Innovative technologies for aerial survey of gas pipes

by **Frank Rathlev, Benedikt Meyer and Sven Juerss**

Thyssengas has initiated a project to monitor high pressure gas pipelines with low-weight, autonomous flying drones in the air. This technique will either replace or be in addition to existing air monitoring by helicopter. These drones, which operate more or less independently, are known as Quadrokopters. They come equipped with optical devices which enable the rapid detection of dangerous interference to the gas pipeline. The first objective of this project is the analysis and pattern recognition of possible threats to the gas pipe (such as heavy construction equipment). Furthermore, the system can be used to survey and map newly built or modified pipes. Compared to conventional monitoring by helicopter, drones have the advantages of high environmental compatibility and low noise, as they emit no CO_2 and are extremely quiet when flying. Furthermore, they provide the necessary security in a cost-effective way.

1. INTRODUCTION

Thyssengas GmbH, which is based in Dortmund, Germany, is an independent gas pipeline operator and one of the leading German LNG transport companies.

The company was established as early as 1921 and operated the first German gas pipeline, built in 1910 between Duisburg-Hamborn and Wuppertal-Barmen.

The transport system stretches across large parts of North Rhine-Westphalia and reaches up to Lower Saxony. To control such pipelines, regulation G 466/I provides for various inspection frequencies, depending on whether a pipeline is located in a mine or in a built-up area, for example. In any case, these frequencies are understood as minimum requirements that must be complied with.

Thyssengas has therefore been carrying out aerial pipeline surveys for many years, as a land-based survey across the entire length of the system would be far too labour-intensive. Due to the location of pipelines in Germany's most densely populated and built-up federal land, North Rhine-Westphalia, and the related ongoing construction work, Thyssengas chose to carry out an aerial survey every 14 days (compared with the legal minimum of one aerial survey every four weeks). Every year, some 16,000 building applications are filed for an area where 4200 kilometres of pipeline are buried and about one third of these applications have a direct or indirect impact on these pipelines, requiring local security measures and instructions on site. Each aer-ial pipeline inspection leads to the generation of about 200 – 400 notifications (depending on the season). About half of these contain new, previously unknown information. All notifications are transmitted to our servers at the end of each survey day through an automated workflow (using GSM/UMTS). From here, automatic messages are created in the GIS (geoinformation system in Smallworld) and in the ERP system (SAP PM for movement data), with no need for manual rework. These messages are available to the master areas for processing. Currently we are working to close the media chain and transfer this data to an offline GIS viewer (Lovion Location Viewer) for further mobile processing.

After on-site inspection and instruction by our mobile staff, the data is prioritized and fed back using the same reporting chain to the helicopter, so that the external supervisors inside the helicopter have the latest information.

Yet this process can be improved and extended even further. To this end, Thyssengas has set up a project aimed at carrying out aerial surveys of high pressure gas pipelines with lightweight, selfsufficient drones or complementing the existing helicopter surveys with this technology. These drones, which operate more or less independently, are known as Quadrokopters and come equipped with optical recording systems. In combination with the latest pattern recognition and evaluation software, these systems allow any external impact on the gas pipeline to be counteracted, based on automatically

Figure 1. Aerial photograph taken by an UAV at an altitude of approximately 100 m.

Figure 2. Microdrone md4-1000 with camera system during flight operation.

generated messages which are transmitted to the operating units.

md4-1000 drones made by Siegen-based specialist microdrones will be used for a pilot aerial survey.

2. INFORMATION FROM THE AIR

Microdrones are used wherever inspection by human supervisors would be impossible or too dangerous. With its rugged, weather resistant carbon fibre body, the md4-1000 achieves a flight time of up to 70 minutes. What is more, drones can be fitted with application-specific sensor systems (e.g., gas sensors).

Our pilot project is mostly intended to evaluate and identify the patterns of risks approaching a gas pipeline (e.g., heavy construction machinery). As the available gas sensors are not DVGW approved (DVGW = German Technical and Scientific As-sociation for Gas and Water), they are not appropriate in this context. These sensors are used for other applications, e.g., by the fire brigade.

Microdrones are independently flying utility aircraft which are steered using remote control or GPS Waypoint Navigation. They can be used for a variety of applications. Around the globe, they help different government authorities and organizations with intelligence and hazard control tasks and all kinds of surveillance. The modular utility concept allows the use of a range of instruments. High resolution digital cameras and camcorders, thermography and measuring systems are just a few examples of the broad selection of available equipment.

This makes microdrones a helpful tool for government authorities, the police, fire brigade or nongovernmental security organisations for surveilling, localizing and fighting major hazards. Microdrones are subject to continuous development within the framework of a number of scientific research projects involving various partner institutes and high-tech companies. For instance, microdrones are currently used by the "AirShield project", which is funded by the German Federal Ministry of Education and Research, in an intelligent swarm to measure and automatically capture propa-gating gas clouds.

Within the framework of the "AVIGLE project cooperation", which is part of the "Ziel2" initiative by the Federal land of North Rhine-Westphalia, microdrones will provide three-dimensional views of buildings and complete neighbourhoods. In addition, they will support the set-up of an ad-hoc mobile network. This is based, among other things, on AAHRS (Altitude, Attitude and Heading Reference System), a system made up of accelerometers, gyroscopes, magnetometers, atmospheric pressure gauges, air humidity and temperature sensors as well as a GPS receiver.

The video and telemetry down link allows the transmission of live video images, as well as all the relevant telemetry data. All the data is graphically displayed using the ground station software which is included in the scope of supply, so the pilot is provided at all times with flight-relevant optical and acoustic information, e.g., battery level, position, altitude, distance, wind speed and other operating conditions.

In addition, all the measurement and position data is captured by the flight recorder and can be used for later evaluation and documentation. The software allows detailed flight planning to get underway prior to the start of the flight.

Mission planning is based on existing pictures and maps. Both georeferenced graphi-cal material taken by the microdrone itself (Map N' Fly) or imported maps from commercial GIS systems can be used for this purpose.

Technical data
- Useful load of up to 1200 g
- Flight time up to 70 min
- Whisper-quiet operation
- Rugged, weather resistant carbon fibre body
- Selectable automatic or manual mode

Drone applications
- Large fires, forest fires
- Search and rescue action
- Traffic monitoring
- Accident analysis
- Border control
- Street riots and demonstrations

3. GPS WAYPOINT

The optional GPS Waypoint system allows pre-defined flight routes to be flown over automatically, thanks to prior programming on a laptop or PC or through a teach-in process. For automated flights using Waypoint navigation, the ground station software incorporates a flight planning module. This can be used to change even the complete flight plan on site at short notice, and completely new routes can be entered with just a few clicks of the mouse.

All flight routes can be saved and restored upon request. The flight routes themselves can have almost any degree of complexity. With functionality such as POI (Point of Interest) and Map N' Fly, missions are quite simple. For instance, the drone holds the Points of Interest within the camera's visual field with just a click of the mouse, no matter what route is selected. With the Map N' Fly function, unknown terrain can be measured, georeferenced and used as maps for flight planning or other geographic applications.

During the planning of a waypoint route, the system automatically tries to avoid operating errors. For instance, critical flight situations such as insufficient programmed altitude above the ground or routes which are too long to manage with just one battery are automatically flagged. The system provides feedback about the estimated flight time and the expected image date coverage of the surveyed area. The precise adjustment of the camera and lenses is particularly important for measuring purposes so that any potential picture overlap can be considered upfront.

4. LEGAL PREREQUISITES FOR DRONE OVERFLYING (UNMANNED AERIAL SYSTEMS, UAS)

The intended aerial survey of high pressure gas pipeline routes using drones is subject to two legal texts, i.e., the German Air Traffic Act (LuftVG) of 2007, governing the use by aircraft of the air space over the Federal Republic of Germany.

Unmanned Aerial Systems (hereinafter referred to as UAS) are addressed in the Air Traffic Act only in the first section, paragraph 1, clauses 1 and 2.

"(1) The use of the air space by aircraft is free unless limited by this act, by the legal provisions enacted for its execution, by nationally applicable international law, by legal ordinances of the Council of Europe as well as legal provisions enacted for its execution."

„(2) Aircraft includes: … 11. other devices intended to be used in the air space, as far as these can be operated at an altitude of more than thirty metres above the ground or water."

In this paragraph and the related clauses, however, the use of UAS in the public area is addressed only to a limited extent.

In addition to the German Air Traffic Act (LuftVG), the Air Traffic Regulations (LuftVO) of 1999 are applicable in Germany. These provide detailed rules for pilots and any aircraft within the Federal Republic of Germany, including the operation of UAS, e.g., in paragraph 4a:

"The provisions of these regulations apply to the operation of aerial sports equipment and unmanned aerial systems unless the particularities of these aircraft, particularly exemption from airworthiness certification and from the requirement to use an airfield, the operating mode or the lack of crew result in the inapplicability of individual provisions."

Thyssengas GmbH plan to use unmanned aerial systems in the project they have initiated. The vision of the project is to ensure the fully independent action of such unmanned aerial systems in the final project stage. In this context, however, paragraph 15a, clause 3 of LuftVO provides critical limitations to the operation of UAS:
„(3) The operation of unmanned aerial systems for the

[1] LuftVG; first section; 1st subsection; "Luftfahrzeuge und Luftfahrtpersonal" (aircraft and airport crews); §1, clause (1)
[2] LuftVG; first section; 1st subsection; "Luftfahrzeuge und Luftfahrtpersonal" (aircraft and airport crews); §1, clause (2)
[3] LuftVO; first section; §4a; "Luftsportgerät und unbemanntes Luftfahrtgerät (aerial sports equipment and unmanned aerial systems)

purpose of paragraph 1 clause 2 no. 11 of Luftverkehrsgesetz (German Air Traffic Act) is prohibited if:
1. it is outside the visibility of the person steering it or
2. the total weight of the equipment exceeds 25 kg."

The visibility is defined later in paragraph 15a, clause (3) of LuftVO as follows:

"The operation is outside the visibility of the person steering it if the aircraft cannot be seen or clearly identified without particular optical aids."

Thus current legislation is clear about this issue for the purposes of the basic project objective: the autonomous operation of UAS is currently prohibited. However in order to progress the project, Thyssengas GmbH has approached the air traffic department at the Regional Government in Düsseldorf, because LuftVO paragraph 15a clause (3) provides the following:

"In areas with flight limitations as outlined in paragraph 11 and where an operation will not go beyond the aerodrome traffic of an airfield, an exception from the prohi-bition as per phrase 1 may be allowed by the Federal air traffic authority in charge if the applied airspace use does not involve any risk to public safety and public order."

Based on this clause, a derogation for the planned test route over a length of approximately 10 km was sought. Within the approval process, the new technology was demonstrated to representatives of the Regional Government across a 800-metre-long part of the test route. This part had been approved for testing purposes in advance by the Regional Government and released for autonomous air traffic.

During the demonstration, representatives of the authorities were able to gain an impression of UAS in a real-life application, e.g., for the purpose of "defining" visibility as set out above. In essence, the Regional Government is committed to supporting and promoting innovative projects of this type within the scope of applicable legislation. At the same time, the representatives of the authorities in charge are currently investigating an application of UAS in industrial fields, as the Regional Government is receiving increasing applications for approval of this technology.

Following the demonstration, the representatives of the Regional Government assured Thyssengas GmbH that they would review the application with a view to granting special authorization.

At the time this article was written, no decision had been taken about granting special authorization for an autonomous aerial survey of routes for high pressure gas pipelines using UAS.

The photos taken during the demonstration for the Regional Government are very high resolution, so that pattern recognition software would be easily able to identify potential risks to the gas pipeline.

5. TECHNOLOGICAL BENEFITS FOR THE PIPELINE OPERATING COMPANY

The aerial route survey using UAS offers various benefits for the overall line survey system. The message and response times are reduced, which greatly contributes to damage prevention. Unlike with conventional overflying, where messages are "only" available in the SAP and the GIS systems the next day, with the new survey systems, messages can be transmitted with a minimum time delay. What is more, these messages can be supported with graphical material, so that staff can preselect messages based on the graphics and prioritize them for further processing.

Another potential application of UAS in the field of pipeline surveillance is to use the system directly for emergency assistance. The UAS could be launched and landed in either fully or semi-automated (activation by an operator) mode. The UAS would then be used as "scouts". By overflying the area concerned, an initial overview of the situation can be gained, which can then be classified in order to initiate further action.

Furthermore, the system could be used for the initial measurement of new constructions or reconstructions, so as to enhance the efficiency and reduce the time schedules for updating existing data in documentation systems.

What should also be mentioned is that UAS, compared with conventional pipeline overflying using helicopters, offer good environmental compatibility and produce little noise. Helicopters consume much more energy (piston engine/turbine drive) and, especially in built-up areas, they are a source of major noise disturbance, due to their surveillance flight altitude of some 80-100 metres above the ground. What is more, UAS do not emit any CO_2 and allow whisper-quiet flight operation.

Last but not least, the pipeline operator is responsible for maintaining sight of surveillance costs, while ensuring the required degree of safety. The estimated overall cost of overflying, i.e., not only the cost of an external helicopter company including equipment, pilot and/or observer, but also internal costs such as starting and controlling surveillance flights, as well as the feeding back of infor-

[4] LuftVO; second section; §15a; "Verbotene Nutzung des LLuftraumes" (proshibited use of airspace); clause (3)
[5] LuftVO; second section; §15a; "Verbotene Nutzung des LLuftraumes" (proshibited use of airspace); clause (3)
[6] LuftVO; second section; §15a; "Verbotene Nutzung des LLuftraumes" (proshibited use of airspace); clause (3)

mation by inhouse ground staff, amounts to EUR 7 per kilometre of overflight operation. Taking into account parallel pipelines (billed kilometres) and short access lines, which will not be paid separately, as well as the required overflight frequency, this amounts to a middle six-digit Euro amount per year. Infrastructure costs such as IT/software and core systems/subsystems such as GIS/SAP are not included, as these must be available for documentation anyway and are also needed for UAS surveillance. In this context, the manageable initial investment for one or more drones and various hangar systems mean that they will pay off after a very short period of time (depending on the length of the network and the surveillance frequency required by the actual pipeline operator).

6. OUTLOOK

Additional steps are needed to put in place the pipeline route surveillance project using drones and the issue of official approval must be settled.

The flight components of the target system planned by Thyssengas GmbH are largely in place and have been implemented from a technical perspective. This includes GPS-based flight operation with Waypoints as well as the automatic launching and landing of drones. The vision is to operate a fully independent system in the final stage of the project. This way, UAS could be automatically start from their hangar and land again. Gas pressure regulating and/or measuring stations can be found between the various pipeline routes at more or less regular distances. This is where the hangars might be set up. The UAS' battery life is a critical factor for planning the distance between hangars. Currently the maximum flight time of the microdrone md 4–1000 is limited to some 70 minutes and the intended additional equipment would reduce the effective flight duration to around 50 minutes.

Regretfully, the reluctant attitude of the legislative authority is restricting the use of this innovative technology by pipeline operators. The argument put forward, i.e., that air traffic safety comes first, is understandable, yet operational pipeline safety would be greatly improved. It should be noted that dredgers are the main cause of pipeline damage. The risk to air traffic of a lightweight drone weighing less than three kilogrammes is incomprehensible, as the flight of birds (with a similar weight) does not imply any risk for flight traffic.

Perhaps DVGW (German Technical and Scientific Association for Gas and Water) might provide support, as otherwise this excellent technology and its potential future applications – not limited to gas pipelines – could be impeded.

There is a long way to go until the outlined objectives and visions can be implemented and this will need the support of the legislative process and DVGW. From a technical perspective, many improvements could be realized as early as tomorrow. ■

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