaded to the internal SharePoint site and project file, external version uploaded to website. Publish evidence of internal senior sign-off confirming successful completion of SDRC 9.1 no later than 19 December 2015.	100% complete.	30 October 2015
	Created and validated 3D models for each trial site accurately representing pipework configuration.		32% complete. On schedule for 100% completion by September 2015.	
	Design of a launch and retrieval device to allow robot insertion into high pressure.		70% complete. On schedule for 100% completion by July 2015.	
	Robotic platform conceptual design(s) completed, computer models and 3D prints produced, conceptual design(s) demonstrates potential to achieve objectives of travelling 100m around 2 bends taking visual readings and wall thickness measurements in buried pipework of up to 100 Bar(G) pressure.		38% complete. On schedule for 100% completion by October 2015.	

9 Intellectual Property Rights



At this stage no IP has been registered in this phase of the project. As part of the NIC submission process, a patent review was conducted which is reviewed on a quarterly basis. Yeadon IP Ltd (a Synthotech Hub Partner) has been brought in to identify the potential areas of IP which could be submitted for patenting on project GRAID.

During the first few months of the project, a set of story boards (ConOps) were developed as part of the patents review. It is reasonable to expect that as the project matures, patent submissions will be made. A register has been created to identify and track patents that may impact on the project. This will be reviewed and updated as part of the quarterly patent review process. The next review is planned for the end of June 2015. Yeadon IP is leading the searches and the information is being logged and reviewed.

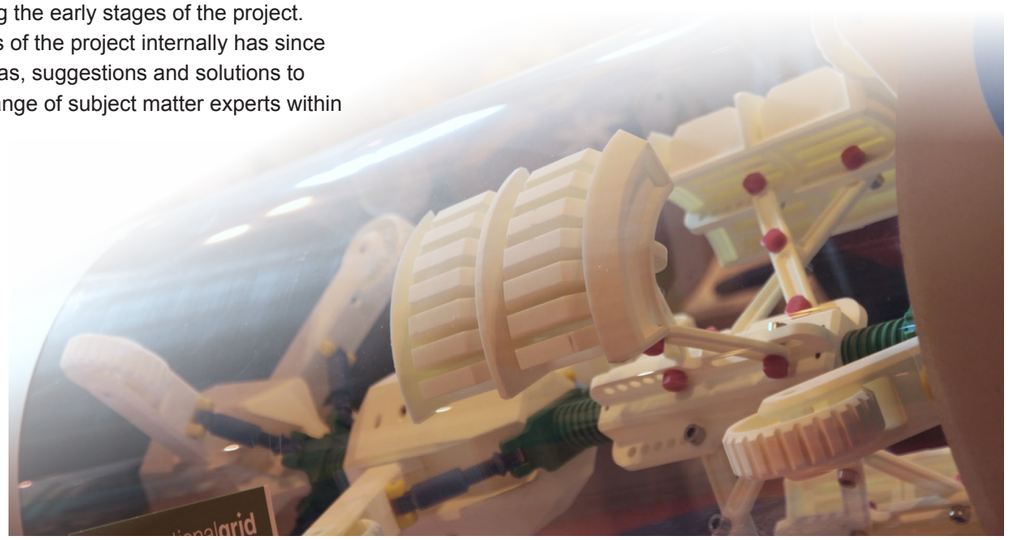
10 Learning Outcomes

During this reporting period, the project team's effort has been focused on the definition of the robot's design specification, the modelling of the three trial sites, initial development of the launch and retrieval device and the design of the offline test facility. Over this period there have been two specific learning outcomes that merit recording.

1. Project Communication.

The scale and span of project GRAID is such that communication is the key to its success. The outputs from the three main project partners are intertwined and they must work closely with each other despite being located in different parts of the UK.

Initial focus was on identifying and engaging external stakeholders when internal stakeholders were more critical to facilitating the early stages of the project. Greater awareness of the project internally has since brought in new ideas, suggestions and solutions to problems from a range of subject matter experts within NGGT. This has been useful in many areas from the selection of the robot's data collection parameters to project data security. Prioritising internal stakeholders during the early stages of the project may have accelerated the project's development by harnessing 'cloud thinking'.



2. Sharing Design Process Methodologies.

The high pressure aspect of this type of work is new to many of the partners involved in the project. Similarly, NGGT is not familiar with the design methodology and approaches used to develop robotic platforms. The sharing of design methodologies at an early stage would have promoted cross-stakeholder understanding of information and design requirements. Improved understanding of these information requirements could have assisted those responsible for delivering it, speeding up the development process.

11 Risk Management

A comprehensive, live risk register has been established and is regularly reviewed in order to identify and monitor technical and project management risks.

The project's risk management strategy revolves around the maintenance of a live risk register which lists the significant threats that may have an impact on the successful delivery of the project as well as identifying threat mitigation control measures. The risk register is updated when required, reviewed informally at each monthly project meeting and reviewed formally at each quarterly project meeting.

Each risk identified is given a score determined by likelihood of occurrence multiplied by severity, which helps to prioritise response measures. Mitigation actions are created for each risk and a risk owner is identified who will be responsible for monitoring the risk and implementing the mitigating actions.

The top 3 project risks are currently:

1. There may be limited access to the robot's tether/umbilical during operation due to the high pressure of the Launch & Receive Vessel. This is being mitigated by joint development of the Launch & Receive Vessel between Premtech and Synthotech. Multiple design options for access to the Launch & Receive Vessel have been investigated and challenge & review workshops conducted to evaluate designs.

2. There is a risk that a re-design will be required if there are IP conflicts during development of technology. This is being mitigated by continual patent searches being conducted by a patent partner, developing multiple options for key pieces of technology and making use of pending patents on new technology as it is developed.

3. There is a risk of the robot failing to meet its prescribed objectives during online trials. This is being mitigated by a thorough testing strategy in a purpose built facility. Recovery plans will be formulated to rescue the robot in the event of it getting stuck. Challenge and review workshops and formal process safety assessment reviews will be used to evaluate design options.

A full copy of the risk register can be found at Appendix 2.

12 Accuracy Assurance Statement

Accuracy Assurance Statement

We hereby confirm that this report represents a true, complete and accurate statement on the progress of Project GRAID in the six month period from 5th January – 19th June 2015 and an accurate understanding of our activities for the next reporting period.

http://www.nationalgridconnecting.com/Robotic_innovation/

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#PROJECTGRAID