2019 Award Nomination

Title of Innovation:
CorrosionRADAR – CUI monitoring system

Nominee(s)
CorrosionRADAR Ltd

Category:
Other - Monitoring

Coatings and Linings	Instrumentation
Cathodic Protection	Testing
Materials Design	Integrity Assessment
Chemical Treatment	Other—fill in

Dates of Innovation Development:
(from [October, 2014] to [October, 2018])

Web site: www.corrosionradar.com

Summary Description:

CorrosionRADAR (CR), a spin-out of Cranfield University UK, is pioneering a novel distributed sensing approach to corrosion monitoring (patent pending) which is especially suited to the problem of early indication of locations of hidden corrosion such as Corrosion Under Insulation (CUI). These sensors are in the form factor of a thin-long-flexible waveguide and are embedded within the insulation near external surface of pipe or vessel. The CR sensors have an outermost sacrificial metallic layer which corrode itself in the presence of water, in a similar way to the pipe surface. The CR sensors are activated using microwave guided radar signals along the long sensor and time-of-flight of wave reflections locate the presence of corrosion and also water near sensor along the pipe length. It uses industrial internet of things (IIoT) systems to ensure information collected by these sensors are able to be accessed, stored and processed remotely. CR technology enables predictive maintenance to CUI, and the collected data is highly valuable to the RBI methodologies.

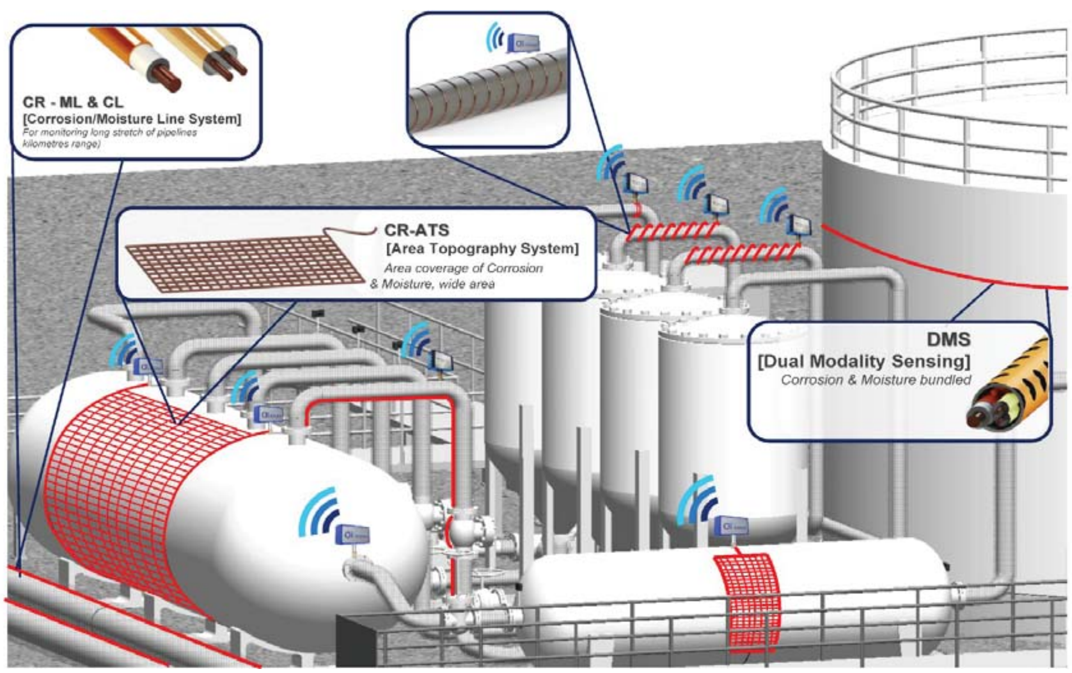
The technology is currently at product pilot deployment stage and a full commercial role out being planned in 2019.

An O&G industry report, CUI Asset Integrity Landscape Study Report 2016 page 97 details the benefits of CR technology for CUI monitoring and benchmarks with competition (https://bit.ly/2y2PPl8).

Full Description:

1. What is the innovation?

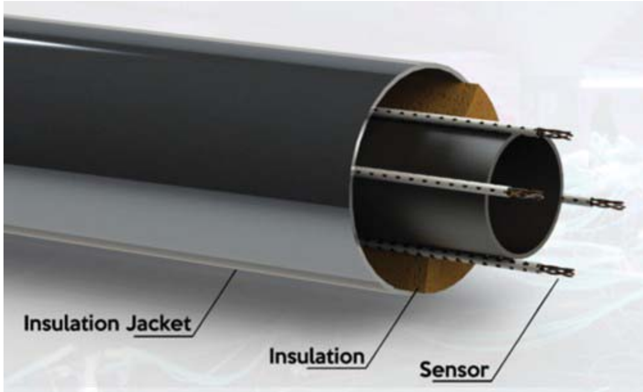
CorrosionRADAR (CR) is pioneering the distributed sensing approach to corrosion monitoring which is especially suited for locating corrosion in inaccessible location such as CUI. CR has developed and patented a corrosion sensor, which is in the form of a long thin flexible waveguide. A coded electromagnetic wave is sent from one end of the waveguide. A wave reflection is generated where the sensor outermost metallic layer gets corroded (representing pipe surface), as the sensor is exposed to the same environment of the pipe. (Pipe is used in the document for convenience as the sensor could also be used to monitor tanks, process vessels and equipment found in refineries or chemical plants). It is a screening tool especially suited for Corrosion Under Insulation on the external surface of pipes and vessels. The key technical innovation behind CorrosionRADAR system is a distributed sensor in the form factor of a flexible wire to locate corrosion at a high resolution. This waveguide is probed using signals used in microwave radar technology originally developed for the aerospace industry and here is being applied into the sensor wire to locate corrosion. The application of CorrosionRADAR system is suitable for wide range of structures and applications including on large surfaces (such as process vessels and tanks) and complex geometries (e.g. valves and flanges) and long-range requirement (e.g. pipelines). CorrosionRADAR provides an embedded and permanently installed sensing system network for monitoring, locating and predicting industrial asset corrosion. The system is aimed at being retrofittable in existing and ageing asset as well as being part of construction phase in new assets. The primary outputs of the sensor system are the identifications of corrosion-prone locations, corrosion rate and future projections (using historical moisture profiling) all along pipe axis



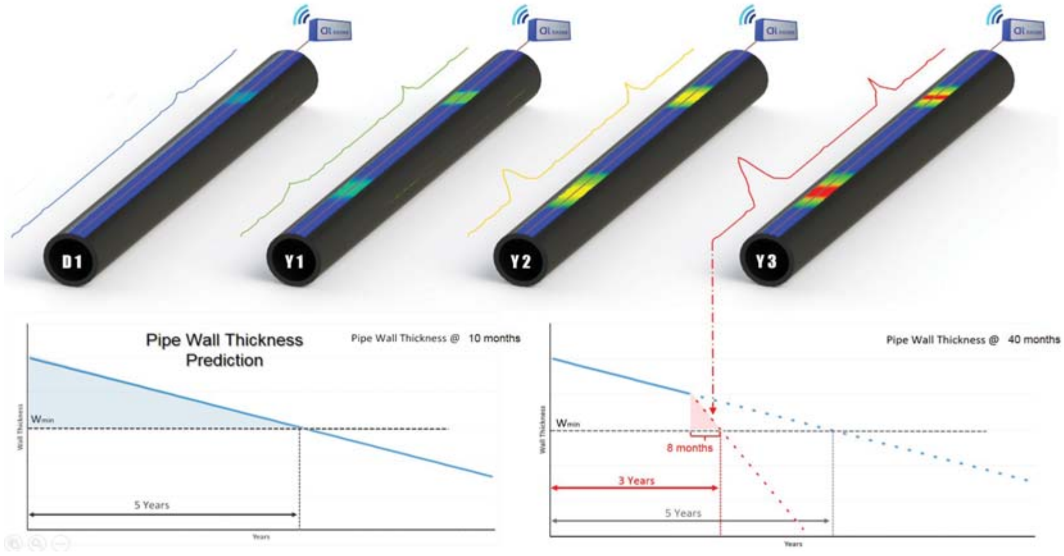
Corrosion Radar suite of sensors and deployment options

2. How does the innovation work?

The working principle of CorrosionRADAR (CR) sensors is based on a new long-range distributed corrosion sensor acting as a thin flexible waveguide line with external layer used as a sacrificial coupon. The coupon layer of the sensor corrodes in the presence of a corrosive environment (inside the insulation and around pipe external surface). When coded electromagnetic signals are sent along the sensor, the time of flight of the reflected signals are interpreted using proprietary algorithms to locate corrosion on the sensor with an accuracy of ± 10 cm. The CR technology can pinpoint the location of corrosion along the sensor length in a range of several hundred meters making it the longest range distributed sensor for corrosion. The corrosion sensor is complemented by a moisture sensor which is also based on the same principle as corrosion sensor using the same electronics but a different waveguide suitable to detect moisture. This data is fed into analytics engine to predict the likely time progression of corrosion along a pipe length.



The CorrosionRADAR system uses latest advancements in Industrial Internet of things (IIoT) providing wireless connectivity and battery powered technology along with cloud-based analytics platforms.



Sensor signals with microwave reflections time of flight indicating onset of corrosion

The sensor provides an axial coverage to a pipe at the locations it is installed at. There can be multiple sensors installed in a pipe to give more coverage. Alternatively, due to the flexibility of the sensor wire, it can be installed in a helical arrangement to provide more surface coverage.

Existing pipe condition does not affect the sensor reading but once installed, the sensor becomes a representative sample of the pipe corrosion but much earlier before catastrophic corrosion levels.

The sensor is not affected by pipe coating or cathodic protection. The sensor locates corrosion prone locations, and then the inspectors interpret this data and evaluate risk to pipe in view of field conditions, such as pipe protection reliability, age etc. This helps in more data-driven Risk Based Inspections.

3. Describe the corrosion problem or technological gap that sparked the development of the innovation? How does the innovation improve upon existing methods/technologies to address this corrosion problem or provide a new solution to bridge the technology gap?

Corrosion has been an inherent problem to structures, machines and equipment since the industrial revolution.

The problem is more challenging in the hidden and difficult to access areas, for example in the case of thermally insulated and buried pipes, where corrosion on the outer surface of the pipes remains undetected due to the surrounding insulation (CUI) or in buried pipes.

A specific high-value problem case is of CUI. The Oil and Gas (O&G) industry suffers severely with CUI in all its segments (upstream, midstream and downstream) spending annually >£3B in identifying CUI, mitigating against the risks CUI poses and repairing the damage CUI causes to their assets. CUI is caused by the presence of moisture in the insulation. Regardless of how secure the insulation is, there are inevitably be areas where water can seep in, thereby creating conditions that subsequently causes corrosion.

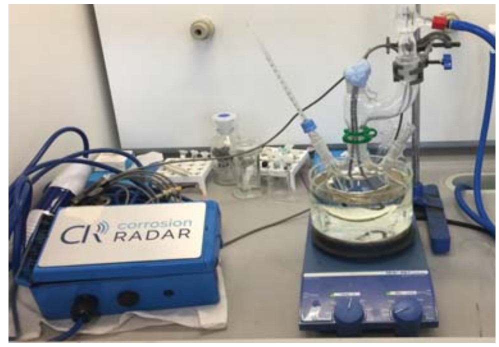
The industry currently follows a Risk-Based-Inspection (RBI) approach based on manual practice to identify the broad zones that are prone to corrosion and use manual spot measurement techniques to check the existence of corrosion. This involves periodically removing the insulation of selected areas for visual inspection. This technique has many limitations and risks attached to it as explained below:

- Heavily dependent on operator knowledge and relies on their experience to identify the areas to inspect, which add a degree of risk as moisture can travel within the insulation and therefore CUI could occur at unexpected locations leading to potentially catastrophic failures.
- It is a labour intensive and time-consuming procedure.
- CUI tends to be localised, and unless the inspected section is accurately positioned, sites of corrosion can be easily missed.
- Cutting sections of the insulation can introduce a fresh source of potential moisture penetration and hence further corrosion.
- Removing insulation is costly, particularly if scaffolding is required which increases the cost of inspection significantly.
- Removal of insulation is messy and may disrupt normal operations.

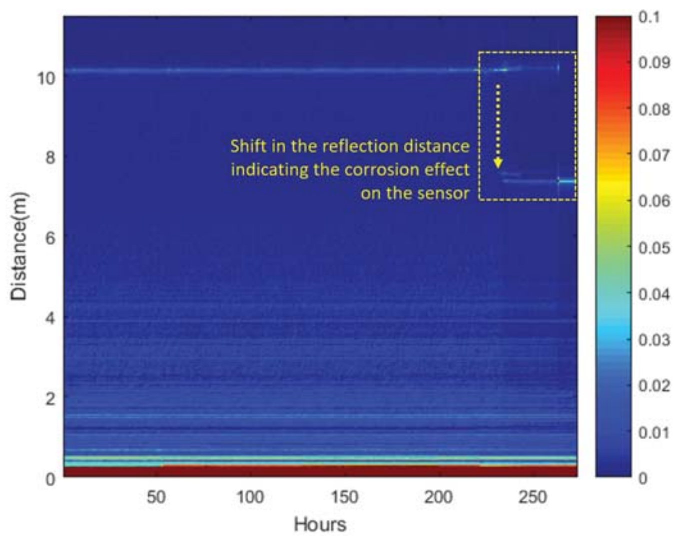
The current practice is based on manual periodic inspection associated with insulation removal. Automated monitoring techniques that preserve the insulation and provide remote data over a long period of time have significant advantages and adds great value to the industry.

4. Has the innovation been tested in the laboratory or in the field? If so, please describe any tests or field demonstrations and the results that support the capability and feasibility of the innovation.

Since 2014, R&D was done in Cranfield University UK, and the spin-out company established in April 2017 for product commercialisation.



The system have undergone extensive accelerated testing in laboratory in Cranfield University UK, Robert Gordon Univeristy UK and University of Strathclyde UK. The experimental tests were done in an aggressive electrolyte which can corrode the sensors in a similar mechanism as in CUI but in a very accelerated manner. The figure below shows the spectrogram of the reflected signal showing the strength in space and time of the current 10m long CR line sensor during an accelerated test. Only reflection from the end is detected till the outer layer begins to corrode at 230 hours. As the sensor corrodes at 7m, the end reflection became weaker while the reflection at 7m became stronger. At 270 hours, the sacrificial layer was completely corroded, there was no more reflection from 10m as now the end of the sensor has shifted to 7m.

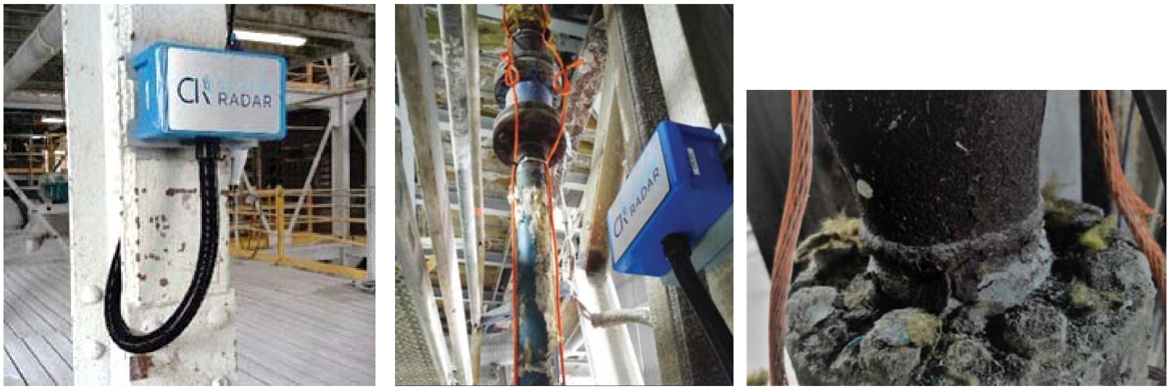


Laboratory test spectrogram of a 10m CR sensor undergoing accelerated corrosion test

Day 6 (144 hour) Day 8 (192 hour) Day 9 (216 hour) Day 10 (240 hour) Day 11 (264 Hour)

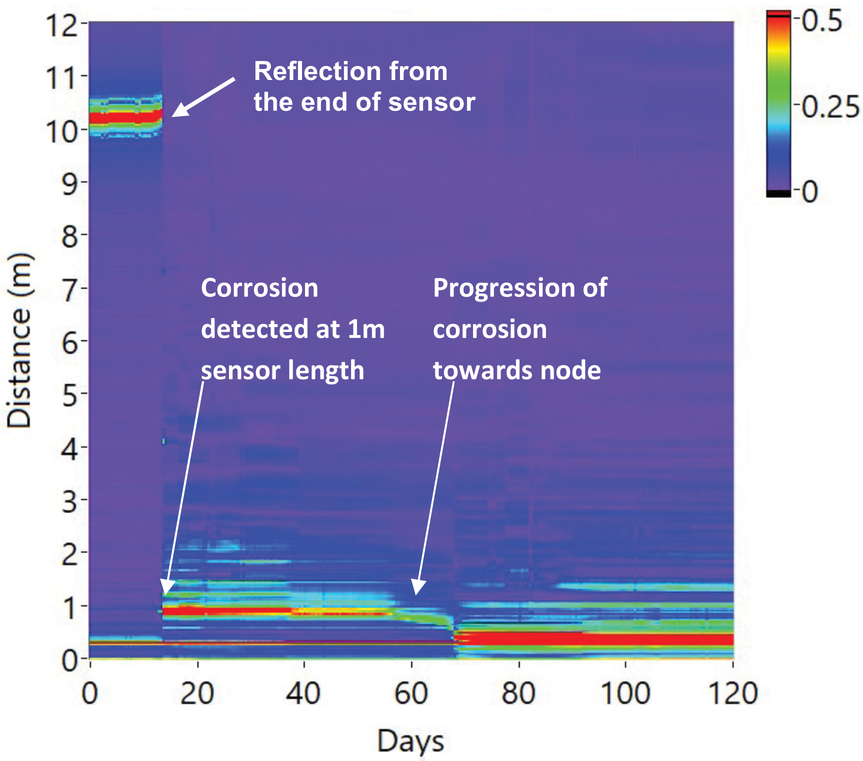
Photos of the progression of accelerated corrosion of sensors in a laboratory test in an electrolyte

CorrosionRADAR installed 3 units of pilot system at a chemical manufacturing plant in northern Spain in March 2018 and this system has been successfully operational for cumulatively over 10000 hours and has been transmitting corrosion data through cellular networks to CorrosionRADAR servers for analysis.



(Left) Field deployed unit, (Middle) Sensor on pipe surface, (Right) Corrosion located

A sensor signal has been detected at the 1-metre. This location is at near the bottom-end of the pipe - close to the CR node - where the sensor enters the insulation.



Results of the field validation where corrosion detected at 1m location along sensor length

Initial analysis has shown the onset of this reflection signal. The continuous reduction in the amplitude of the reflection signal indicates the progression of corrosion. As it can be observed from the spectrogram, the reflections collected from the sensor has moved closer to the CR Node indicating the progression of the corrosion activity towards the CR node. This progression is particularly visible between the day 55 to day 68.

5. How can the innovation be incorporated into existing corrosion prevention and control activities and how does it benefit the industry/industries it serves (i.e., does it provide a cost and/or time savings; improve an inspection, testing, or data collection process; help to extend the service life of assets or corrosion-control systems, etc.)?

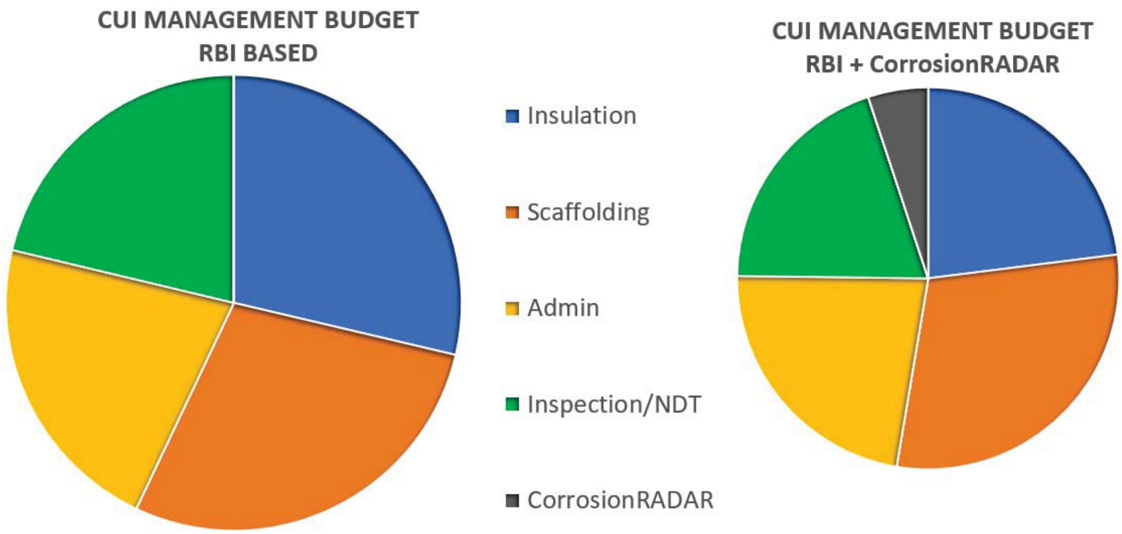
The CR corrosion and moisture sensors are installed under the insulation, adjacent to an external wall of pipes or process vessels. A single line sensor can provide spatially continuous coverage of complex pipe network (hundreds-of-meters in length) from a single location and can locate corrosion with an accuracy of +/-10 cm. The sensors can be used for complex pipe layouts and the range and sensitivity is not affected by the condition or geometries of the pipe. It can also cover large surfaces such as vessels and tanks by installing the line sensors in various configurations (e.g.mesh).

CR Sensor systems are IIoT enabled allowing remote monitoring, data collection and storage. The collected data is fed into analytical models to determine the location of suspicious insulation spots and severity of the threat to the structure-essentially creating a highly reliable and accurate corrosion map of the asset. CR system allows asset managers to make informed decisions in RBI methodology, carry out what-if analysis, plan and deploy their resources to maximum effect. As a result, the risk & the inspection costs will be reduced by narrowing down the suspicious zones.

For a new build pipeline, the sensor is easily mounted during the construction phase. For existing structure, the installation requires opening the insulation and manually placing the sensor under the insulation which is best done during an inspection program. A retrofitting 'insertion tool' is under development to minimise the need for insulation removal.
CorrosionRADAR enables operators to switch from relying solely on RBI to inspect damaged metal, to CUI monitoring using real time and historical data points, resulting in a number of improvements to a CUI management program:

- Reduced intensity of inspection as CorrosionRADAR will be continually screening the asset giving operators the ability to optimise two factors which are major factors in the cost of CUI management:
    - Location – CorrosionRADAR accurately pinpoints areas of corrosion, and therefore, the number of spot inspection locations can be reduced.
    - Timeframe – The large quantity or data CorrosionRADAR records can be used to determine the optimal timeframe between inspections.
- The improvements to a CUI management programme that CorrosionRADAR can unlock has a direct and significant impact of the demand for scaffolding construction and the volume of insulation removal and replacement.

Using a conservative approach, the resulting financial savings to the facility were 28% of the annual CUI management costs. It's estimated that this number will increase in the future as CorrosionRADAR will progressively change the CUI management approach.

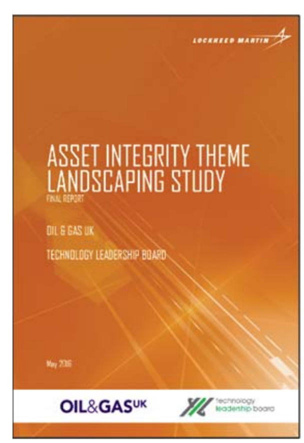


CorrosionRADAR gives operators real time information about the corrosive environment that is hidden from view. This gives operators an early indication of minor corrosion, which can be rectified quickly and with a relatively low cost. Over time the impact of CUI (cost and risk) increases exponentially and the use of CorrosionRADAR system will help in avoiding costs associated to that

6. Is the innovation commercially available? If yes, how long has it been utilized? If not, what is the next step in making the innovation commercially available? What are the challenges, if any, that may affect further development or use of this innovation and how could they be overcome?

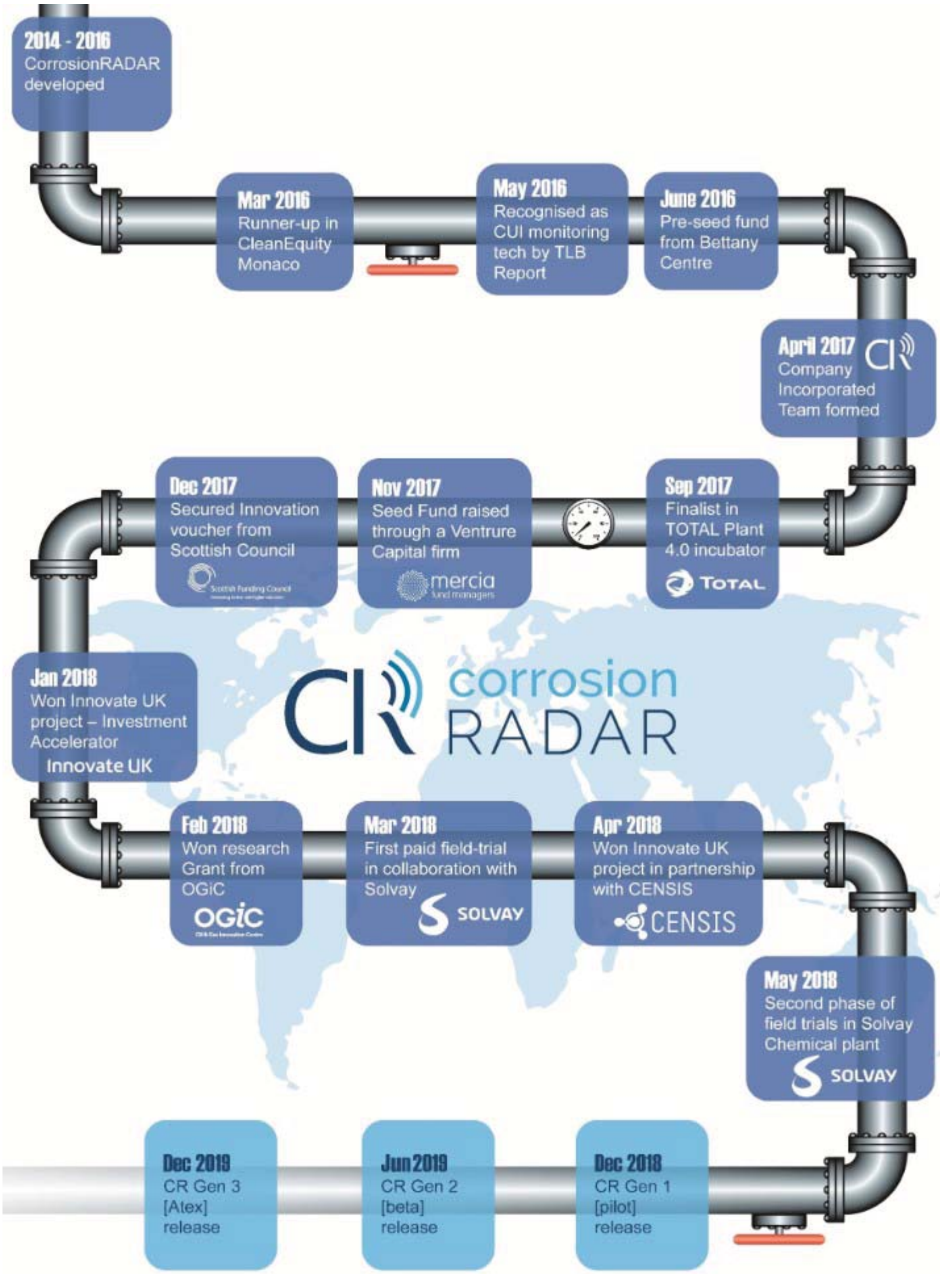
Since the incorporation of the CorrosionRADAR company in April 2017, eight systems have been deployed for field pilots in chemical plants in Europe and India by the end of 2018. The following technical milestones have been achieved:

- Development of the functional product of the CorrosionRADAR system which has undergone extensive laboratory testing.
- The system is currently rated at IP65, a waterproof rating to allow for installation without the need for additional weather protection.
- Moisture detection sensors are being developed to allow for the earliest alerts to water ingress into insulation, these have undergone successful laboratory and pilot scale testing.
- The system will achieve ATEX certifications in early 2019
- Full scale commercial product is planned in 2019



Several players of O&G industry namely the O&G Innovation Centre (OGIC), TOTAL plc, Foster Wheeler AMC came together in 2015 and commissioned Lockheed Martin Business Services to scout for technologies for CUI detection and map out their performance and maturity. In this industry commissioned report, CorrosionRADAR was recognized as a promising technology and was identified as a potential solution for CUI monitoring.
(Ref: https://oilandgasuk.co.uk/wp-content/uploads/2016/05/TLB-Asset-Integrity-.pdf)

The Diagram below shows key milestones that have been achieved since the incorporation of Corrosion Radar Ltd

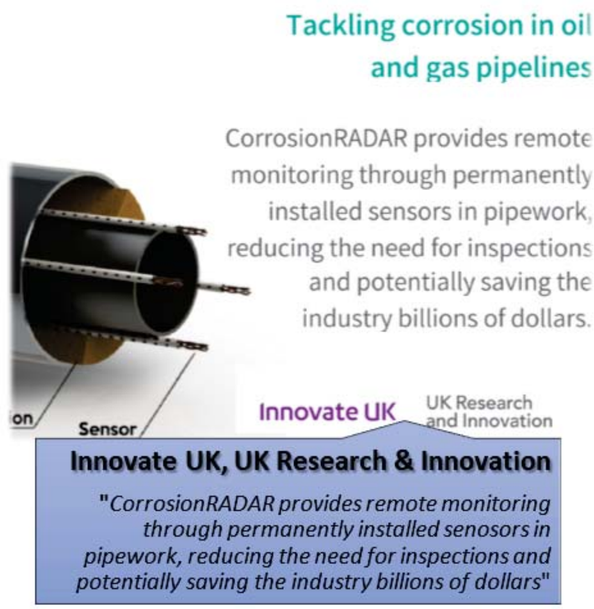


Key milestones in the development of the CorrosionRADAR technology and product

7. Are there any patents related to this work? If yes, please provide the patent title, number, and inventor.

Patent Title – Corrosion Monitoring System, Patent Number - PCT/GB2017/050203, filed 26.1.17, Inventors – Dr Prafull Sharma, Prof Hoi Yeung

The achievements of CorrosionRADAR and key milestones have been captured by the media through different routes and journals as shown in the examples below[1]



[1] References;

1. The Engineer; https://bit.ly/2CqUpy7
2. The Oil & Gas Technology Magazine: https://bit.ly/2sc5snF
3. OGiC: https://bit.ly/2IHUu4c
4. UK Research and Innovation: https://bit.ly/2Lv9sIK