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Dear Reader...

Dr. Klaus Ritter
Editor in Chief

The Pipeline Sector is Facing a Major Boom

Globalization means that many countries and regions, which quasi have hitherto been pre-industrialized, are striving to strengthen their economic base by bringing them closer to the international level of industry. Thereby the coverage of energy and water requirements via pipelines always plays a decisive role.

And it is not just the transport lines, which transport oil, gas and water partly over many thousands of kilometres, but also the distribution and drainage networks, which must be built and operated economically, reliably, safely and compatible for the environment.

The civilized world has constructed some 3.5 million km of high pressure pipelines for oil, gas and water over the last 100 years - about 25,000 km of new pipelines are added every year. On the side of medium and low pressure pipe networks for gas and water distribution, district heating and cooling as well as sewers for waste water disposal the estimate will be about roughly 25 million km.

Considerations today assume that the demand for pipelines, pipes and sewers is even a multiple of the current pipe lengths. Despite the strong use of renewable energies, the highly industrialized regions of North America and Western Europe with the largest existing pipe lengths still play an important role here, since the energy starter is still high. Despite the increased use of LNG, for example, there are vehement efforts in Europe for possible natural gas routes from Russia, Azerbaijan, North Africa and the Middle East.

In North America the routes from north to south are fiercely contested.

There is a great need for additional pipelines in China, where the government is planning to double its use of natural gas. There have been some 70,000 km of new pipelines in the last two planning periods of the programs "West to East", "North to South", "Offshore goes onshore" and "Supply from nearby". But in the coming years, however, pending demand will be much higher.

Other regions in which we are expecting in the near future major developments in pipeline construction are Middle East, West Africa, Iran and India. The Pipeline Technology Journal will keep you informed about these developments on a regular basis. But we have more to offer: to develop the international exchange of experiance in order to meet all these challanges, we have established a new conference & exhibition, the **Pipeline - Pipe - Sewer Technology (PPST)**, which will take place for the first time from 17-19 September 2017 in Cairo, Egypt.

We are working constantly to uphold the continuous exchange within the international pipeline community. You are welcome to make use of the extensive opportunities we created. Kindly find additional information on our websites or contact us directly via mail:

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- www.pipeline-conference.com

Yours Sincerely,

> Dr. Klaus Ritter, President EITEP Institut

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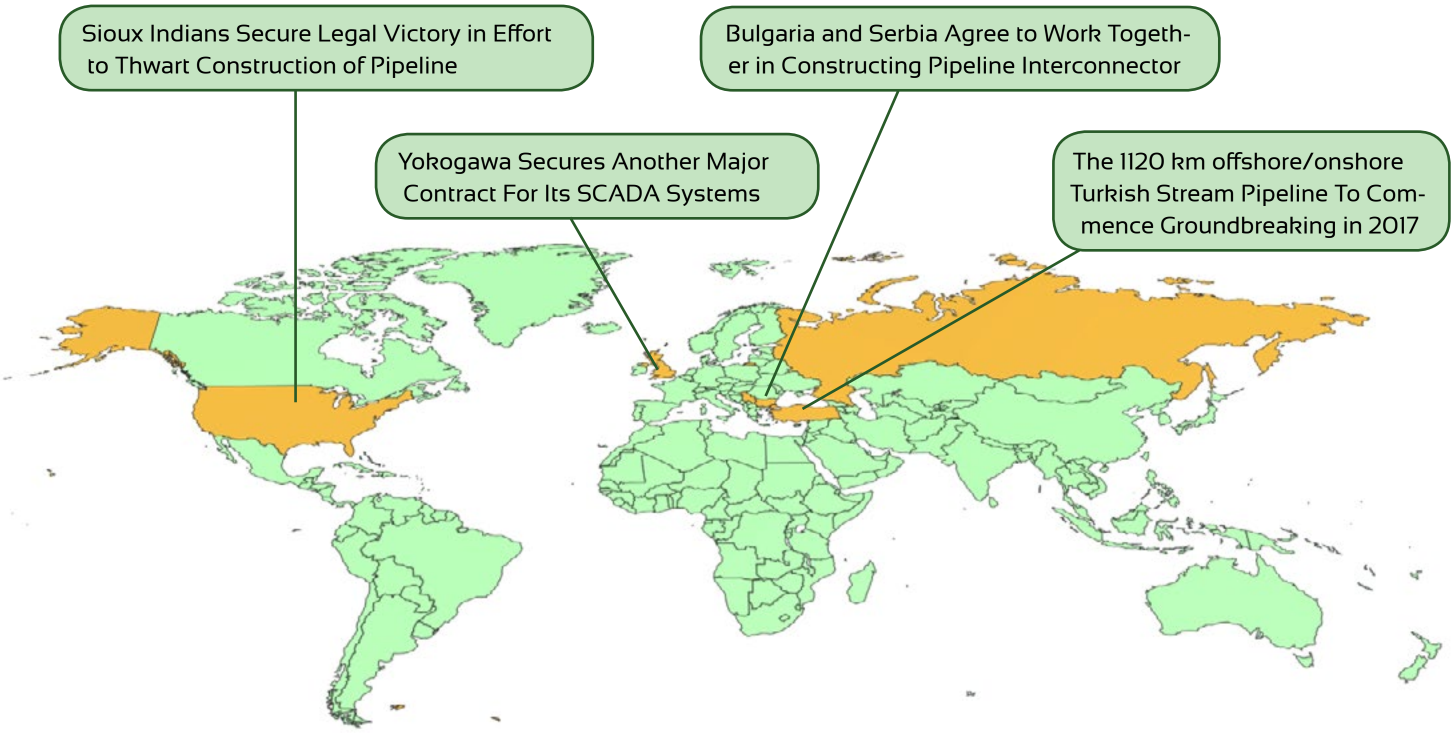

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Taking-off with UAVs:
Just hype or a future key technology in pipeline integrity management?

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Mike Liepe > Siemens AG

Abstract

Unmanned aerial vehicles (UAVs) have been gaining immense attention in the last years for commercial applications as well as for private users. In this work we analyze the momentum of UAVs in the context of pipeline inspection. We briefly present general trends and existing regulations with respect to UAVs deemed to be relevant in the context of oil and gas transmission pipelines. Next we give an overview of potential UAV-based applications in pipeline integrity management including change detection, leak detection, and surface inspection tasks. We report on a technical solution developed at Siemens including our field experiences and results obtained with pilot customers.

INTRODUCTION

Recent worldwide media attention has placed unmanned aerial vehicles (UAVs) in the spotlight. It is important to distinguish between military and non-military use of UAVs. Until recently, media coverage has focused mainly on military use, coining the term 'drone' and leaving many with negative attitudes towards this new technology. At the present time, the civil and commercial applications for UAVs are manifold. Figure 1 depicts some of the most prominent applications. Applications in the inner circle address the domain of industrial automation and digitalization.

Multirotor UAVs are bridging the gap between terrestrial and traditional aerial image acquisition and are therefore well-suited to enable easy and safe data collection. In our context a UAV is a platform carrying diverse (imaging) sensors. Data analytics is required to interpret the raw sensor data and proper visualization of information, e.g. in a SCADA system, allows for deriving appropriate control actions.

The remainder of this paper is structured as follows. We begin by providing some formal definitions and giving a brief look at the existing regulatory framework. Next, we briefly present various UAV build types and their associated properties and highlight relevant sensor modalities, which we summarize in a modular functional model for UAVs for monitoring & inspection tasks. We sketch relevant applications in the context of pipeline integrity management and dive into the concept of change detection as a universal tool for many monitoring & inspection tasks. We show the benefit of change detection for pipeline corridor monitoring and present pipeline depth-of-cover monitoring as a use case of special interest. Finally, we present some thoughts on how change detection could be useful for above-ground pipeline inspection tasks.

TERMS AND DEFINITIONS

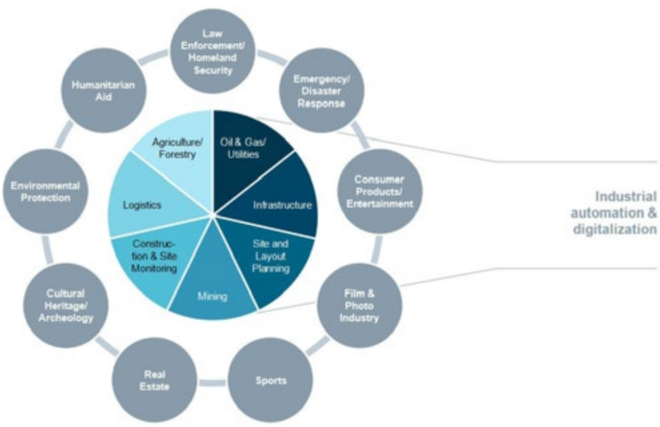

Figure 1: UAV application space

Besides UAV several other terms are out there that are sometimes used synonymous with UAV despite they bear a clear differentiation.

'UAS' (Unmanned Aerial System) is the more up-to-date internationally accepted term in use today. UAS is an all-encompassing description and is an entire package needed to operate the system, encapsulating the UAV itself, the (ground) control system, GPS, payload sensors, and the software. 'RPAS' (Remotely Piloted Aircraft System) is defined by ICAO as a form of UAS which is non-autonomous in its capacities, the aircraft being subject to direct pilot control at all stages of flight despite operating 'remotely' from that pilot. The locational delta between an unmanned aircraft and the Remote Pilot in Command (PIC) are termed either Visual Line Of Sight (VLOS) or Beyond Visual Line Of Sight (B- VLOS) operations.

Visual Line Of Sight (VLOS) operations: refers to literally keeping the unmanned aircraft in visual-line-of-sight at all times. This means not flying an unmanned aircraft into clouds or fog, or behind trees, buildings or other (even partial) obstructions. VLOS additionally means unaided vision except for prescription glasses or sunglasses, and not having to use binoculars, telescopes or zoom lenses to see the unmanned aircraft. In Europe, maximum VLOS is typically set at not more than 400 ft AGL vertically and 500 m horizontally.

Extended Visual Line Of Sight (E-VLOS) operations: relates to the operating method whereby the remote pilot relies on one or more remote observers to keep the unmanned aircraft in visual sight at all times, relaying critical flight information via radio and assisting the Remote Pilot in maintaining safe separation from other aircraft (manned or unmanned).

Beyond Visual Line Of Sight (B-VLOS or BLOS) operations: means flying an unmanned aircraft without the remote pilot having to keep the unmanned aircraft in visual line of sight at all times. Instead, the PIC flies the aircraft by instruments from a Remote Pilot Station (RPS). Eurocontrol is actively considering B-VLOS already within the 2014-2018 time frame [3]: "B-VLOS operations at very low level will be further developed, which could enable initial operation in very sparsely populated areas or over the high seas", while for the time frame 2019-2023 Eurocontrol states: "B-VLOS operations will be further expanded and possibly include operations over populated areas."

First Person View (FPV): refers to a remote pilot operating an unmanned aircraft by reference to an onboard video camera, providing the remote pilot on the ground with a live 'cockpit-view' from the unmanned aircraft.

THE REGULATORY FRAMEWORK

Nowadays in Europe UAS/RPAS fall under a fragmented regulatory framework. Pending the publication of the final EASA rule, the EASA mandates an interim rule for the operation of unmanned aircraft to the EASA Member States.

The Member States have included requirements for the operation of unmanned operation into national regulations. Table 1 provides an overview of different regulations in place with respect to Maximum-Takeoff-Mass (MTOM) and VLOS / BLOS operation as described above. In the U.S. the history on UAV regulations can be briefly summarized as follows: In 2007 the Federal Aviation Administration (FAA) issued a policy statement prohibiting the use of drones for commercial purposes.

In 2012 the congress passed the FAA Modernization and Reform Act, which encouraged the integration of drones in U.S. airspace. Meanwhile the "Section 333 Exemption" in place since Sept. 2015 is an interim certification process that allows for the commercial use of "drones" prior to the FAA finalizing the rules on small UAS.

Figure 2 gives a roadmap of the ongoing UAV rule-making progress in the EU and U.S. and indicates foreseen dates of milestones by EASA and FAA respectively as known in Jan. 2016.

RPAS REGULATION IN EUROPE								
		MTOM	In place		MTOM	In Preparation		Comments
01	Austria[F]	< 150 kg	VLOS					
02	Belgium[F]				< 150 kg	VLOS		Finalised (2013), but not in force
03	Bulgaria							
04	Croatia							
05	Cyprus							
06	Czech Rep.[F]	< 150 kg	VLOS	BLOS				In place (May 2013)
07	Denmark[F]	< 150 kg	VLOS					In place (Jan. 2004)
08	Estonia							
09	Finland[F]				< 150 kg	VLOS		Expected mid 2014
10	France[F]	< 25 kg	VLOS	BLOS	< 150 kg	VLOS	BLOS	In place (Apr. '12) - To be update in 2014
11	Germany	< 25 kg	VLOS					In place (2013)
12	Greece[F]							
13	Hungary[F]				< 150 kg	VLOS		
14	Ireland[F]	< 20 kg	VLOS					In place May 2012)
15	Italy[F]	< 25 kg	VLOS					In place (Dec. 2013)
16	Latvia							
17	Lithuania[F]	< 25 kg	VLOS		< 150 kg	VLOS		Expected mid 2014
18	Luxembourg							
19	Malta[F]				< 150 kg	VLOS		In preparation
20	Nethlerlands[F]	< 25 kg	VLOS		< 150 kg	VLOS		In place (2012) - Update in preparation
21	Poland[F]	< 150 kg	VLOS	BLOS				In place 2013
22	Portugal							
23	Romania[F]							
24	Slovakia							
25	Slovenia[F]							
26	Spain[F]				< 25 kg	VLOS		In preparation
27	Sweden[F]	< 150 kg	VLOS					In place (Mar. 2013)
28	UK[F]	< 20 kg	VLOS					In place (2002) + Several updates since
	Sub-Total		12	3		8	1	
29	Iceland				< 150 kg	VLOS	BLOS	
30	Norway[F]							Expected mid 2014
31	Switzerland[F]	Model aircraft rules apply			VLOS over people/crowds			Directive expected 2014
	Sub-Total					1	2	
	Total		12	3		9	2	

[F] RPAS aerial operations facilitated = Permit to Fly is granted by NAA, based on specific national rules, possibly on a case-to-case basis & for a limited duration *(incl. in countries where no national regulation exists)*.

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Table 1: RPAS Regulation in Europe (as of March 2014). (Source [17])

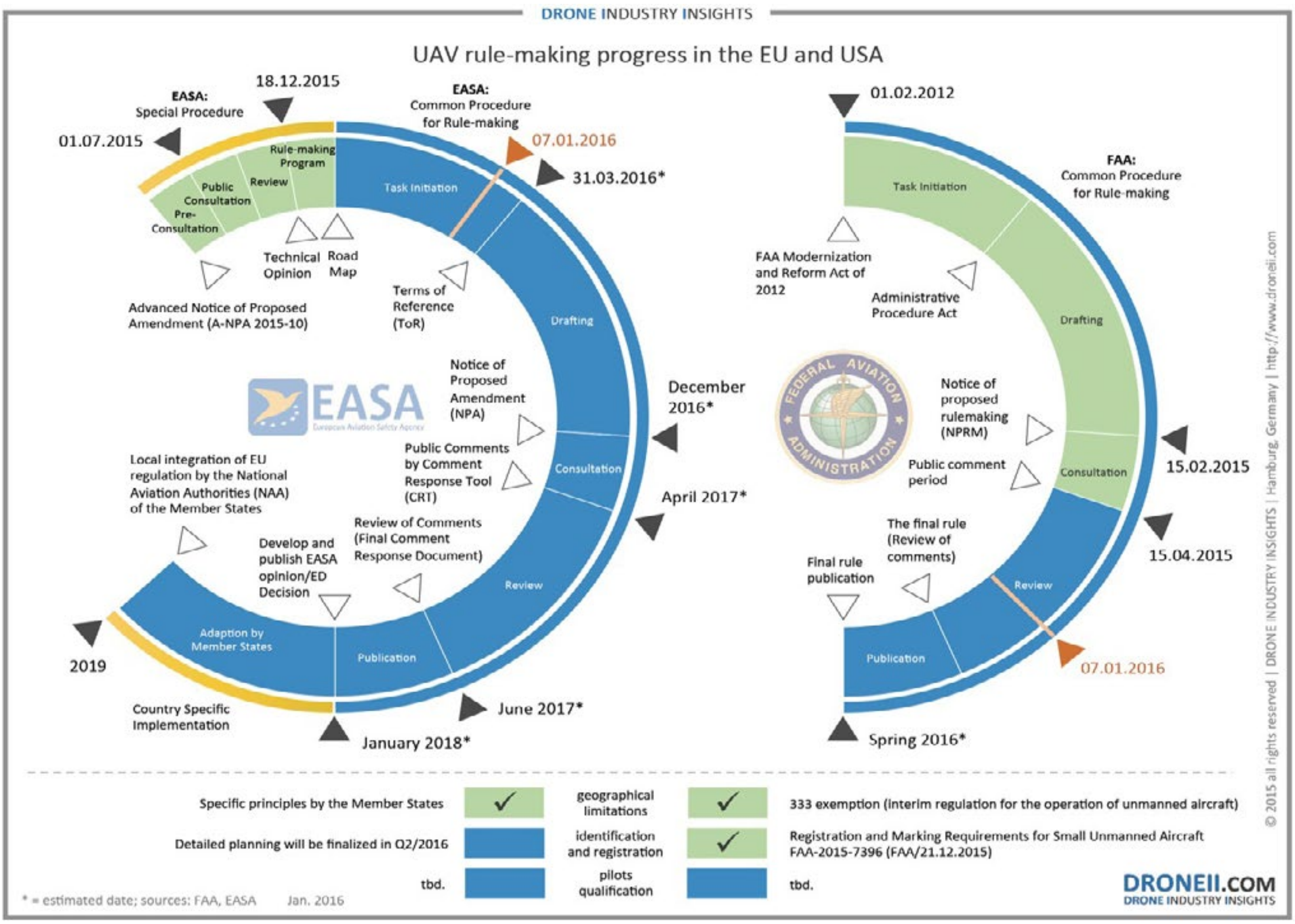


Figure 2: Roadmap of UAV-rule making progress in the EU and USA. (Source [16])

The FAA will soon publish their final rule for small UAS, which will replace the interim Section 333 Exemption process. The comment and consultation phase was closed in 2015. The EASA just completed the pre-consultation phase, publishing the Technical Opinion (see above).

As a brief overview of the content, the table below highlights the most popular regulatory topics.

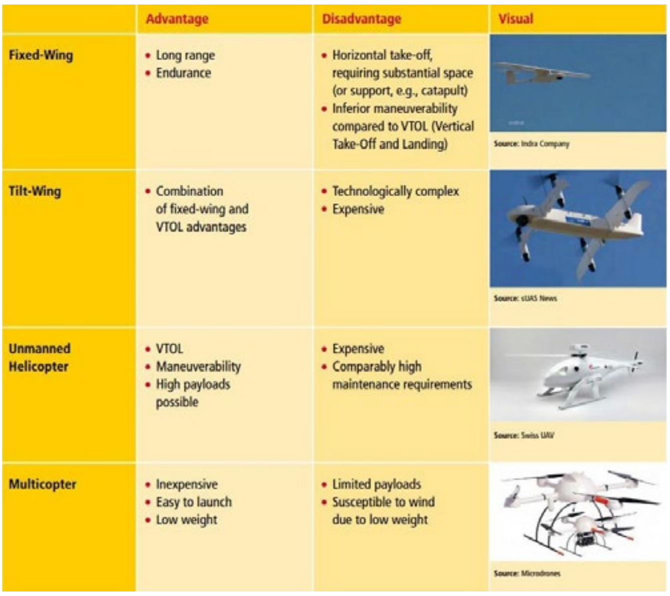
Topics	EU/EASA Technical Opinion	FAA NPRM
Type of categories	Based on the operational risk, UAV types are categorized into three classes: "open", "specific" and "certified"	No categorization
Weight limit	Mandatory for all unmanned aircraft below 130kg (290lbs)	Mandatory for small types of UAV, less than 55lbs (25kg)
Operation surveillance	BVLOS is possible according to safety-risk mitigation procedures.	VLOS only
Pilot license	Not required	Not required
Airspace segregation	Non-segregated airspace, but not specified yet	Segregation is according to ICAO airspace classification

Table 2: Overview on regulatory topics. (Source [16])

For the remainder of the paper, the focus is placed mainly on the technical aspects of UAS. This is driven by the rationale that aviation regulations on RPAS/UAV are shaping and will be subject to harmonization and liberalized (how fast is a matter of discussion). However, there is good indication and a strong push also from the industry side, including Amazon's [1] and Google's [2] announcement for a parcel delivery service in 2017 involving B-VLOS operation.

UAV BUILD TYPES

The following figure taken from [4] provides a good indication on the variety of different UAV build types.



	Advantage	Disadvantage	Visual
Fixed-Wing	• Long range • Endurance	• Horizontal take-off, requiring substantial space (or support, e.g., catapult) • Inferior maneuverability compared to VTOL (Vertical Take-Off and Landing)	Source: Indra Company
Tilt-Wing	• Combination of fixed-wing and VTOL advantages	• Technologically complex • Expensive	Source: sUAS News
Unmanned Helicopter	• VTOL • Maneuverability • High payloads possible	• Expensive • Comparably high maintenance requirements	Source: Swiss UAV
Multicopter	• Inexpensive • Easy to launch • Low weight	• Limited payloads • Susceptible to wind due to low weight	Source: Microdrones

Figure 3: UAV build types (taken from DHL [4])

Across those build types different functional aspects need to be considered:

- maximum operating range and endurance
- maximum payload contributing to a Maximum Take of Mass (MTOM)
- ability of hovering flight
- ability for vertical take-off and landing (VTOL)

Essentially the same classification can also be applied to manned aircraft vehicles like a helicopter. In our thinking, Micro-UAVs (like a multirotor) and manned helicopters form a continuum. The same of course also applies to wing-based constructions.

Figure 4: Continuum between a micro-UAV and a manned helicopter

Larger aerial vehicles offer longer operating range and endurance. The advantage of a smaller size is the ability to get closer to the target of interest, which is important for close-up inspections. Helicopters can – via more sophisticated (and thus expensive) sensor setups – partially compensate for larger observation distance but cannot compensate for ill-posed viewing angels in particular for elevated and branched infrastructures. Since helicopters are costly (around $3000 per flight hour [5]) it seems to make a lot of sense to replace them. Nevertheless in the transition phase before regulations on UAVs are liberalized to support B-VLOS as well as UAV technology is capable operating safely in a fully autonomous manner, helicopters remain efficient for long-range comprehensive inspection. On the other hand, helicopters are stressful or inefficient for close-up inspections. Hence for application domains such as visual inspection of power lines, today's best practice is to combine long-distance inspections from helicopter flights with close-range inspections by detecting candidate points of interest from the long-distance inspection that could be later submitted to detailed inspection by means of UAV [7].

Finally one could also extend the idea to include satellite imagery, e.g. the startup Spire maps the entire world every nine minutes [13], whereas Planet Labs [14] maps the world on a daily basis with 3-5 m per pixel and has already launched more than hundred satellites into orbit.

"Key differentiation between UAV-based monitoring & inspection solutions has to be expected from PROCESSING, which incorporates domain specific knowledge"

> Josef Alois Birchbauer, Siemens AG Austria

AN OVERVIEW ON SENSOR MODALITIES FOR MONITORING & INSPECTION

A comprehensive listing of available UAV-mounted sensors is given in [8]. The tabular information lists imaging sensors, non-imaging sensors, as well as others. The last category includes, for instance, actuators such as illuminators. Since [8] aims to give the global perspective on RPAS, the authors cover both military and non-military applications. The market for imaging sensors appears to be the broadest, and offers a variety of different modalities. In the terminology of [8], imaging sensors encompass both 2D and 3D (i.e. depth) sensors.

Spatial Dimension of Sensed Data	Sensor Type	Active (a) / passive (p)	Field of Use (exemplified)
2D	Visible Spectrum (RGB)	p	Image documentation
	Near Infrared (NIR)	p	Vegetation classification, precision agriculture, forestry
	Thermal Infrared (TIR)	p	Building insulation, defect detection on solar panels, natural gas leak detection, oil leak detection, thermal profile of power poles, etc.
	Multispectral (usually a combination of RGB+NIR)	p	See optical camera + NIR
	Hyperspectral (Large number of spectral bands up to several 100)	p	Precision agriculture, forestry, geological research, and environmental monitoring
3D	RGB + Structure from Motion (SfM)	p	Surveying, remote sensing, 3D reconstruction, change detection
	Stereo Camera Pair	p	3D reconstruction, collision avoidance
	LiDAR	a	Surveying, 3D reconstruction, change detection, vegetation penetration
	Time of Flight (TOF)	a	3D reconstruction, collision avoidance
	Structured Light	a	3D reconstruction, collision avoidance
	Synthetic Aperture Radar (SAR)	a	Remote sensing, change detection, vegetation penetration
1D	Laser Spectroscopy	a	Natural gas detection
	GNSS/RTK	p	cm-accurate data alignment (*x,y,z*)
	IMU	p	inertial navigation (*x,y,z/roll, pitch,yaw*)

Table 3: Sensor modalities for monitoring & inspection

We classify the sensor modalities in the following categories with respect to spatial dimension (see Table 3). Key for all sensing modalities is precise alignment of data (geocoding). This is achieved by GNSS/RTK, which in contrast to standard GPS with about 5 m uncertainty allows for cm-grade absolute positioning in real-time. The precision of the geographical alignment also sets a lower bound on the smallest detectable geometric deviation in change detection between consecutive data acquisitions.

A FORMAL FUNCTIONAL MODEL FOR UAS-BASED MONITORING & INSPECTION

Any UAS for monitoring & inspection tasks can be divided formally into three different pillars:

- PLATFORM: An UAS encompassing the UAV as a physical aerial carrier vehicle, plus the flight planning and flight control
- SENSING: A payload consisting of the measurement instrumentation (sensors)
- PROCESSING: The data analytics that converts the raw sensor data into valuable insights. This also calls for appropriate visualization e.g. in SCADA in order to derive the right control actions.

The authors of this paper tend to believe that the degree of innovation we are going to see within the next years will form a 'ü'-like shape amongst these three pillars.

While in terms of mechatronic design the PLATFORM is already a widespread (basic) technology, innovation is likely to come from fully autonomous flight control with respect to collision detection and prevention ("sense and avoid"). In this respect DARPA is pushing an ambitious program called "FLA" for lightweight autonomous flying in cluttered (including indoor test scenarios and hence GPS-denied) environments and reports on achieving target speed of 20 meters per second [11]. In addition, boosting endurance is a hot topic. A promising approach for long range observations appears to be hybrid-electric technology as showcased by the startup Skyfront [12]. Skyfront offers the "Tailwind", a multirotor UAV featuring up to 4 hours of flying time with 2 kg of payload.

The SENSING devices required for the vast majority of monitoring & inspection tasks are already commercialized, as briefly presented in the previous section. Incremental innovations are expected with respect to miniaturization of electronic components as well as a reduction in price. Hence the key differentiation between UAV-based monitoring & inspection solutions has to be expected from PROCESSING, which incorporates domain specific knowledge and is highly specific for the task hand. This means the task specific adaption across the three pillars is clearly progressive. The UAV is mostly generic, the SENSING is a selection of proper sensing components for the measurement task, while the PROCESSING is highly tailored. This by no means precludes the possibility that PROCESSING itself be built upon reusable's. 'Change detection', for instance, is a general concept of data analytics applicable to various monitoring & inspection tasks. However, the interpretation of detected changes as relevant or not is highly application specific. The three aspects are to a certain degree interchangeable as long as given constraints are met. For instance a sensory head can be mounted on any vehicle as long as payload constraints are met and the flight characteristics of the vehicle are sufficient for data capture at reasonable data fidelity. The PROCESSING can be tightly coupled to the SENSING and the PLATFORM in terms of an onboard processing, but for many use cases one could think on an offline processing for instance offered as a cloud-service.

In accordance with these findings, we propose the architecture of our solution as follows. We make a clear distinction between the UAV ("Acquisition Layer") and the data processing and analytics ("Pipeline Processing Platform" - PPP). Communication/user interaction is preformed using a web interface. Within the framework of the PPP, we make a distinction between time-consuming modules ("Core Modules") that run as batch-jobs, and online reporting modules, which generate the requested information on demand ("Analytics Modules"). Geospatial data is stored in a geospatial database [18].

PIPELINE INTEGRITY MANAGEMENT WITH UAVS

Inspection and monitoring of pipelines can be either periodic (i.e. pre-emptive) or event- driven. An UAS offers advantages in both types of application.

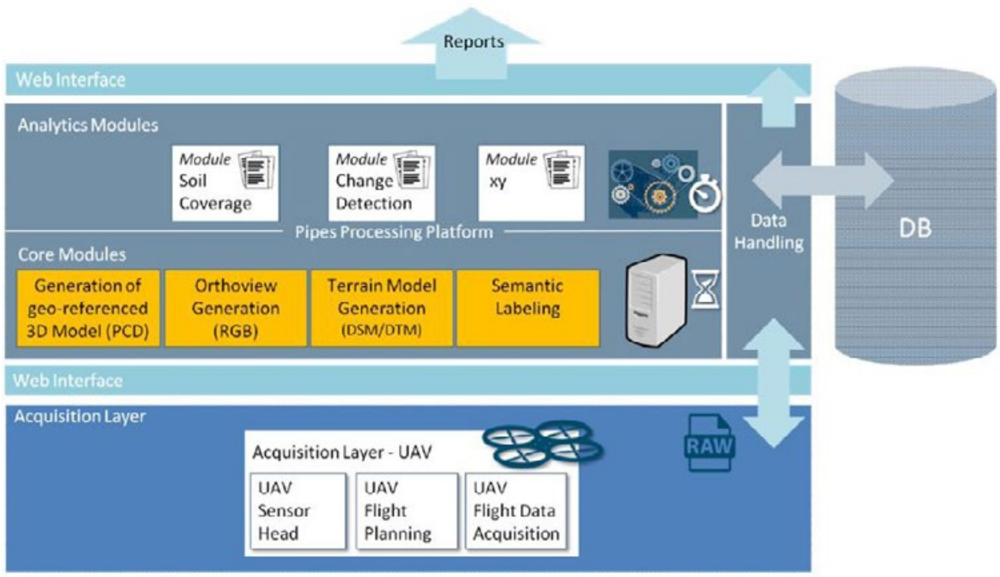


Figure 5: Siemens Processing Framework for UAV Pipeline Data

In the event-driven case an UAS allows for fast deployment, thus reducing reaction times and potential follow-up costs. This modality offers potential for a high degree of synergy with 24/7 monitoring techniques like fiber-sensing. The fiber-sensing system triggers an alert that is locally verified with a UAS. A future scenario could consist of UAVs situated at predefined locations along the pipeline, like block valve stations. Upon an alert, the UAV located closest is identified and is send to the point of interest fully autonomously. When returning to the block valve station, the data is uploaded to the cloud for further analysis. One might also think of live data streaming from the UAV, however bandwidth constraints (since high quality imaging data is very large) and regulatory restrictions limit this type of architecture. Online processing on the platform could be the answer, or at least a two-step approach to coarsely analyze the data online while in-depth analysis is kept for offline processing.

Triggering an event could also happen by means of other modalities. As mentioned above, satellite imagery is at the present highly up-do-date. Whilst the image quality is impressive it still cannot compete with close range observation from UAVs, yet could trigger them.

In the pre-emptive use a UAS allows for more frequent data acquisition than traditional means of data acquisition by either ground-based workers or helicopters, thus increasing the value and trust of periodic inspection & monitoring. That way change detection gets an increasingly powerful tool. A good example is the implicit detection of excavation work by means of damaged grassland. This type of detection will work reliably only if the time interval between two consecutive observations is small enough to detect the grassland was actually damaged before new grass has a chance to grow. Change detection and prognosis are ultimately about trends; a trend becomes increasingly trustworthy the more observations underpin it. A small but still steady decline in soil level at a specific location could indicate a potential future problem long before the problem actually becomes acute.

Finally, we list some of the most relevant scenarios for pipeline monitoring with UAVs that apply to the pipeline right-of-way (ROW). Reporting of observations in some cases is also relevant in a specified proximity of the ROW.

- Soil upheaval, erosion, deep vehicle tracks and water-logged surfaces.
- Construction work, earth movement and excavation, laying of cables, sewers, drainage systems and pipes, erection of buildings, foundations, pylons, etc., boring and pressing.
- Vegetation monitoring above the pipeline (with respect to planting of new shrubs and trees).
- Leak detection either directly by means of natural gas (CH_4) measurement, or indirectly by discoloring of vegetation above the pipeline or the thermal profile of the soil around the pipeline.
- Intrusion detection including illegal tapping.

CHANGE (DETECTION) IS IN THE AIR

In this section we aim to introduce change detection as a universal and flexible concept within the context of pipeline integrity management.

Traditionally, automatic monitoring & inspection tasks take observations from the real world and compare those observations with a predefined (static) knowledge base in order to confirm the intended state or detect deviations from it. These approaches work fine as long as a reasonably accurate target model of the nominal condition can be given or learned.

The latter is nowadays frequently achieved my machine learning techniques and in particular deep learning [19] [20] is becoming increasingly popular. However, techniques based on deep learning still require that training data be available and has to be labeled manually.

In the case of soil upheaval and erosions this concept is likely to perform weakly since such soil changes inherently form a relative instead of an absolute condition. Change detection on the other hand can simply compare consecutive observations as long as the data observations can be aligned with reasonable precision.

Change detection actually subsumes three different aspects (see Figure 6), and these aspects partially overlap. For instance by no means are all geometric and/or radiometric changes semantically relevant in the context of pipeline monitoring. Also some relevant conditions can be determined equally in the radiometric as well as geometric domain (e.g. a damage of grassland due to excavation work), while some show up only in one domain (e.g. discoloring of plants in an early stage of dying vegetation).

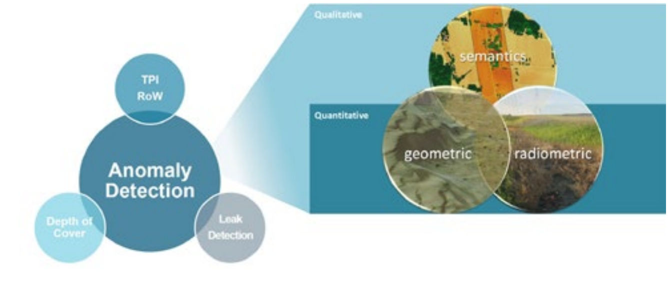


Figure 6: Aspects of change detection.
(Semantic labeling result credit of Definiens Imaging GmbH)

For most semantic interpretation tasks the human performance is still unmatched in terms of domain know-how as long as the amount of data to be observed is kept reasonably small. Hence by means of automatic change detection – in the radiometric and geometric domain - we greatly reduce the amount of data requested for human investigation, whilst the judgment of whether or not a change is semantically meaningful is left open to the human observer.

An impression on what is technically feasible by means of Airborne Laser Scanning (ALS) is given in Figure 7. Key to obtaining these results has been proper post- processing ("automatic strip adjustment") [15]. In ALS point clouds are collected strip wise with a considerable overlap. The redundant information contained in these overlap areas can be used, together with ground-truth data, to re-calibrate the ALS system and to compensate for systematic measurement errors.

In Figure 8 we present some results obtained with our processing workflow that aims for estimating the limits of geometric change detection by placing objects on the ground. At Siemens we have an in-house Structure-From-Motion (SfM) workflow that generates amongst other representations and RGB-NIR-D orthophoto which is the perfect base for change detection both in the geometric and radiometric domain. SfM [9] refers to the process of estimating three-dimensional structures from two-dimensional image sequences which may be coupled with local motion signals. In our case geometric alignment is based on GNSS/RTK measurements of a NovAtel OEM617 [10].

PIPELINE DEPTH-OF-COVER MONITORING

Depth-of-cover refers to how far a pipeline is buried underground. Most pipelines are under a soil cover of about 1 m and depending on pipeline diameter, 4 m to 10 m wide ROW (Right-of-Way) is specified above the pipelines. During the life-time of a pipeline soil cover may be altered due to excavation activities, erosion, cultivation, construction, flooding, ground subsidence or other environment factors or human intervention. It is an obligation of the pipeline operator to make sure that the depth-of-cover still meets applicable minimum regulatory requirements, while it is common practice to exceed the minimum regulatory requirement during construction, e.g. 1.2 instead of 1.0 m.

Deviations in the soil cover can be detected either between consecutive observations (relative change detection) or with respect to the locations given by the initial terrestrial surveying during construction of the pipeline (absolute change detection). Terrestrial surveying yields "cadastral accuracy" which implies targeted accuracies for about ± 3-5 cm. Considering the tolerances during pipeline building we conclude that we need to measure deviations in soil cover with overall accuracies of about 10 cm, which also implies that the accuracy of data alignment of consecutive measurements or with the terrestrial surveying data respectively needs to be kept at a fraction of that range since the cumulative error of data alignment and data measurement needs to stay < 10 cm.

In Figure 9 we sketch our workflow for the case of deviation analysis with respect to given terrestrial surveying. Figure 10 shows some sample results obtained for a pipeline section of about 1500 m. The data has been recorded in September 2015 jointly with terranets bw (https://www.terranets-bw.de/en/) in Baden Württemberg. The terranets bw transmission system has a length of approx. 2000 km and ten entry points directly connect with transmission systems of the grid operators Open Grid Europe GmbH, GASCADE Gastransport GmbH, Fluxys TENP TSO S.p.A., bayernets GmbH as well as Open Grid Regional GmbH.

"Means of automatic change detection – in the radiometric and geometric domain - we greatly reduce the amount of data requested for human investigation"
> Josef Alois Birchbauer, Siemens AG Austria

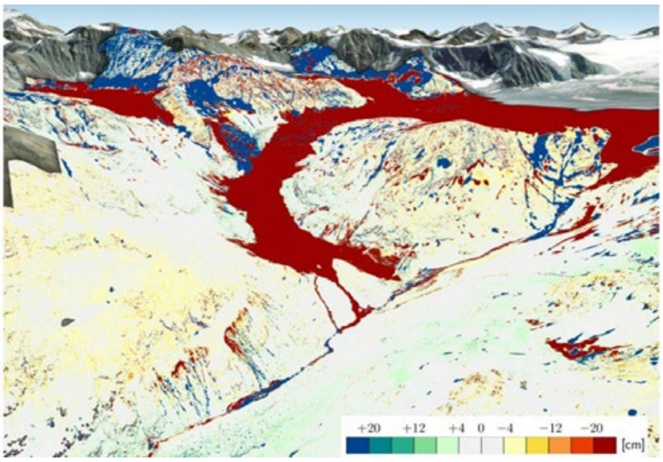


Figure 7: Change Detection based on Airborne Laser Scanning (ALS) [21].

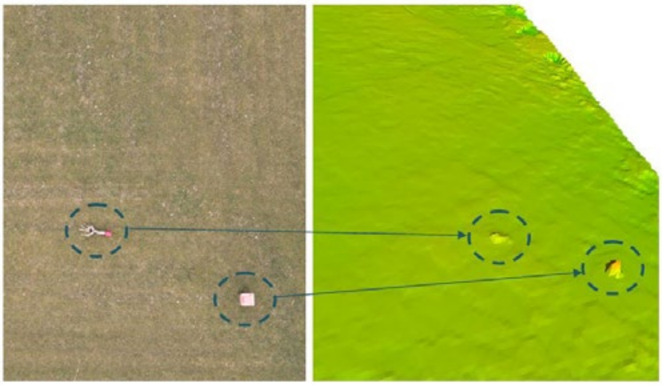


Figure 8: Change detection with objects placed on the ground for a 3D model generated with SfM

The acquired image dataset consists of 162 raw image acquired at a flight height of 60 m and has been processed by our Siemens SfM Pipeline. Figure 10(a) shows location of our test-site in Google earth with the orthophoto as KML-overlay. In Figure 10(b) a glimpse on the geometric data fidelity is given.

Note in particular the reproduction of the subtle diagonal vehicle tracks in the field. Figure 10(c) shows the resulting orthophoto in which an overlay of the pipeline is drawn. The surveyed pipeline route has been provided by terranets bw and aligned automatically with the DTM and orthophoto representation respectively. The color coding indicates the local depth-of-cover.

For the purpose of better visibility an image section is enlarged in Figure 10(d), while Figure 10(e) shows geometric relations from an elevation profile view. As can be observed the local depth-of-cover does deviate at the selected point, however it is not as thin at the borders at it might look on a first sight. This is caused by the fact that the terrain elevation hides the visibility of the pipeline polyline.

The top of the pipe is known in absolute position (x,y,z) and with sufficient accuracy due to terrestrial surveying during pipeline construction.

During the process of aerial data acquisition the absolute UAV-position in space (x',y',z') is recorded in sub-decimeter (down to 1-2 cm) accuracy via GNSS (RTK or offline processing). For the purpose of geographical alignment it is sufficient to get GNSS information at some data points; however GNSS/RTK can also act as an additional source of information during image based reconstruction (SfM) in order to limit drifting effects and thus a dense availability is preferred. The latter is even more relevant in case we replace the 2D camera system with a LiDAR sensor. Given the aerial data a 3D Digital Terrain Model (DTM) is generated and is geographically aligned according to the known GNSS/RTK positions.

The perpendicular distance from the given upper edge of the pipe and the DTM surface can be measured as depth-of-cover.

OUTLOOK: CHANGE DETECTION FOR ABOVE-GROUND PIPELINE INSPECTION

For above-ground pipelines surface inspection (e.g. corrosion detection) is important, however surface effects are only one aspect to consider. A traditional camera does not detect defects to internal heat insulation and the escapes of media below the surface of ground. With the timely discovery of areas where the insulation is thinner or where the cladding on the tube is damaged, major accidents can be prevented. A thermal camera can detect such defects. On the basis of the difference to the surface of the pipeline hidden defects can be found.

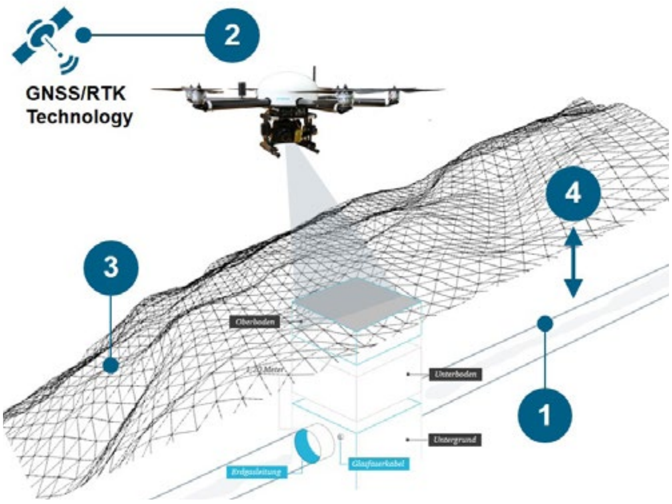


Figure 9: Depth-of-cover measurement workflow.
(soil cover illustration credit to terranets bw)

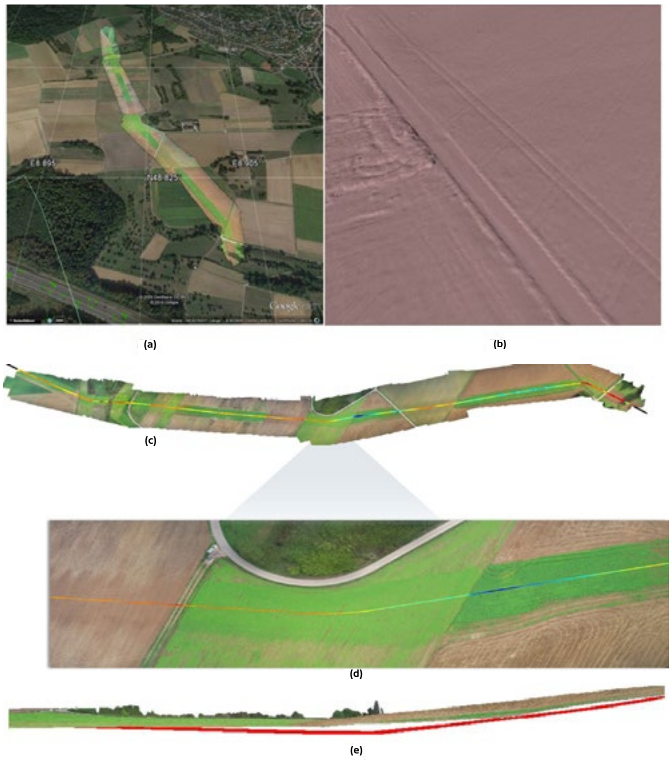


Figure 10: Depth-of Cover sample result on a 1500m pipeline section.
(a) location of the test-site in Google earth with the orthophoto as overlay, (b) qualitative impressions on the DTM data fidelity, (c) orthophoto with depth-of-cover color coding, (d) image section of (c) for better visibility of details, (e) elevation profile view

Due to of the 3D pipe-structure that needs to be inspected a birds-eye view is not suitable as opposed to pipeline monitoring. Furthermore the UAV needs to get reasonably close to the pipe structure to get a sufficient data resolution for capturing details. This results in a more challenging flight operation. Also an orthophoto is no longer a straightforward representation. Instead one has map the image data onto the pipeline shape, being either the real one or synthetic one. Next one needs to unfold or unwrap the pipeline shape to a flattened structure for producing and orthophoto-like cylindrical mapping. We haven't talked about capturing geometric defects so far. The reason is we do not believe that sub-millimeter accuracy is achievable from UAV observations, whereas very prominent geometric defects like dents should be.

Again the question arises how to classify surface textures or temperature distributions as being worthwhile reporting. While for temperature the answer is relatively simple, i.e. anything that shows a clear different local temperature distribution than its surrounding, texture analysis is far from trivial if you want to cover ALL types of defects that could happen on the surface. And not all surface changes are defects if you think for instance on dirt or bird droppings. A criterion that makes a surface change worth reporting is persistency. This is again where our change detection paradigm jumps in. If for several consecutive observations a surface change is persistent or is even getting extended we can conclude its worthiness of reporting without explicit classification and without the necessity to model or learn all kind of potential surface problems explicitly.

CONCLUSIONS

In this work we presented various aspects of UAS technology with respect to pipeline monitoring and inspection. In particular we highlighted change detection in the pipeline corridor, and presented depth-of-cover monitoring as a specific instance of change detection setting challenging requirements on the measurement accuracy. We briefly provided an outlook to what can be done for above-ground pipelines, again following our paradigm of change detection instead of explicit modeling of all kinds of defects.

In the earlier part of the paper we analyzed the dualism between UAVs and helicopters. At the time of writing, the thinking should neither be pro-UAS nor pro-helicopter; it should be pro-'data analytics' based on mobile sensors. Instead helicopters and UAS will complement each other in a phase of transition before regulations on UAS will relaxing and get harmonized. Autonomous (B-VLOS) flying – at least over sparsely populated/unpopulated areas – will become a common practice in the (near) future.

Glossary

AGL... Above Ground Level
In aviation a height measured with respect to the underlying ground surface. This is as opposed to altitude/elevation above mean sea level (AMSL).

DTM... Digital Terrain Model
A DTM represents the bare ground surface without any objects like plants and buildings.

EASA... European Aviation Safety Agency
The EASA is an agency of the EU with regulatory and executive tasks in the field of civilian aviation safety.

FAA... Federal Aviation Administration
The FAA is the national aviation authority of the US. As an agency of the United States Department of Transportation, it has authority to regulate and oversee all aspects of American civil aviation.

GNSS... Global Navigation Satellite System
GNSS is the standard generic term for satellite navigation systems that provide autonomous geo-spatial positioning with global coverage. This term includes e.g. the GPS, GLONASS, Galileo, Beidou and other regional systems. The term GPS is specific to the United States GNSS system, the NAVSTAR Global Positioning System.

ICAO... International Civil Aviation Organization
The ICAO is a specialized agency of the UN. It codifies the principles and techniques of international air navigation and fosters the planning and development of international air transport to ensure safe and orderly growth.

LiDAR... Light Detection And Ranging
A surveying technology that measures distance by illuminating a target with a laser light. LiDAR is popularly used as a technology to make high-resolution maps and is sometimes simply referred to as "laser scanning" or 23D scanning".

MTOM... Maximum Take-Off Mass
The MTOM of an aircraft is the maximum weight at which it the pilot ist allowed to attempt to take off, due to structural or other limits.

Orthophoto
An orthophoto or orthoimage is an aerial photograph geometrically corrected ("orthorectified") such that the scale is uniform: the photo has the same lack of distortion as a map. Unlike an uncorrected aerial photograph, an orthophoto can be used to measure true distances.

RTK... Real Time Kinematics
A satellite navigation technique used to enhance the precision of position data derived from GNSS. It uses measurements of the phase of the signal's carrier wave, rather than the information content of the signal, and relies on a single reference station or interpolated virtual station to provide real-time corrections, providing up to centimeter-level accuracy.

SfM... Structure from Motion
SfM refers to the process of estimating three-dimensional structures from two-dimensional image sequences which may be coupled with local motion signals.

VTOL... Vertical Take-off and Landing
A VTOL aircraft is one that can hover, take off, and land vertically. This classification includes fixed-wing aircraft as well as helicopters and other aircraft with powered rotors, such as tiltrotors.

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Asset Management of High Pressure Installations: Project GRAID - an innovation project to develop a robotics system for internal inspection of buried pipework

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Abstract

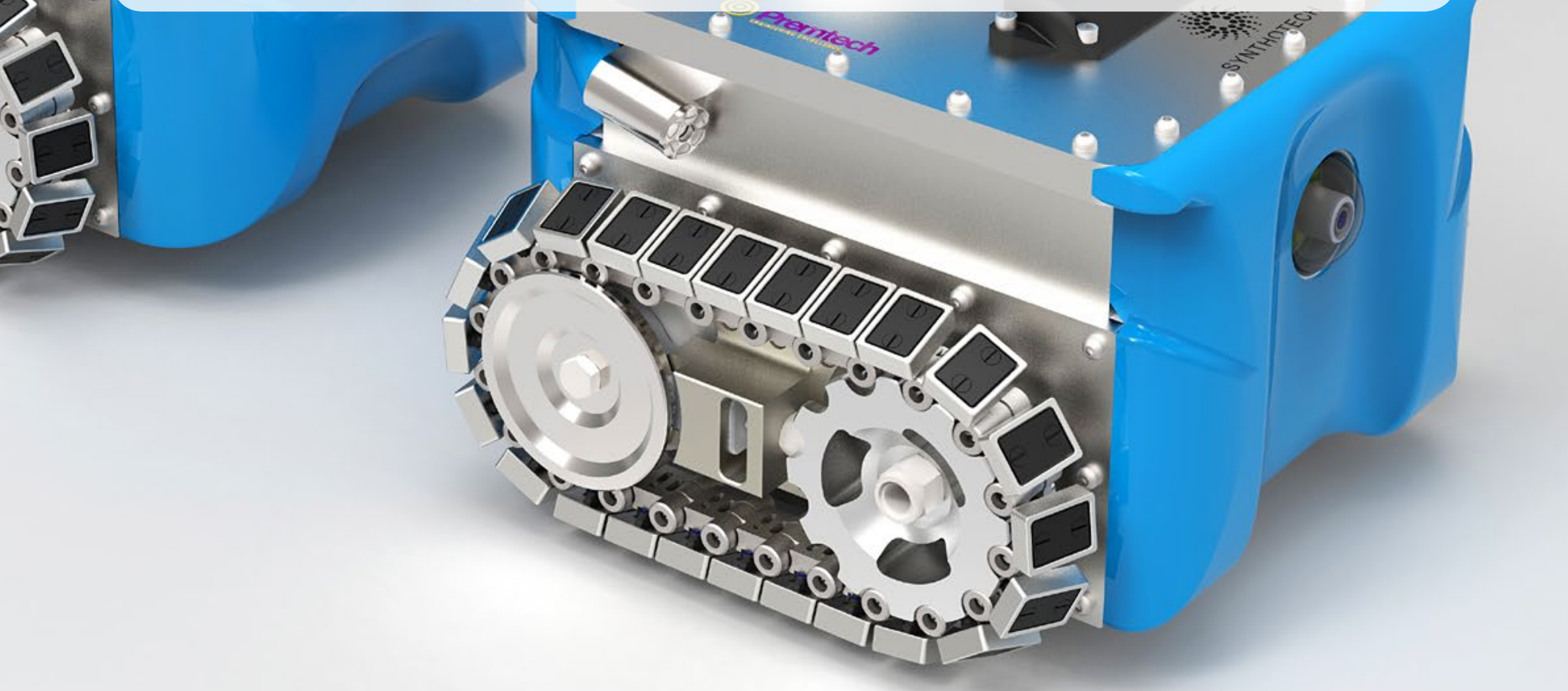
A robust Asset Management strategy is essential for installations that transport hazardous products, and the search for innovative solutions permits the Operator to develop the best tools and techniques to address this need.

National Grid and its partner organizations are engaged in an exciting project that is addressing the challenge of how to inspect the complex, below-ground pipework existing at High Pressure Installations. The robotic platform will negotiate its way through complex pipework geometries and varying gas flows whilst withstanding extreme pressures of up to 100 Barg.

The robotic platform is intended to provide real-time data on the condition of high pressure underground assets not previously in-line inspected, allowing the Operator to more effectively manage the asset life.

National Grid is working with three organizations to develop methods to accurately assess the condition of its pipework assets that cannot currently be inspected via traditional Pipeline Inspection Gauges (PIGs). The complexity of pipework at High Pressure Installations, combined with the extreme conditions within the Gas Network, presents a significant challenge for any robotic solution.

Project GRAID (Gas Robotic Agile Inspection Device) commenced in January 2015 and will be completed in November 2018. Stage 1 of the project has been completed, and this presentation describes the progress to date, project objectives, technical strategy and the key activities to design, build and demonstrate its functionality.



INTRODUCTION

The purpose of this paper is to share the details of Project GRAID with industry, and explain the following:

- The participating project partners
- The role of Project GRAID in an Asset Management Strategy
- Background, objectives and key project tasks
- Technical strategy to meet the objectives
- Progress to date
- The next phase of the project

THE ORGANIZATIONS

National Grid is an international electricity and gas company and one of the largest investor-owned energy companies in the world, employing nearly 24,000 people. It is the sole owner and operator of gas transmission infrastructure in the UK. National Grid owns and operates the high pressure gas transmission system in Britain and its distribution business delivers gas to 11 million homes and businesses.

In the US, National Grid delivers electricity to approximately 3.3 million customers in Massachusetts, New Hampshire, New York and Rhode Island, and manages the electricity network on Long Island under an agreement with the Long Island Power Authority (LIPA). National Grid owns over 4,000 megawatts of contracted electricity generation that provides power to over one million LIPA customers. National Grid are also the largest distributor of natural gas in the north-eastern US, serving approximately 3.4 million customers in Massachusetts, New Hampshire, New York and Rhode Island. The company also has a number of businesses operating in related areas such as LNG importation, land remediation, metering and interconnectors.

The National Grid UK National Transmission's System (NTS) covers over 6000km of high pressure pipelines which operate to a design pressure of up to 94 barg, see Figure 1.

Gas flows to 106 offtake points for 8 distribution networks, and between 26 compressor stations. The NTS is managed from National Grid HQ in Warwick. Gas comes from offshore fields in the North Sea and Irish Sea. It's also imported from Belgium and the Netherlands via interconnector pipelines, and in the form of liquefied natural gas (LNG).

Premtech provides engineering, consultancy and design management services to companies involved in the development, construction and operation of high pressure gas transmission assets, including assets that form the existing NTS. Premtech is based at Ashby de Zouch in Leicestershire within the UK, with currently 20 employees.

Synthotech is developing the robotic platform with the focus on ability that will be capable of visually inspecting assets, whilst providing limited NDT. Synthotech is based in Harrogate in North Yorkshire within the UK, with currently 47 employees.

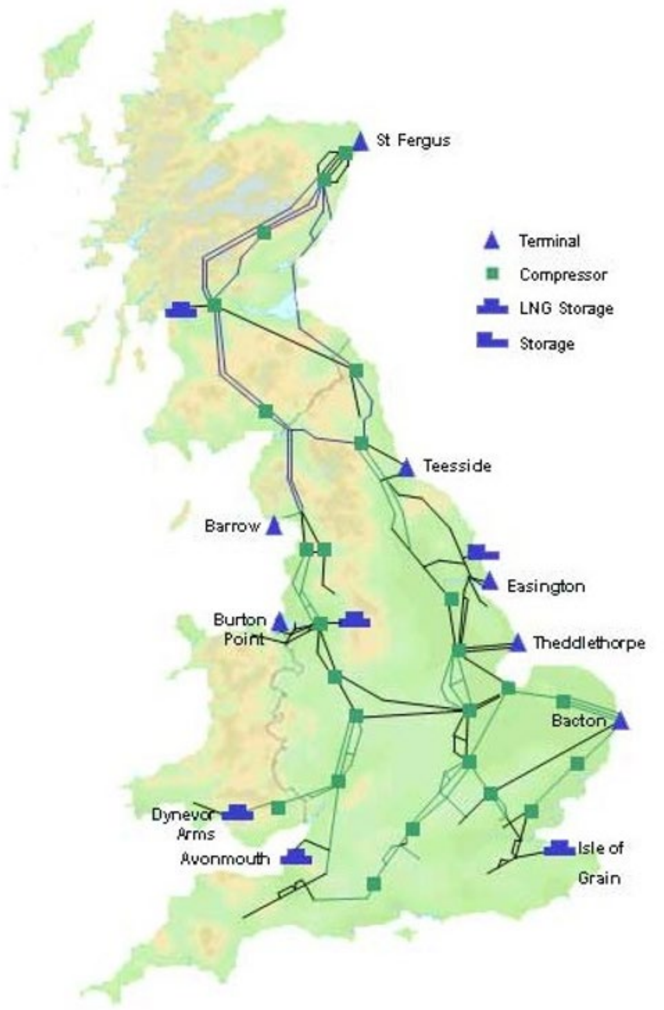


Figure 1: National Transmission System

Pipeline Integrity Engineers (PIE) is a professional pipeline engineering consultancy which was established in 1998. The consultants have extensive knowledge and experience of pipeline integrity management, pipeline operations, project management and engineering support requirements.

ASSET AND INTEGRITY MANAGEMENT

The term Asset Management is used in variety of ways, but owners and operators of critical infrastructure/plant commonly use the term 'asset management' to mean, the investment, utilisation and maintenance of physical plant and infrastructure over its life cycle. The driver for this has been the emerging need to demonstrate clear responsibilities for safety, efficiency and cost effectiveness.

Asset management systems provide a framework for defining and specifying what, why and when activities should be undertaken, including the linkages between asset management strategies and the overall objectives and plans for the entire organisation. It recognizes that there is diversity in asset type, condition, performance and business-criticality.

A key requirement in the asset management of major hazard infrastructure is integrity management. Integrity means that the quality and condition of the asset is such that it is fit for purpose to meet operational requirements with an adequate safety margin. This means that the probability of failure must be low as reasonably practicable at all stages of the asset's life cycle. Management of integrity over the life cycle involves ensuring the correct level of integrity is established at design and construction stages, and then maintaining a level of integrity which ensures the pipeline is fit for purpose to meet operational requirements with an adequate safety margin.

Typically, the change in the probability of failure of an asset varies throughout its life is described by the bathtub curve (Figure 2):

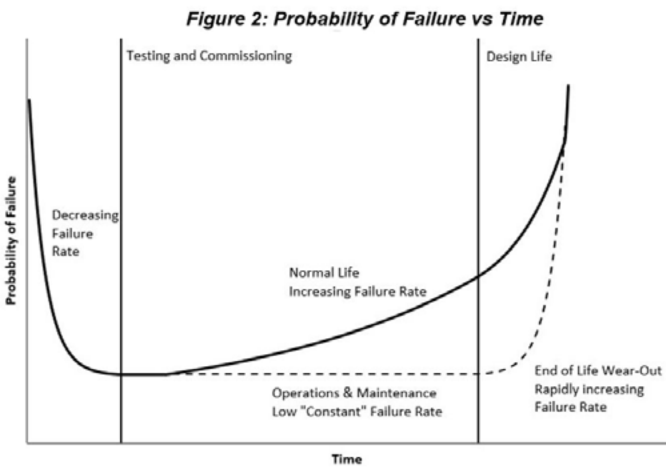


Figure 2: Probability of Failure vs Time

In considering high pressure gas assets, the potential for a high probability of failure at the start of life is removed by the pre-commissioning pressure test, which removes material, construction and fabrication defects and establishes a low probability of failure as the asset goes into operation. The probability of failure is then controlled throughout the operating life by inspection and maintenance activities. In the event that the asset is subject to degradation due to time and or duty, the probability of failure will eventually increase with time that signals the end of life.

However, where the integrity management process includes identification of damage, inspection to characterize and size defects caused by damage, assessment of detected defects and repair of any defects which threaten the integrity of the asset, the increase in the probability of failure which indicates the end of life is avoided and the asset integrity is confirmed or validated. When this process is repeated at regular intervals, the asset integrity is revalidated and the operation of the asset is confirmed as safe for a further period of time (Figure 3).

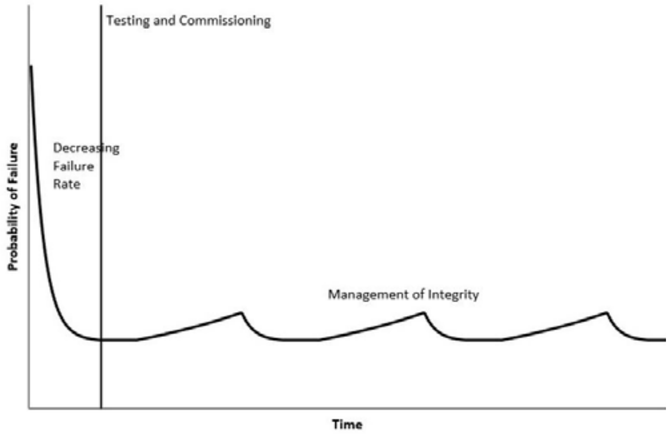


Figure 3: Inspection Intervals

The primary activity in integrity management during operation, particularly as assets age, is inspection and defect assessment. For pipelines, inspection is carried out by regular inline inspection. The inspection technology applied is robust and mature, and the detection of damage features and accurate sizing of these is established. The results of an in line inspection run provide defect locations and sizes, and assessment methods are applied to determine whether the defect is acceptable or requires repair. As repair is disruptive and requires planning to minimize operational disruption, defects that are currently acceptable but may increase in size are identified and the timescale for re-inspection is established so that potential growth of the defects can be monitored.

The simplest inspection and maintenance philosophies are those in which activities are carried out at fixed intervals based on time or duty. In the last 30 years, significant effort has been directed to development and implementation of condition and risk based philosophies in the oil and gas industry. The main drivers are to ensure cost effective and efficient inspection and maintenance, that targets intrusive maintenance and inspection and repair activities at assets which require this. Condition based approaches are applied to plant and equipment in which changes in condition can be monitored, while risk based approaches are applied to assets for which causes of failure are known, data related to frequency and consequences of failure exist allowing failure to be predicted. Condition and risk based approaches are applied to specific assets, and so good asset records including, type/design, age functionality and operating regime, as well as condition monitoring, inspection and maintenance histories and fault histories. In addition, risk based approaches require assessment of threats and control measures, so that these can be included in the prediction of risk levels.

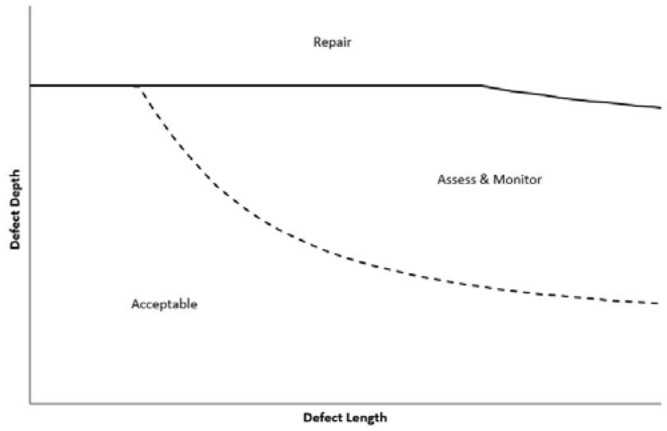


Figure 4: Defect Action Requirements

The primary causes of damage to gas (dry) pipelines are external interference, external corrosion, ground movement and natural causes such as flooding. For the associated installations that are located within a secure site, the primary cause of damage is external corrosion. External corrosion of above ground pipework and components can be detected by visual inspection, but below ground pipework on the NTS cannot be easily inspected. Inline inspection of installation pipework is not possible due its complexity. Therefore the GRAID project is investigating a robotics solution to permit inspection of buried pipework at installations which will then allow condition assessment algorithms to be developed, permitting the operator to optimize their asset management strategy.

PROJECT CONCEPTION

The project came about as a result of Ofgem's (Office of Gas and Electricity Markets) Gas Network Innovation Competition (NIC), which is an annual opportunity for gas network companies to compete for funding for the development and demonstration of new technologies, operating and commercial arrangements. Funding is provided for the best innovation projects that assist all network operators to understand what they need to do to provide environmental benefits, cost reductions and security of supply as Great Britain (GB) moves to a low carbon economy. Up to £18m per annum is available through the NIC scheme.

The NIC process began in May 2014 with an initial bid containing a detailed description of the problem that needed to be solved and how the project will solve that problem, with particular reference to the financial and environmental benefits to UK gas consumers. The bid then went through an Ofgem screening process and a panel interview for the key members of the bid team. Further project details were provided at the request of the panel team and in Nov 2014 the project was awarded £5.6m with a further £630k provided by NG as a compulsory contribution. Project direction was received in December 2014 and the Project GRAID commenced on 5th January 2015.

PROJECT OUTLINE

Project GRAID will design and develop a remotely operable robot that can be inserted into live, high pressure (up to 100barg), mild steel pipework systems to undertake both visual and physical inspection of the otherwise inaccessible buried sections of the system. The robot will be self-powered, highly articulate and able to move at will throughout the pipework.

Traditionally the onshore pipeline industry has only been able to in line inspect high pressure pipelines using PIGs. In line inspection of pipelines provides the most accurate and reliable information on the condition of buried pipelines, other inspection methods external to the pipeline have a number of limitations. This innovative robotic technology will however increase precision in the applied predictive methods. Ultimately, below ground pipework on installations however cannot currently be in line inspected because of a number of engineering challenges associated with complex pipework geometries, lack of access, retrieval points and flow factors.

The project has four key objectives:

1. To accurately and reliably determine the condition of high pressure below ground pipework at AGIs using an internal inspection robot.
2. To generate a proactive, rather than reactive, risk based approach to the management and maintenance of aging assets, based on the knowledge of the actual condition of pipework.
3. Minimise the occurrence of annual unnecessary excavations and eradicate premature replacement of assets reducing significant carbon emissions and generating cost savings of circa £58m over 20 years. The reduction of unnecessary excavations and reduction in premature replacement of fittings as well as resulting in a financial savings also results in a carbon footprint saving. Each excavation and fitting has a carbon footprint, therefore eliminating or reducing the need for excavations or fitting replacement reduces eliminates or reduces the carbon footprint.
4. Minimise the likelihood of asset failure through proactive asset management, thereby significantly reducing the risk of a high pressure gas release into the atmosphere and the consequential financial, environmental and reputational impact.

The robotic platform will undergo a series of offline and online trials to ensure it can effectively solve the current asset management challenge of inspecting below ground pipework at high pressure installations. A bespoke offline pipe configuration will be built in order to trial the robot within a high pressure environment, and before it is trialed on a live site.

There are three clear solutions which will be enabled by solving the current challenge NG has with its asset management strategy for below ground pipework at high pressure installations:

1. Repair and maintenance of critical assets will be better targeted allowing for a reduction in unnecessary excavations.
2. The life of assets will be extended due to an accurate understanding of condition ensuring that premature replacement will be prevented.
3. The likelihood of a high pressure release will be significantly reduced.

The project is divided into 5 stages:

STAGE 1 – SOLUTION DEVELOPMENT: JAN 2015 – OCT 2015

Stage 1 of the design process involved 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 print 3D space models. These space models are used to test first principles of concept design and will be developed further during stage 2. Simultaneously, Premtech will design and a prototype insertion and extraction device. Its design must be specific to the robot proposed by Synthotech, therefore a close working relationship between Premtech and Synthotech is required. It will be designed and appraised in accordance with relevant NGGT design codes.

Site surveys and laser scan profiling (see Appendix 1 for details) will be carried out to support the data taken from as-built drawing records of each site. Production of 3D digital models of the chosen live trial sites will be produced from this data for numerous uses later in the project.

STAGE 2 – DEVELOPMENT TESTING: OCT 2015 – SEPT 2016

This phase will see the development of the 3D space models with conversion to metallic and plastic components as well as the addition of bespoke electronic components (circuits and motors) drive mechanisms (gear boxes), software development, and power. Using the 3D trial site models, insertion and extraction points selection will take place early in this stage to allow site design changes to be carried out and reported. The selection of the insertion and extraction points will also allow robot route selection and determination, the extent of which will be limited by its design parameters and illustrated on a 'go / no-go' style drawing.

A large scale test assembly for field trials will be developed to allow the robot to be tested through pipework with geometry similar to that it will encounter on the sites whilst in a pressurised environment.

Using knowledge gained during the site design changes in stage 2 future site design requirements will be identified and reported. All of the preceding work at this point will be used to determine the inspection carbon footprint.

STAGE 3 – FIELD TRIALS: SEPT 2016 – APR 2018

Stage 3 relates to the detailed process of testing the design and functionality of the robot and is essentially broken into specific stages:

1. Offline Testing – To be carried out on bespoke simulation test rig.
   This will be carried out on the specifically developed simulation rig, to provide a safe testing facility to validate the robot's ability to carry out tasks and determine improvements in design related to function or performance prior to commencing any 'live' trials.
2. Online Testing – To be carried out on an installation under 'Live Gas' conditions.
   This will be carried out under live gas conditions on selected NGGT AGIs during summer outage. The purpose of these trials will be to validate the design and performance of the robot in the 'real world' and allow for refinement of designs and processes for inspection of unpigged sections of the AGI.

At the end of stage 3, analysis of measurement and inspection data obtained during the field trials will take place. It is proposed that condition assessment algorithms will be developed to allow confidence estimations to be made on the condition of pipework that is unable to be accessed by the robot. Data will also be used to establish a site condition index and condition assessment criteria.

STAGE 4 – DATA ANALYSIS APR 2018 – SEPT 2018

Stage 4 is focused on the further development of the robotic platform into a pre- commercially viable solution and the validation of data generated during the complex testing during stage 3. The data validation will be carried out independently of Synthotech and Premtech, by PIE, in order to ensure third party assurance.

Stage 4 may require further online field trials on an AGI, but this will be purely to refine data capture results to allow the creation of algorithms to within an agreed standard deviation so that data collected can provide an accurate indication of the asset condition.

From a product validation perspective all online tests will be used as an opportunity to train the agreed process owner, which will be the National Grid Pipeline Maintenance Centre (PMC).

STAGE 5 – BUSINESS READINESS: SEPT 2018 – NOV 2018

Stage 5 relates purely to the activities required to provide a pre-commercialised robotic solution to the agreed end user, this involves the dissemination of all data required for operation, calibration and maintenance of the inspection robot.

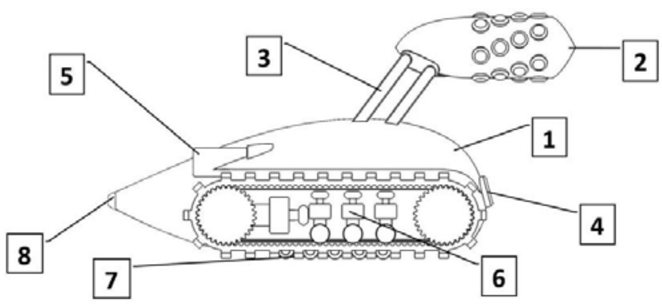
PROGRESS TO DATE

Project GRAID has completed stage 1 (30th October 2015) and stage 2 is underway, due to be completed September 2016. The project team has been mobilised and solution development has enabled the project to construct a validated design definition, feeding the development of the robot design concepts. The conceptual design of the test facility and launch and receive vessel are completed.

In summary:

ALPHA DEVELOPMENT

Alpha development of the robotic platform represented Synthotech's design methodology for stage 1 of the project. It encompassed all of the activities contributing to the eventual production of the preferred design in 3D printed models. Since the last progress report Alpha development has focused on drive systems, vision and sensor packages, control software, the umbilical/tether and computational fluid dynamics (CFD). CFD has grown in importance as the team has developed its understanding of the environmental conditions found inside high pressure pipework. Synthotech have produced two 3D printed prototypes of the preferred design and the backup design for bench testing. They have also conducted experiments with wireless technology, investigating the range and integrity of wireless signals inside buried pipework, the results of which will be included in dissemination activity. Three different robot concepts have been investigated by the project, and an example is illustrated below.



1. Streamlined low profile body
2. Modular NDT scanning module
3. NDT Articulation system
4. Forward camera
5. Rear Facing camera
6. Drive tracks and suspension system
7. Magnetic free rolling wheels
8. Umbilical connector

TRIAL SITE MODELLING

The closure of stage 1 saw the completion of the 3D models for the project's three trial sites. This has been one of Premtech's main work packages and resulted in three highly accurate 3D models of Above Ground Installations (AGIs). The data contained within the models has provided the project with the means to identify potential launch locations as well as identify routes that the robot can take in order to meet the project's scope definition. This is crucial as access to the pipework at high pressure installations is limited due to the fact that they were never designed to be in-line inspected. Site access will determine robot routes, which in turn determines what percentage of each AGI can be inspected. The 3D models have also proven useful to other parts of the business with various projects realising savings of £63k as a result of using data from the models.

TEST FACILITY CONCEPTUAL DESIGN

The offline test facility has been the subject of much analysis, particularly concerning its construction and location. Following a tender process followed by a cost-benefit analysis, it was decided that outsourcing the test rig to a third party represented the lowest risk option and the best value for money. Stage 1 saw Premtech complete the conceptual design for the test facility, which will now be transferred to the third party contractor for detailed design and construction (subject to contractual confirmation). The conceptual design has enabled Synthotech to produce a draft test strategy for offline trials and better understand the characteristics the robot must be able to demonstrate before the project team is allowed to conduct online trials.

LAUNCH VESSEL DESIGN

This reporting period saw the completion of the conceptual design of the launch and receive vessel. The vessel's final design is dependent on confirmation of the robot's dimensions and the end-closure that will be used, which is subject to an NGGT safety approval process. The key features are the through-wall connection providing power and connectivity to the robot, and external hand wheel and through-wall stem for manual retraction of the robot in the event of a power failure.

CFD STUDY

An important element identified during this reporting period has been the requirement to understand the drag forces that will be applied to the robot while it conducts an inspection of the buried pipework in a live gas environment. A preliminary numerical analysis has been conducted and formally reported by Newcastle University which included the development of a theoretical model for the calculation of the drag force on an object subject to high gas pressure and flows in a pipework system. The next stage in the study is to conduct Computational Fluid Dynamics (CFD) simulations in order to be able to relax some of the assumptions made in this study, and specifically to improve on the one dimensionality of the flow and include the effects of fluid compressibility. Premtech has been primarily involved in the creation of accurate 3D models of the three online trial sites and the conceptual design of the offline test facility and launch and receive vessel. See figures 5 and 6.

By using a combination of laser scanning and original design documents, with the use of component / pattern recognition software (see Figure 7) to develop component and material information (see Figure 8), they are creating accurate 3D computer models of the three online trial sites.

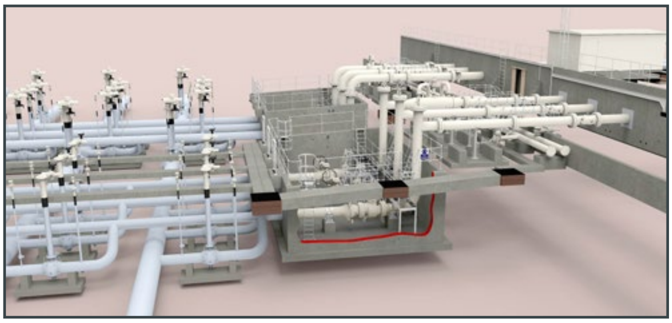


Figure 6: 3D Model Example (complex)

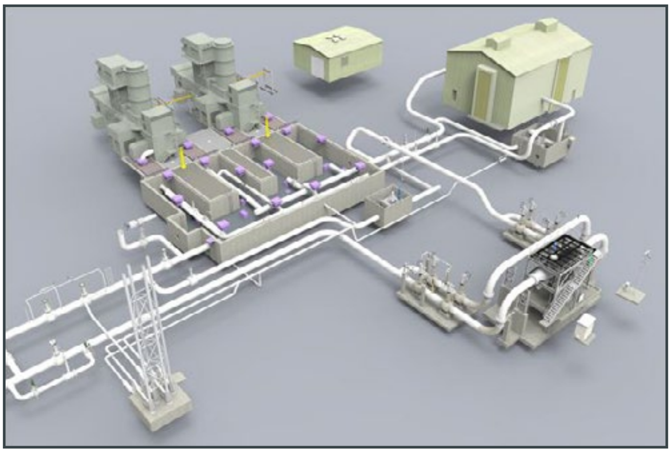


Figure 5: 3D Model Example (simple)

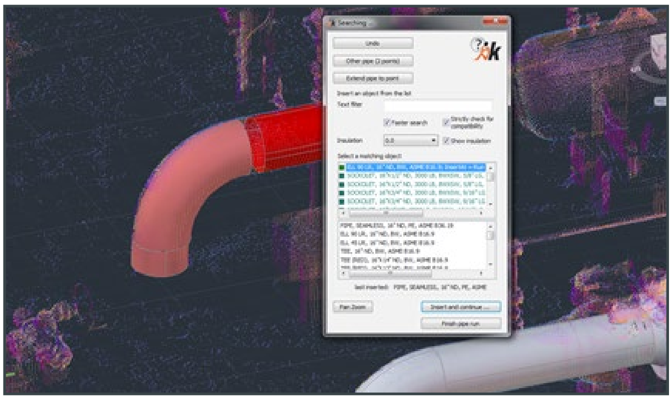


Figure 7: Component Recognition Software

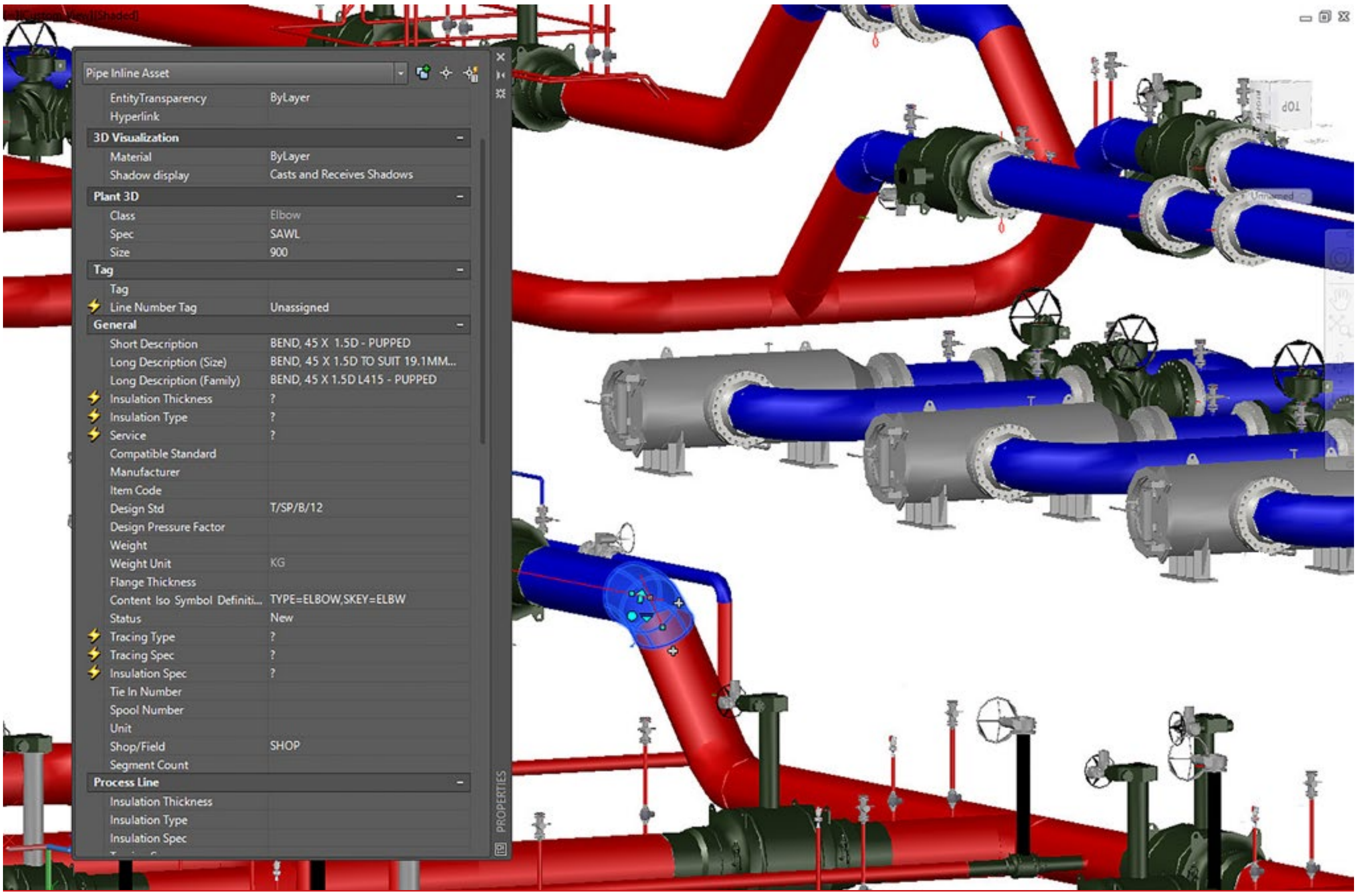


Figure 8: Component / Materials Details

This will feed the robot's navigation system as well as preparation of the trial sites for the robot's insertion. Laser scanning is a non-destructive, non-contact technology that digitally catches the shape of physical objects using a laser – see Appendix 1 for further details.

The conceptual design of the offline test facility and launch and receive vessel will enable the start of the materials procurement process and construction activities, the delivery of the offline test facility and launch and receive vessel will be closely linked to the robot's development.

Synthotech's activity has so far revolved around the themes of concept studies and early design development (Alpha design) of the robotic platform. During the early part of the stage they conducted a detailed study into the project's design requirements, refining and defining the specification scope in order to focus the development of the robot's key sub-systems and sensor packages. By analysing the robot's anticipated operating scenarios the team has been able to investigate a range of cutting edge technologies to support data gathering, mobility, and survivability. By bringing together a team of subject matter experts they have been able to conduct novel studies on the condition and behavior of natural gas at high pressure and how it might affect the robotic platform. Concurrently, a review of applicable legislation and regulations has ensured that the robot's design accounts for any necessary compliance.

Synthotech are also working very closely with their supply chain and more importantly academia (University of Leeds, University of Aston, University of Newcastle), and this approach was a key factor in Ofgem's confidence that a knowledgeable and extended "Hub" will support the project.

PIE has provided a technical assurance and governance role by providing an independent assessment of technical documentation, and assisted in developing the project technical strategy. Conducting defect sensitivity calculations and an assessment of robot drag forces has provided further support.

LOOKING FORWARD

The project is now progressing into stage 2 to develop a working prototype ready for offline trials. The key tasks and areas that are now being addressed are:

- Implement design and specification changes from Stage 1 to Stage 2.
- Manufacture and assemble bench test prototype.
- Laboratory and workstation testing.
- Construction of test loop for offline testing
- Determination of connection locations for live site test
- Design review and design for manufacture analysis (DFM).
- Stage 2 bench test demonstration.
- Stage 2 technical report.

The next project phase (stage 3) will include construction and commissioning of the offline test loop, followed by robot testing.

APPENDIX 1: DESCRIPTION OF LASER SCANNING TECHNIQUE

INTRODUCTION

Laser scanning is a non-destructive, non-contact technology that digitally catches the shape of physical objects using a laser. Laser scanning requires a high accuracy scanner mounted to a fixed Surveyor's tripod. The scanner rotates at very high speeds while a laser delivers a reflecting beam with exceptional precision at physical objects, potentially recording up to one million points per second.

Once all points have been collected by laser scanning a "Point Cloud" of data for a specific object can be created. Essentially, 3D laser scanning is a way of capturing physical objects precise size and shape by converting it into a digital 3 dimensional representation.

Laser scanning has the ability to measure fine details of free form shapes and can produce very precise point clouds. It is ideal for the inspection and measurement of contoured surfaces and complex geometries, which would require huge amounts of physical data to accurately describe; this is impractical using traditional methods.

TYPICAL SCANNING EQUIPMENT

LEICA P20 OR LATER MODEL OR SIMILAR APPROVED TIME OF FLIGHT LASER SCANNER

A "Time of Flight" laser scanner measures the distance a laser beam travels to an object and how long the laser beam takes to bounce back. By knowing the speed of light and measuring the time it takes the laser to bounce back, the distance can be calculated by multiplying the time divided by two and multiply it by the constant for the sound of light. The scanner will also measure the horizontal angle from a given known line and the vertical angle from gravity. Once these are computed X, Y, Z positions calculated.

Therefore a "Time of Flight" scanner does nothing more than measure a distance and horizontal and vertical angle for every position it is at. This is done by the scanner moving in a grid fashion in 360 degree in the horizontal plane and 330 degree in the vertical plane.

LEICA TS15 I 1 R1000 IMAGING TOTAL STATION

The Leica TS15 I 1 R1000 is a precision angle measurement instrument that is used in advance of the scanner to provide high accuracy distance and horizontal and vertical circle readings that are automatically corrected for any "out of level" by a centrally located twin-axis compensator. The coaxial Electronic Distance Meter (EDM) measures to a prism located on temporary tripods at an accuracy of 1 mm + 1.5 ppm (parts per million). With a resolution of 0.1 mm. These advance readings allow the surveyor to create an adjusted closed loop traverse of the site to the highest possible accuracy.

LEICA GS15 GNSS RECEIVER

Leica GS15 GNSS (Global Navigation Satellite System) is a satellite system that is used to precisely locate the geographic location of a user's receiver anywhere in the world. Satellite based navigation systems use triangulation to location the receiver, through calculations involving information from a number of different satellites. The GS15 will generally be set up just outside the entrance to a site or if the site has a datum point it can be positioned there to find its exact location. This will allow the transformation of all coordinates measured on site to reference British Ordnance Survey National Grid coordinate system and datum.

MAGNETIC TARGET PLATES

To allow accurate geo-referencing of scans, the surveyor will strategically position magnetic target plates around the site either on the security fence (If metallic) or on any existing infrastructures such as pipework or supports. The magnetic target plates will be positioned in the areas that are to be 3D laser scanned. Generally a larger site will have between 6 – 12 targets. These target locations can be altered if required. To correctly geo-reference each scan at least three targets have to be in the line of sight of the scanner.

LASER SAFETY

Lasers in some cases can be harmful, however the lasers used in this laser scanning process are safe under all conditions of normal use and are not dangerous to anyone or anything.

TRAINED SURVEY PERSONNEL

A suitably qualified and experienced engineering surveyor shall oversee all aspects of the laser scanning and data processing procedures. To maintain the highest levels of quality the Surveyor should be a full member of the Royal Institution of Chartered Surveyors (RICS), Chartered Institute of Civil Engineering Surveyors (ICES), or of equivalent professional status and / or experience. Both the RICS and ICES have minimum competent standards for full membership as well as a continuous professional development structure that requires all members to be up to date with developments in best practice. Details of these standards can be found on the appropriate web site.

FEATURES TO BE SCANNED

The following is a list of key features that should be recorded during the laser scan of a gas site:

- Gas Pipework, Equipment and Components
- Buildings and Structures
- Security Fence and Egress Gates
- Roads, Ducting and Kerbing & Drainage
- Civil Bases
- Ground Levels
- Masts, Gantries, Overhead Structures
- All Signs / Posts

Unless otherwise stated the internal features of buildings will not be laser scanned. All scanning will be limited to the sites external environment unless otherwise stated by the Designer.

CALIBRATION

All laser scanning equipment and measuring equipment should be fully calibrated before any laser scanning can commence. The equipment should be fully calibrated as per the manufacturers manufacturing recommendations and servicing agreements.

The Surveyor shall guarantee the calibration of each piece of equipment and shall provide copies of relevant certification to the Designer. Under no circumstances shall equipment that does not have a current calibration certificate be taken to site and used.

LIMITATIONS

Scans require a direct line of sight between the scanner and the object of interest. Any unwanted items should be removed from the area of interest as the scan will pick them up.The quality of the scan depends on the reflectivity of the objects in the survey area. Specific surfaces and the angle of incidence can affect the quality of the scan. And also any dark surfaces will not reflect the laser as well as lighter surfaces and with transparent objects the laser will travel straight through.

WEATHER

The quality of the scan will be affect by poor weather such as rain and snow as these types of weather produce unwanted noise that the scan will pick up. It is recommend that the weather should be checked before going to site and if it was to rain or snow heavily during a scan, the scan should be suspended.

SEASONS

Generally scans will take place between the hours 09:00 and 17:00. During winter month's theses hours will not be possible and also visibility will generally be poorer than in spring and summer. For scans to be of a good quality, a bright day is required as the duller / darker the day the poorer the quality of the scan.

It should be noted that the limitations above can be eliminate by proven field techniques combined with the use of sophisticated point cloud processing software. Shadows

Direct line of sight is required to all survey areas to create a complete point cloud. Where this is hampered by objects obscuring the survey area 'survey shadows' are created. Shadows will be minimised by utilising multiple survey points as well as alternating high and low setups. Some shadowing is inevitable but by applying best practice it will be reduced to a minimum.

AUTODESK AUTOCAD PLANT 3D

Autodesk Plant 3D uses a combination of different Autodesk design suite packages that helps to streamline 2D drafting, Piping and Instrumentation Diagram (P&ID) design, 3D modelling and the creation of documents.

AUTODESK PLANT 3D

Autodesk Plant 3D is a mechanical design package for designing three dimensional plants. All part components in Plant 3D are full of underlying data that is exchanged directly between P&IDs, Piping Isometric and orthographic drawings to help keep all drawings consistent and up to date.

AUTOCAD P&ID

Designed especially for P&ID Designers AutoCAD P&ID is full of design tools to help automate and simplify designs. AutoCAD P&ID has symbol libraries that are full of industry-standard symbols that can be placed in drawings.

PLANT 3D PART CATALOGUES

Plant 3D streamlines the placement of pipework, fittings and associated infrastructure by using spec-driven technology and standard part catalogues such as ANSI/AMSE B16. Plant 3D will require the development of custom National Grid specification catalogues. Site specific catalogues will be required with site specific data such as correct specifications when constructed, material grades and thickness.

KUBIT POINTSENSE

Kubit PointSense is an add-in to Plant 3D that helps to process point cloud data. It has automation and pattern recognition that allows the use of the "Walk the Run" function that is used by selecting two points on a pipeline in the point cloud. The software will then instantly calculate what size diameters pipe it is, calculate the pipes centreline and position the pipe correctly. With the use of the catalogues bends, tees and other fittings are recognised and positioned accurately using the point cloud data.

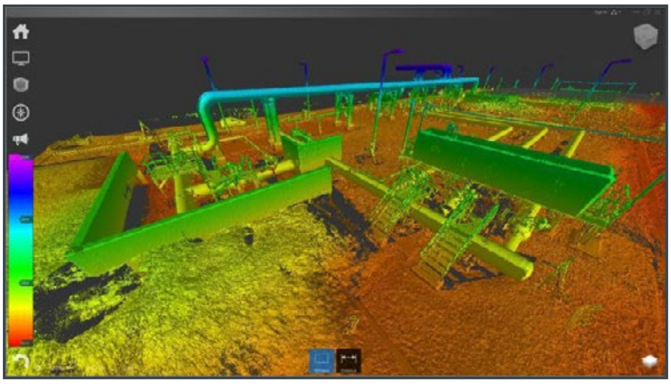


Figure 9: Laser Scan Outputs

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Hot tapping and product theft on pipelines: A way to detect and locate these spots during normal operation

Rene Landstorfer > GOTTSBERG Leak Detection GmbH & Co. KG, Germany

Abstract

About 10 years ago, theft on pipelines had been a crime that was taking place in only a few regions far away from Europe. Within the last years this problem approaches nearly every country faster and faster. In 2013 there had been the first big incident of this kind in Germany. A 12" product line had been tapped, product had been stolen and 5000 m³ of soil had been polluted. Still this isn't common practice here in Germany, but it starts to become so.

In other countries the situation is much worse. Nigeria for example is losing almost 15 % of its oil production through theft on pipelines. At current prices this would mean a financial loss of almost 3 Billion $ per year. Another example for the increase of vandalism is Mexico where an incline of up to 58% of registered pipeline taps took place in the first quarter of this year compared to last year`s first quarter

Today the criminals are working very sophisticated with a lot of experience and professional equipment, so that there occurs for example no big pressure wave that can be detected by pipeline monitoring systems. Also the holes they drill are so small, they cannot be detected with online leak detection systems. Even the amount of product removed is small enough to not be detected by flow measurement from input to output of the pipeline.

One of the few ways to detect and locate spots where hot tapping and theft is taking place are leak detection pigs like the ones from GOTTSBERG Leak Detection. They are directly passing the actual leak and therefor can detect very small holes in the pipe wall. This would also be the benefit of these tools when the operator is not expecting the event of thievery along their pipeline.

Defects along the pipeline that are too small to be detected with metal loss or crack detection pigs can lead leaks that then will also not be recognized through permanent monitoring technologies. These are without exception not capable of finding small leaks of less than a few hundred liters per hour leak rate.

The GOTTSBERG tools however have a certification from the German TÜV for a smallest detectable leak rate of 6.8 liters/hour at 6 bar, which corresponds to a drilling hole of around 0.3 mm. Additionally the GOTTSBERG tools are the only intelligent pigging devices in the world with an ATEX certification for Zone 0. This means an immense simplification when it comes to handling and regulations for the use of the pigs in explosive atmospheres.

The presentation will give an overview on the world wide thievery of product out of pipelines and its development in the past and future. Using the example of the Gottsberg Leak Detection tools, different approaches in detecting and locating these leaks during normal pipeline operation will be presented.

INTRODUCTION

Pipelines have ever since been a subject to vandalism and theft. Political conflicts for example have often led to vandalism. Also acts of terrorism where pipelines have been destroyed and catastrophic consequences occurred have been common problems in the last decades.

Nowadays pipeline theft more and more becomes an issue. With oil prices that had been high until 2014 it became a lucrative business for criminals. Fuel theft for example in Mexico has evolved from a small time criminal activity carried out by robbery rings and corrupt distributors to a sophisticated operation linked to Mexico's main criminal groups, the drug cartels.

Thieves drilled around 2,500 illegal taps in the first nine months of 2014, and stole more than $1 billion in fuel. They have recognized the high profits that can be made and slightly widen their business. One gang member gave an interview and said he chose oil theft as a safer alternative to armed criminal activity, said that stealing 10,000 liters of crude from one pipe represented a profit of about US $4,600, and tapping into the pipeline took about half an hour.

Additionally it is safer to steal oil or products than to smuggle drugs. The officials said: "If you manage to hold a suspect, it is still complicated because of the fact that it is almost impossible to determine the owner of stolen oil, it is impossible to determine "Who does it belong to?" And as a consequence - it is impossible to prove the guilt of the criminal."

But this is not only a problem in Mexico. All over the world hot tapping and thievery at pipelines is a growing problem and it is not anymore only related to developing countries. In China it is the cause for 40% of all pipeline leaks.

In England thieves have stolen 1.4million gallons of fuel from an Esso pipeline that runs underneath the Liberal Democrat Deputy Prime Minister's land. This was an £8MILLION oil heist and almost 300,000 liters a day were stolen from the pipe, which runs under Clegg's Chevening House estate, in Sevenoaks, Kent.

Also in Germany this sort of crime gets more and more common for pipeline operators. The thieves are mostly well equipped and bring a lot of experience to not being caught. They can for example vary the method including intermittent taps, graduated taps and/or smaller volume taps. Also in many cases they seem to have good contacts to the operators, so that they know when certain products are transported and when it is the right time to siphon them off.

In most cases they are hot tapping the pipelines, attaching something like a valve and a hose that can even be kilometers long so that the point where they load the product is far away from the place where the pipeline is damaged. They then for example load the product to vans equipped with tanks or even underground storage facilities and can escape without causing a stir.

Figure 1: Pipeline Leckage

Figure 2: Loading tool into launching trap

Figure 3: Pig trap

SOLUTIONS FOR DETECTION

There have been a variety of ways in which these hot taps have been discovered, which can vary from specialist pipeline monitoring technology to a member of the general public discovering it while walking their dog.

In worst cases the criminals abandon the place where they have drilled the pipeline even without shutting off the generated leak and leave it spilling to the surrounding. That of course can lead to immense environmental pollution, loss of product and a big damage to the operator's image even though this "accident" is not the operator's fault.

This all is the reason why pipeline companies have to take great endeavors to make their lines safe and to detect hot tapping spots as early as possible.

There are technological ways to find these spots already when they are created. For example optical fibers can be installed along a pipeline and can detect the vibrations or sound from drilling into the pipe wall or even digging next to it. This technology can be a solution for future pipelines that still have to be built, but for financial reasons it is hard to be installed on already existing pipelines that are buried. Also it is very easy to disable these systems by just destroying or cutting the fiber.

In this case visual arial or overground inspection is possible or inline tools are used to detect the noise produced by the leak.

The holes drilled into the pipeline are in most cases very small, so that they cannot be detected by any online monitoring system. It is common that thieves try to stay below the threshold of these technology to not being detected. Besides the threshold rises with the size of the pipeline and that makes it possible to siphon relatively big amounts of product without being discovered.

GOTTSBERG Leak Detection is developing and producing very sophisticated leak detection pigs that are capable of detecting smallest leaks or siphons down to a leak rate of less than 10 liters per hour. This is way below the amount that would be lucrative for oil theft.

Still there is one challenge to be accepted. The tool only works when the leak is actually open. Only then it produces the noise that can be recognized by the device. The noise arises from cavitation that occurs when a pressurized liquid expands to a vicinity with lower pressure. Gottsberg has recently done some series of tests to evaluate the working principle for the case that the pipeline is not leaking into the environment around the pipeline but instead into a long hose attached to the actual leak. As sound travels very good in liquids, the pressure difference producing the cavitation can also be far away from the actual hole in the pipe wall and therefore be detected reliably with the GLD tool.

There are different ways to solve the problem with theft that can only be detected when it effectively is in use.

First one would be to do runs very frequently and especially at the time when the theft is suspected to take place. As the Gottsberg tool is very easy in handling, it takes not more effort to run the tool than to do a cleaning run. That is why it is no problem to repeat a run as soon as the tool has finished the last one. Also it would be possible to run more than one tool and start a new one at certain intervals for example.

The second way would be to place the tool in standby into the launching trap and then start the run when the theft is taking place. That can for example be done by time when the operator knows that they are tapping during a certain time of the day, but also when for example the SCADA system recognizes discrepancies in flow or pressure. In that case the tool is just used to pinpoint the spot where product loss takes place.

Therefor the Gottsberg engineers have developed a new and very precise way to locate anomalies along the pipeline. A combination of odometer wheels with speed and distance measurement, an IMU and the pipe tally lead to an accuracy of 2 – 3m during the first run. This is way below the precision that comparable tools can achieve. In the past, Gottsberg has detected and located several cases where illegal connections had been fitted to pipelines and product had been stolen. Therefor some of our customers rely on the Gottsberg tools in these cases.

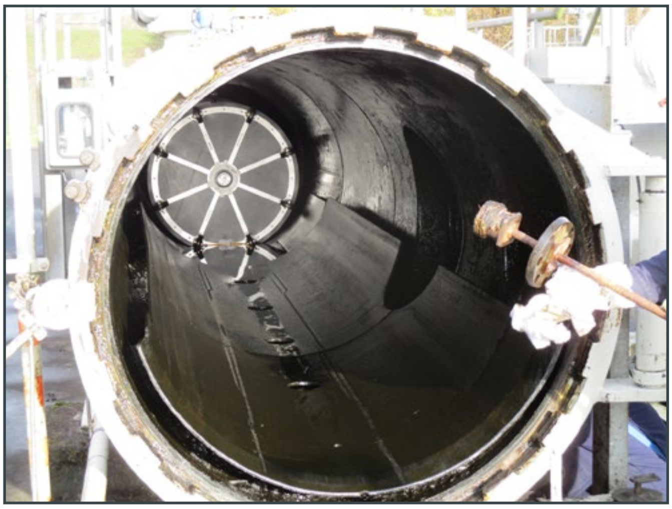

Figure 4: Leak detection pig in pipeline

GOTTSBERG LEAK DETECTION PIG GLD 202

The GLD 202 is not only for the detection of product theft but also for any other leakage detection and can be used as part of an comprehensive pipeline monitoring especially because it is one of the few systems capable of detecting even the smallest leaks. Some of the Gottsberg customers run their tools once a week but, depending on the length of the line, the runtime and the needs of the customer, the devices can be used much more frequently.

The latest generation of leak detection pigs from GOTTSBERG Leak Detection GmbH has been designed to detect and locate even smallest leaks beginning at a TÜV approved leak rate of 6.8 L/hr at 6 bar.

Special attention had been paid to the reliable and simple operation of the tool.

It is the only intelligent pig in the world with an ATEX certification for Zone 0 which means that it can be launched, received and operated without fulfilling any regulation concerning explosive atmospheres around or in the pipeline. That makes it easy for the operator to do runs more frequently because the tool can be used like any simple cleaning or batch pig.

The GLD 202 also runs in pipelines during normal operation. It works at nearly every speed and pressure and the conditions in the pipeline can change during the runs without affecting the operation of the tool. During the run, the tool also records pressure, temperature the distance travelled and speed but most important the noises in the line to detect the leaks.

Compared to other systems working on the same basis, the Gottsberg device splits all recorded noises into 128 channels and works with frequency analysis. This helps avoiding false alarms which is one of the benefits regarding reliability.

Knowing where a noise has its origin is essential when it comes to evaluation of the recorded data.

Figure 5: GLD 202 -200

The complete frequency band is divided into three main parts. The ultra-low frequencies from 10 to 250 Hz, low frequencies from 250 to 2000Hz and the high frequencies from 2kHz to 64kHz where typically the noise of leaks is situated. For example a rumbling of the chassis in the pipeline or contacts with the pipe wall in bends produces noises displayed in the ultra-low frequency band, whereas the noise of a car or engine running next to the line would be displayed in the low frequency band. That gives a very precise view of the origin of a noise.

Turbulences, for example from liquid running around a not fully opened gate valve, would also produce explicit high frequency noises. This is another benefit for the operator, because these sounds help to find positions where the line is not running with laminar flow which means that more energy is needed to run the line.

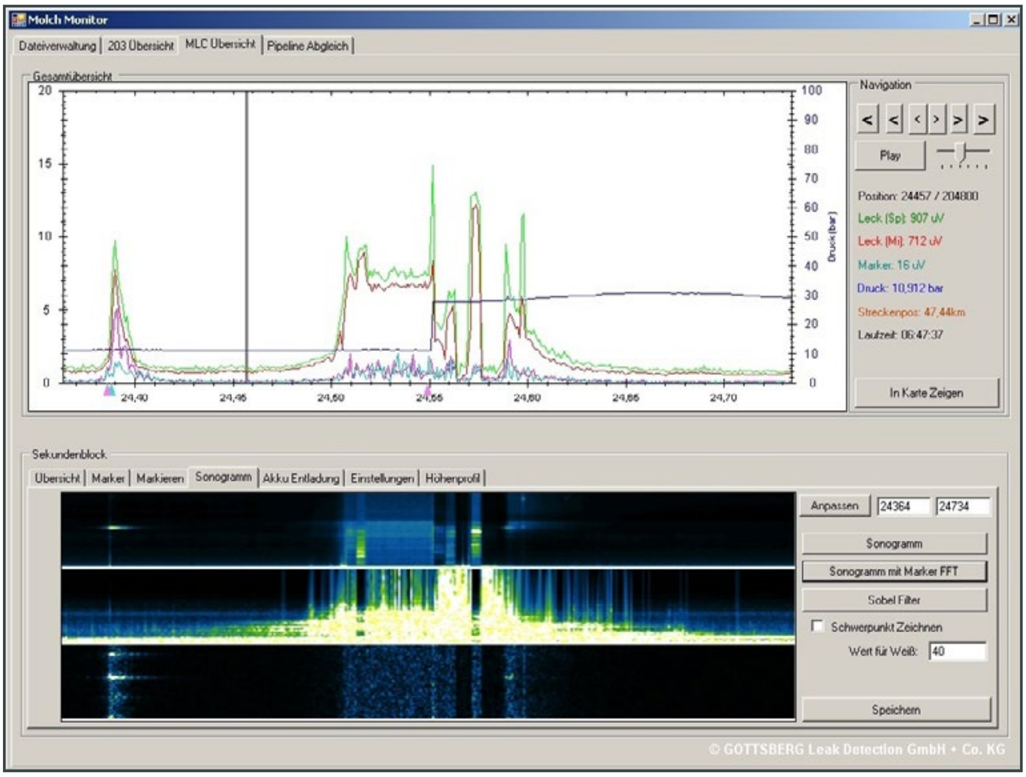

Figure 6: View of a tool passing a pumping station

Figure 6 displays the sounds recorded by a GLD tool running through a pumping station. It can be seen as a good example of the information received by analyzing the noises.
The tool is approaching the pumping station and passes an electronic marker which is displayed in the beginning of the upper third part of the sonogram window by the small white line and also by the first peak in the upper window of figure 6.

Afterwards the device is getting closer to the pumping station and mechanical noises displayed by the right areas in the middle of the sonogram window. It shows all noises from engines running and mechanically moving parts of the station.

The two green vertical lines in the middle of the upper sonogram part are the sounds of the bypass gate valves doors closing and afterwards opening while the pig is lying in the bypass waiting for the pressure to be raised. This sound has its origin in the turbulences of the liquid running around the valve doors. After the pig has left the bypass again a small bright line can be seen in the upper part.

This is from another marker showing that the tool has passed the station. Then the noises from the pumping station are getting quiet while the tool is continuing its detection run.

Another advantage is that the tool itself can be mounted to different chassis to make it suitable for different pipe diameters without the need for a complete new tool for every pipeline size.

Many of the GLD customers have chosen to buy the system and use it on their own. Unlike other leak detection pigs it is so easy to use and so reliable that, after a few days of training by the Gottsberg engineers, the customer can run the tool and do the data evaluation on their own.

Following is another screenshot from the GLD700 Evaluation software (figure 8). This especially developed software can largely work automated and will for example search for the interesting points in the run to list them for the analysis of the operators personnel. Included is also a report function to generate the run reports directly in the software. These reports can be delivered and are accepted by all German authorities.

Figure 7: GLD Chassis GLD 303 – 400, 500, 750

Location of the defects is already done during the run in combination with a GIS. With their own electronic markers GLD 501 and the ability to use virtual markers the tools are able to improve the accuracy know from classic odometers significantly.

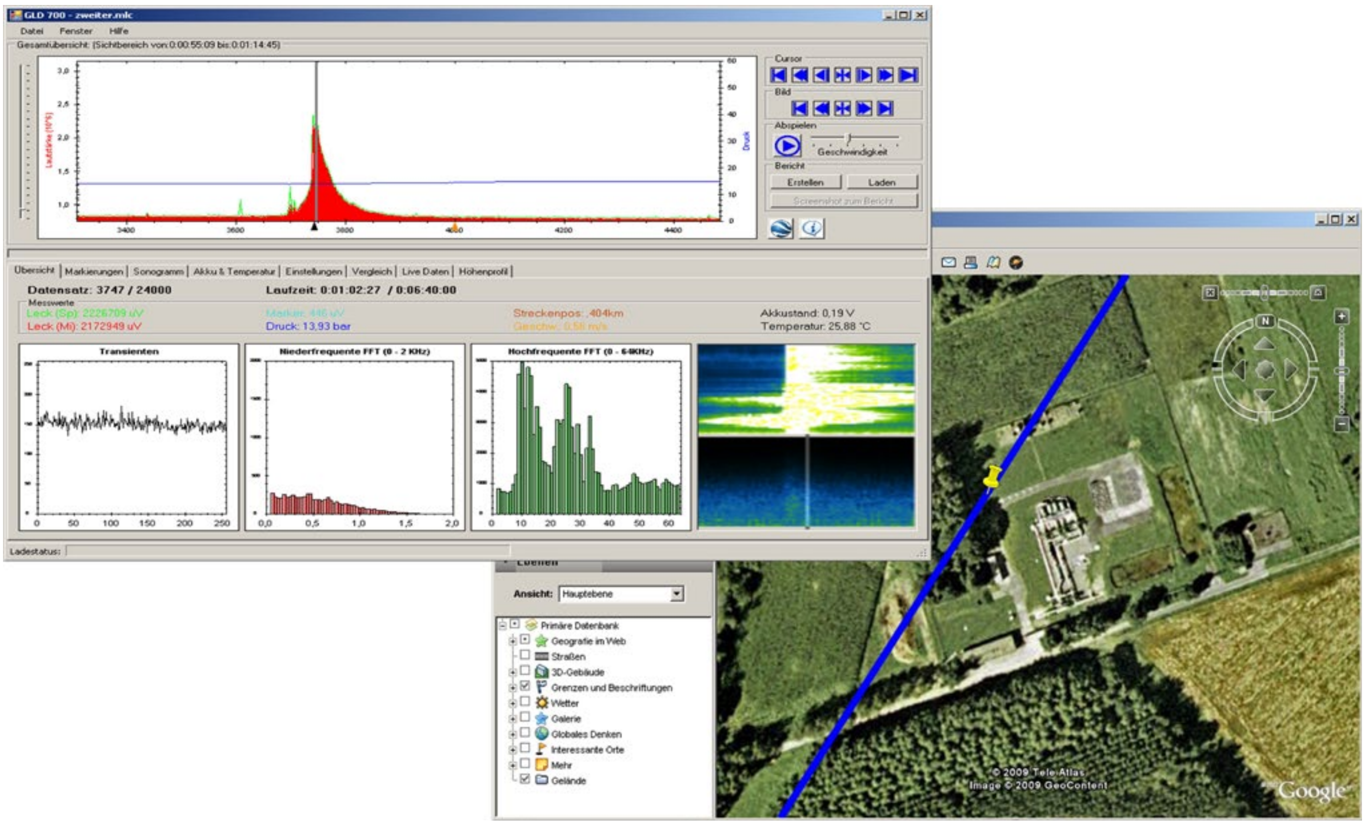

Figure 8: GLD software combined with GIS

The virtual markers can hereby be everything along the pipeline that produces noises at a certain point, like Road crossings, factory but even hill peaks or river crossings.

Besides the leak detection pigs, Gottsberg is also developing and producing other pigging equipment. All necessary product for the safe and reliable function of our tools, like Markers, nonintrusive and therefor safer pig detectors, artificial leaks in electronic and mechanical design for testing of the whole leak detection system.

With their team of experienced engineers it is possible for Gottsberg to provide customized solutions for the clients that fit exactly their needs and wishes.

Author

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The practical nature of ptc was always based on the cooperation with our technical and scientific supporters and on a top-class international advisory committee. The conference will feature lectures and presentations on all aspects surrounding oil, gas, water and product pipeline systems. One of the focus topics at ptc 2017 will be "Pipeline Construction".

Please take a closer look into the Confernce Program and get involved now - register as conference delegate or reserve your booth at the accompanying exhibition. (www.pipeline-conference.com)

I am looking forward to hearing from you!

Yours,

Dr. Klaus Ritter
Pipeline Technology Conference Chairman
Pipeline Technology Journal Editor in Chief
President of EITEP

Core Statements from ptc 2016

Asle Venas,
Global Director Pipelines at the technical service provider DNV GL

"The ptc conference has become the biggest and most important pipeline conference in Europe. I have long time missed a big pipeline event in Europe that could compete with IPC in Calgary and IBP in Rio".

Fouad Mohamed,
Construction Enginner at Kuwait Oil Company

"This is my 1st time in the pipeline technology conference. I think it's a very good opportunity to meet people and share experience and I think I will attend it every year. It is very useful to see other business and technology partners. It is really a good gain for everybody".

DO YOU AGREE WITH THESE STATEMENTS?

Serhil, Konovalov
Global Energy / O&G Lead / IoT Solutions Group - Cisco Systems Inc.

"IoT technologies are demonstrating real economic impact to improve integrity and safety of pipeline operation. However, the lack of operational Cyber Security capabilities puts breaks on innovation and new business opportunities. I believe that pipeline industry like no other, has tremendous potential to harvest benefits of IoT and bring cyber threats under control. Big thanks to ptc and EITEP for leading these important discussions".

Francesco Negro
Mechanical Enginner PROTEC (Projects and Technical Services)
eni Gas & Power Division

"Yearle Chance to be part of Pipeline Technology Excellence".

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Gastech Conference and Exhibition	04-07 April 2017	Tokyo, Japan
12th Pipeline Technology Conference (ptc)	**02-04 May 2017**	**Berlin, Germany**
Pipeline - Pipe - Sewer - Technology (PPST)	**17-19 September 2017**	**Cairo, Egypt**