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Inspection and Maintenance of Railway Infrastructure with the Use of Unmanned Aerial Vehicles

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Summary
The paper discusses the application areas of UAVs and their regulations. Particular attention is paid to the inspection and maintenance of railway infrastructure. The use of UAVs in many railway networks around the world is reviewed. The implementation of autonomous solutions is highlighted. The safety of UAVs on railways is analysed and directions for their implementation at PKP PLK S.A. are indicated.

Keywords: UAVs, inspection, infrastructure, railway, security

1. Introduction

The commercial use of UAVs, also called Unmanned Aerial Vehicles (UAVs), has been gaining in popularity in recent years due to their undoubted advantages. Both the efficiency and feasibility of potential UAV applications in professional tasks depend equally on flying skills and on many other technical, organizational, legal and standardization factors [31].

When considering the usefulness of UAVs as tools, it is necessary to take into account the practical technical capabilities in individual groups of applications. The simplest ones include intrusion monitoring, the deterrence of intruders (thieves) and vandalism [9]. More sophisticated ones include the following:

- monitoring and inspection of infrastructure, such as:
  - bridges and viaducts (detection of defects, such as cavities, fractures, deformations, structural corrosion and intelligent maintenance) [14, 17, 21, 23, 26],
  - tunnels (gauge) [30, 38], dams and water reservoirs (leaks and washouts),
  - landslides (slopes and cliffs near buildings and traffic routes),
- roads (damage to surfaces, screens, stops and barriers),
- tram and railway lines (deformations and surface defects of rails, cracks in sleepers, control of turnout heating, maintenance of switches, losses in track structure, and vegetation) [1, 12, 18, 24, 25, 29, 33, 34, 37],
- power lines and railway traction (poles and lattice structures, insulators, wires and transformer stations),
- buildings (technical condition, energy efficiency and construction disasters),
- mapping (high-resolution geodetic images of areas and facilities),
- environmental protection (measurements of air pollution, combustion of unacceptable materials, and landfill monitoring),
- agriculture (scale of destruction of crops and resulting insurance) [36],
- crisis management (natural disasters, floods, earthquakes and large scale fires),
- law enforcement and medical services (transport accidents – transport of blood and respirators [32],
- detection of hazards during gatherings and demonstrations),
- courier services.

Technically and thematically, some of the identified areas of application overlap, but may require different equipment, are organised differently, are assigned to specialized units or are regulated by specific regulations. Therefore, monitoring serves to support daily routine activities in the successful implementation of tasks. Meanwhile, inspection serves the technical support of supervisory activities required by technical, construction and technical inspection regulations.

There are UAVs on the market with the option to mount the highest quality imaging equipment and

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various sensors, allowing users to record data not only of practical use, but also to conduct scientific research work. Operators are gradually learning to perform precise flights in conditions that guarantee images with the photogrammetric quality required for a given type of measurement. Depending on the specific application, UAVs with different equipment can be considered, and information processing can be planned with IT tools tailored to specific needs or requirements.

It should be emphasized that the UAV market in the last decade has been growing exponentially on a global scale [11], and in railway applications, in 2019, it reached around 4 billion dollars, with an annual growth trend of 40% [16].

Therefore, the article focuses on UAVs used to inspect railway infrastructure, analysing their application on railway networks, with particular emphasis on autonomous systems. The development of research techniques using these aircraft is also supported by increasingly clear legislative provisions that cover all EU countries and those introduced on other continents [16].

The adventure with UAVs in Poland began in 2014, when PKP Cargo purchased a UAV called Bielik (and other models in the following years) to warn off thieves from transports of coal, metals and fuels in the Silesian region and to supervise container transports, gradually extending the scope of activity

Table 1

Rules governing the operation areas of UAVs

Country	Regulatory body	UAV weight [kg]	Maximum speed [km/h]	Maximum flight altitude	Distance from the operator
Europe					
France	French Civil Aviation Authority	≥ 25	Not defined	150 m above ground level or 50 m above any object of a height greater than 100 m	VLOS and BVLOS operations within a specific regulatory framework, depending on the UAV weight
Germany	German Federal Aviation Office (FAO)	5–25 commercial	Not defined	100 m or 50 m for controlled airspace	VLOS operations
Spain	Spanish Aviation Safety and Security Agency (AESA)	≥ 2 private, 2–150 commercial	Not defined	120 m above ground level	> 500 m, > 15 km for approved BVLOS flights
Great Britain	Civilian Aviation Authority (CAA)	≥ 20 private, 20–150 commercial	Not defined	122 m above ground level	VLOS operations. Commercial BVLOS operations are forbidden
North America					
Canada	Transport Canada	≥35 private, < 35 commercial	Not defined	90 m above ground level	> 500 m
USA	Federal Aviation Administration (FAA)	≥ 25 commercial	161	122 m above ground level or structure	VLOS operations
Asia-Pacific					
China	Civil Aviation Administration of China	≤ 0.25	100	122 m above ground level	VLOS and BVLOS operations within the defined regulatory framework
Japan	Japan Civil AviationBureau, Ministry of Land, Infrastructure and Transportation	< 0.200 grams	Not defined	150 m above ground level	VLOS operations
New Zealand	Civil Aviation Authority of New Zealand	≥ 25	Not defined	122 m above ground level	VLOS. BVLOS operations allowed after certification
Africa					
South Africa	South African Civil Aviation Authority	≥ 20	Not defined	122 m above ground level	VLOS. BVLOS operations are permitted with special authorisation

[Owne elaboration].

to other regions of the country. UAVs allow places that are difficult to access on railway tracks to be observed and, when equipped with a thermal imaging camera, during the night too. Information on possible theft is transmitted to the management centre, so the response can be very quick. The investment paid off quickly as theft fell by about 40% after a year [9].

Similar measures, but on a larger scale, were undertaken in 2018 by the British Network Rail (NR), on the South Western railway route. A UAV was used there to record and send photos of intrusions and illegal activities to the British transport police. The same year, the Belgian railway company Infrabel implemented UAV night flights that operated out of sight, BVLOS *Beyond Visual Line of Sight*, to combat the theft of traction cables.

Also in 2018, PKP PLK S.A. signed an agreement with Fotoraporty Sp. z o.o. to provide services monitoring selected railway projects using UAVs. The procurement covers cyclical and ad-hoc monitoring of construction work progress on selected railway lines using photogrammetric data and video material.

Railway infrastructure research with the UAV system in sight, VLOS *Visual Line of Sight*, in the field of railway traffic control devices, was undertaken at the Faculty of Transport of the Warsaw University of Technology [19, 39].

Therefore, there is no doubt that the time has come to establish appropriate rules governing the market of UAVs [2]. Hence in 2008, the European Parliament and the Council of the European Union (EU) issued Regulation 216/2008 on the establishment of the EASA – *European Union Aviation Safety Agency* and gave it legal authority for civil aviation, including UAS (Unmanned Aircraft Systems). EASA has allowed each EU Member State to develop its own laws and regulations for UAVs of 150 kg or less, Table 1 [8].

2. Overview of the use of UAVs on railway networks

An increasing number of railway network managers are striving to create an innovative "digital railway", an accurate and dynamic visualisation tool to identify actual and potential damage to railway infrastructure. This involves obtaining data of the highest quality, which supports decisions made during the planning and prioritization of railway development, maintenance, repair and renewal [16].

UAVs, which can inspect significant sections of railway lines in real time, have become a new support tool. These solutions lead to rapid damage detection and accident prevention. The use of UAVs also significantly reduces the input of labour, saves cost and time and provides immediate access to accurate data. Measurement is made with an accuracy of fractions of or single millimetres. Once recorded, overlapping aerial images are processed in photogrammetry software to produce an accurate 3D point cloud. By comparing with the reference point clouds from previous inspections, changes in infrastructure can be monitored. Unlike with traditional vision testing methods for railway facilities, data from topographic surveys is supplemented with orthoimages, with the projection plane parallel to the reference plane, of very high resolution (Fig. 1).

Professional UAVs are equipped with devices that allow extremely precise aerial images to be taken, using Ultra 4K cameras with an image resolution of 100 MPx and UHD video recording – *Ultra High Definition* with a resolution of 4096×2160 with differing frame rates and a variable viewing system – vertically or horizontally, depending on the inspected object. At such high resolution it is possible to identify defects in the rail head tread [37], markings on the sleepers, the assembly quality of fixations and rail bonds, or dam-

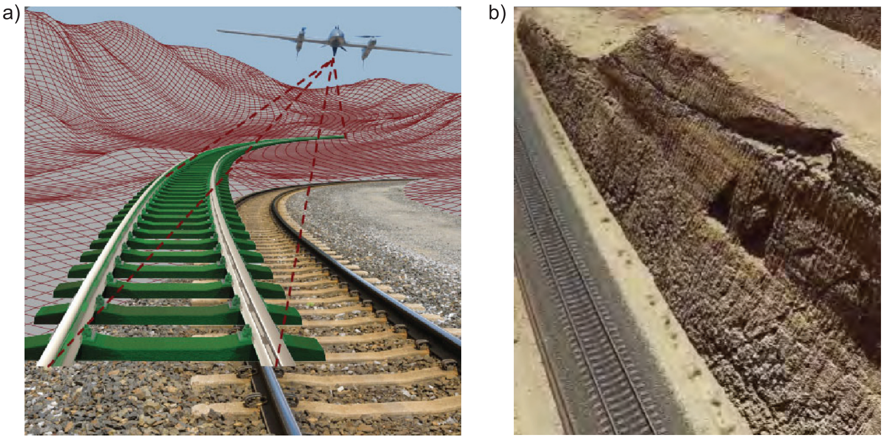

Fig. 1. Vision scanning of a railway line with a UAV: a) an illustration of the survey [28], b) a 3D photogrammetric image of railway infrastructure [30]

age to the structure and surface of viaducts and bridges (Fig. 2) [10]. This is a key function when checking railway track and the accompanying infrastructure. Different European countries are testing or already using UAVs in their railway networks for monitoring, inspection, testing and maintenance etc. (Table 2) [8].

France

The Société Nationale des Chemins de fer Français (SNCF) has been using UAVs for its inspection, surveillance and maintenance work since 2013. The authorities have set up a subsidiary, Altametris, which provides customised UAV solutions with a focus on sensors, designs

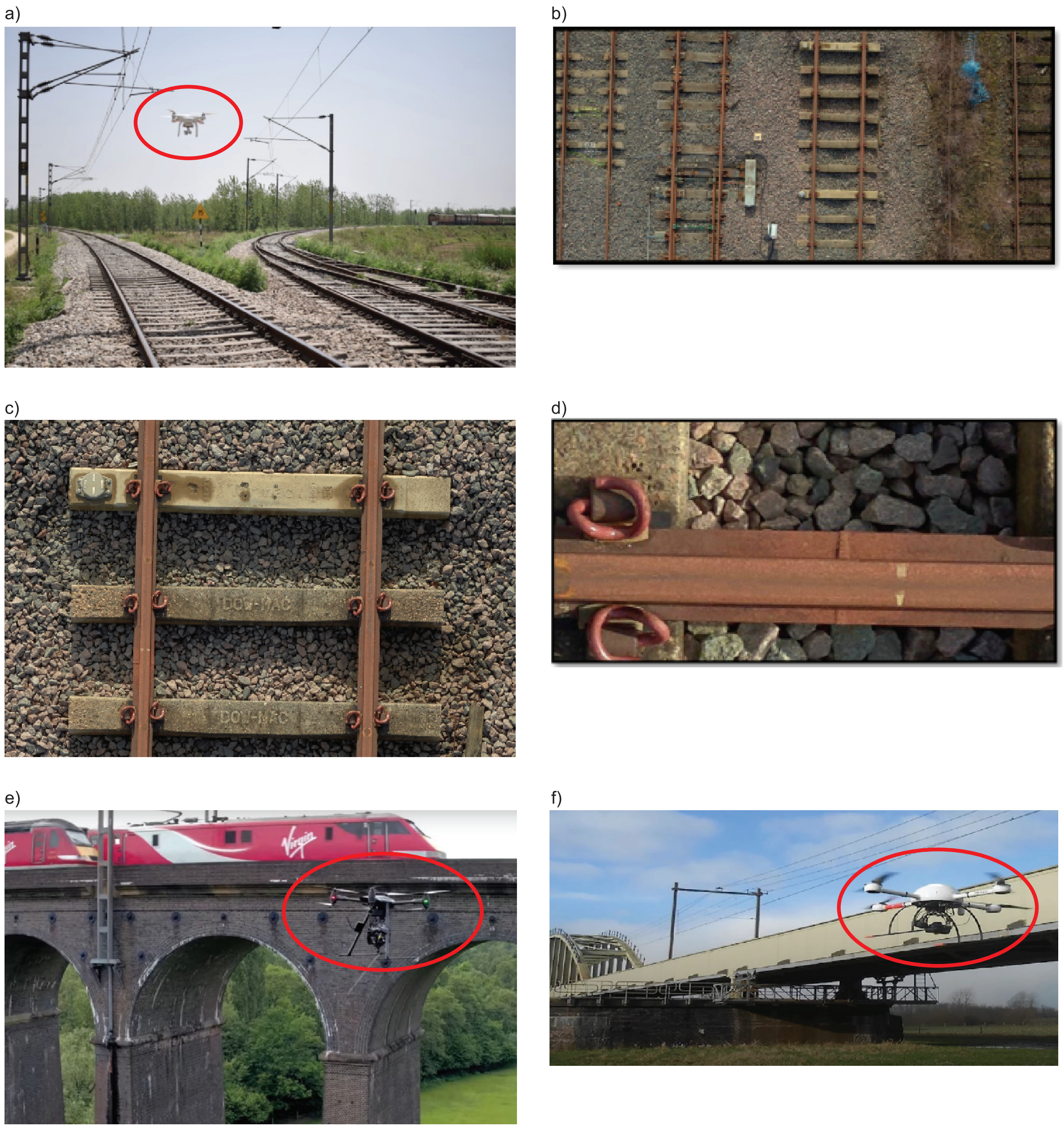

Fig. 2. Inspection of railway infrastructure with a UAV: a) track inspection [13], b) a general view of a track from a height of 25 m [7], c) an approximation of a track section – sleeper designations visible [7], d) a view of a rail with elastic fixations – weld visible [7], e) inspecting the condition of the concrete structure of a railway viaduct [7], f) testing the corrosion of the steel structure of a railway bridge [27]

Table 2

UAV system applications on European rail networks

Country	Responsible body / company	Implementation purpose	Key supplier
France	SNCF Réseau	Topographic measurements, network mapping, inspection work, supervision, maintenance	Altametris (subsidiary of SNCF Tech, DGAC, ONERA
Germany	Deutsche Bahn (DB)	Supervision, inspection and evaluation, construction planning	Microdrones (manufacturer)
The Netherlands	ProRail	Control of switch heating systems, control of corrosion protection of steel structures	Arcadis
Norway	Bane NOR	Monitoring and lubrication of point machines by means of autonomous UAVs	Nordic Unmanned, Total Trafikkhjelp, IRIS Group Nordic
Spain	CAF Signalling	Geolocation of signalling systems on high-speed lines	SigmaRail, UC3M Intelligent Systems Laboratory
	Thales, Adif	Madrid-Seville high-speed line error detection tests (for maintenance work) *Automatic Train Operation* (ATO)	SigmaRail, UC3M Intelligent Systems Laboratory
Great Britain	Department for Transport (DfT)	DfT's Pathfinder tests and trials	SenSat
	Transport for London (TfL)	Measurement and maintenance of the London Underground network	Lanes Rail
	Network Rail (NR)	Inspection work and track maintenance	Aecom, Cyberhawk, NR Air Operations crew

[Owne elaboration]

innovative solutions, and processes data. Table 3 shows details of the UAVs operated by Altametris.

Altametris has established scientific and regulatory partnerships with various organisations and companies, such as:

- ONERA, the French national aerospace research centre;
- DGAC, Directorate General for Civil Aviation;
- Delair Tech, a start-up specializing in UAV design and data analysis;
- CNIL, National Commission on Informatics and Liberty, and
- ARCEP, an independent French agency in charge of regulating telecommunications in France.

In addition, Altametris cooperates with other electricity operators based in France, as well as with foreign operators (e.g. the Swiss Railways).

Germany

From 2015, DB has been operating UAVs throughout the country to supervise and plan construction, and to check the trees around railway lines. The authorities use 12 types of UAVs, differentiated on the basis of load capacity, flight time and operational capability. Each UAV is equipped with cameras that can record video and make high-resolution digital or infra-red images [22].

The Netherlands

ProRail has used UAVs equipped with infra-red sensors to inspect the turnout heating systems on its tracks. Moreover, Arcadis has used UAVs to control steel infrastructure (bridges and viaducts) [27]. It visually inspects the condition of corrosion protection, estimates the remaining life cycle of coatings, and advises on maintenance activities.

Table 3

Data of UAVs operated by Altametris

Parameter	Details
Mass	2–20 kg
Sensors	High-resolution video/photographic equipment, multispectral thermographic cameras (infra-red band) and/or LiDAR (3D environment laser system)
Fleet	12 UAVs and robots

From July 2018, ProRail has used UAVs and 3D scans to map trees along the Dutch railway network. The company uses this technology to identify trees at risk of falling or loss of branches, thus enabling preventive measures to be undertaken before the trees cause a risk for movement on the tracks. Nederlandse Spoorwegen (NS) monitors the infrastructure of railway stations and their surrounding tracks.

Norway

In December 2016, Bane NOR awarded contracts for the supervision of six infrastructure areas under the jurisdiction of national railway administrations. Total Trafikkhjelp secured a contract for the northern province, IRIS Group Nordic secured a contract for the western province and Nordic Unmanned secured contracts for the other four provinces. These companies provide high quality video footage and photos, enable infra-red photography, and conduct terrain model analysis.

In 2018, Bane NOR announced plans to develop a system in which an autonomous UAV lubricates point machines. The system is programmed according to the route using map coordinates. Bane NOR is the first company responsible for the national railway infrastructure in the world to introduce UAV technology for railway maintenance [4].

Spain

SigmaRail provides CAF Signalling and Thales solutions based on UAVs for asset management on high-speed rail lines in Spain. The company developed UAVs in cooperation with UC3M Intelligent Systems Laboratory. Table 4 shows details of the UAVs used by SigmaRail on Spanish high-speed lines, Table 4 [15].

SigmaRail provided CAF with an automated UAV solution for the installation of a signalling system, based on the European Rail Traffic Management System (ERTMS) standard along the Alicante – Murcia high-speed line. The company has developed special tools for uploading data downloaded from UAVs in a format that could be used by CAF for programming ERTMS devices.

Thales and the Administrador de Infraestructuras Ferroviaria have implemented UAVs for damage detection tests. This process reduces the amount of time invested in track maintenance, as well as the number of railway stock inspections [15].

Great Britain

Transport authorities in the country are implementing UAV systems from different suppliers to individual railway segments [7, 8, 10]. The Department for Transport (DfT) launched the Pathfinder programme in 2017, which focuses on a number of partnerships between government and industry in key sectors. As part of the SenSat programme (on behalf of DfT), it conducts tests and trials to find out how UAVs can be used to improve services in different sectors. In June 2018, the company obtained special permission to implement trials at a distance of more than 500 m up to 12 km from the operator, i.e. BVLOS.

In December 2018, SenSat completed a UAV survey on the 230km High Speed 2 (HS2) route (from London to Birmingham). The company registered 18.2 billion data points in three weeks.

Transport for London (TfL), after a 12-month period of testing and approval, granted Lanes Rail permission to explore assets on the London Underground network using UAVs. This is the first contractor to obtain a long-term license to use UAVs in TfL resources. In May 2017, the company signed a five-year network maintenance contract. It is responsible for the maintenance and repair of a wide range of resources, including tracks, station buildings, bridges and engineering work implementation, where UAVs provide significant support. Network Rail (NR) has implemented UAV systems for:

- Identification of problems with infrastructure and earthworks.
- Surveillance of water-related hazards, such as water reservoirs and washouts near rivers.
- Vegetation growth management and animal intrusion monitoring.
- Identification and monitoring of violation and suicide spots.

Table 4

SigmaRail UAV parameters

Parameter	Details
Video equipment	RGB or thermal imaging cameras
Location	Each image is geographically located using the on-board GPS system
Survey capacity	Approx. 6 km of the section in less than an hour
Memory	2 GB of data on a 20-minute flight

The authority's overall approach is to improve efficiency by remotely monitoring assets and reducing the need for on-site inspections by field staff. Table 5 shows the parameters of the UAVs used by NR [8].

Australia

The maintenance of Australia's extensive sixth rail network imposes specific requirements, especially in remote areas. Therefore, the Institute of Railway Technology (IRT) in Monash implements unmanned aircraft systems to help move to autonomous track inspection [3, 30, 38].

The use by IRT of the latest technologies, such as the *Instrumented Revenue Vehicle* (IRV), allows the identification of visible defects in rails, as well as missing parts, such as rail fixations and rail bonds. In addition it allows the identification a lack of elements in rail fastenings and connections.

Metro Trains Melbourne uses UAVs to detect vandals and intruders. They are equipped with cameras, including thermal imaging cameras, and are deployed in specific network sections to respond to incidents. The data is transmitted to the control centre and forwarded to the police.

UAVs exploring tunnels are capable of safe flight with limited space (no GPS coverage). To this end, they are equipped with laser sensors to enable both the measurement of enclosed spaces and positioning in confined spaces, Fig. 3.

United States

According to the Association of American Railroads, the United States has about 225,000 km of railroad networks and more than 61,000 bridges, which are tested with specialized vehicles and hand tools, according to the track and bridge safety standards of the Federal Railroad Administration. However, railways have been implementing and testing UAVtechnology to supplement their inspection activities since about 2015 on a vast network of main tracks and sidings [35].

One of the first implementations was the measurement of bridge motion dynamics. Such direct field

Table 5

Parameters of the UAVs used by NR

Parameter	Details
Mass	7 kg (maximum)
Range	A flight of up to 500 metres from the operator is permitted
Flight	Permits flying up to an altitude of 122 m
Flight time before recharging	20 minutes
Crew	At least two people (one operator-in-command and one observer/camera operator)
Camera	4K high resolution video and high resolution image systems
Features	● Embedded on-line geospatial environment (GEO) ● Embedded protocol RTH – *Return to Home* ● Multiple motors and rotor blades

Fig. 3. Tunnel inspection: (a) a UAV during inspection [30], (b) a 3D point cloud of a tunnel with cavities [38]

surveys are difficult and costly due to the inaccessibility of a fixed reference point. Therefore, a UAV integrated with a Doppler laser sensor was used for such tasks. The purpose of such an inspection was to examine deformation of the bridges under a passing train load to check its stability. AMROS operational sets are also able to precisely locate a UAVs position with respect to the bridge.

BNSF Railway Co. has been using fully autonomous UAVs to collect data from extensive railway infrastructure since 2015. These are BVLOS inspections and the UAV is programmed according to plans. Such flights must have the Federal Aviation Administration's approval. Derailments are also inspected as they allow railway staff to safely and efficiently observe areas that may be inaccessible in emergency situations. In 2016, Union Pacific Railroad used live transmissions from one of its UAVs to explore the track during the floods in northern Iowa.

The railways also have aviation rights, including track-side infrastructure that offers an electricity grid for charging UAVs. This is an opportunity to bring rail assets to market for UAV supply leaders, such as Amazon and Walmart, who usually have distribution facilities close to major rail lines.

3. Examples of autonomous UAVs system implementation

In recent years, Centrum Diagnostyki PKP PLK S.A. has successfully implemented surveillance methods of railway line inspection. As a rule, the cameras are attached to a specialized handcar or a car, and algorithms based on neural networks are used to recognize defects [20]. This is usually an expensive implementation with some inspections, due to the track occupation of the measuring vehicle, requiring the scheduled trains to slow down, which may have an adverse effect on the railway system.

Therefore, managers of other railway networks are increasingly bold in supporting such inspections with UAVs (see point 2), with a particular focus on autonomous. UAVs. They use fully integrated technologies of interaction with systems installed on the track, as shown in Fig. 4 [5]:

- Autonomous inspection of infrastructure (Switches & Crossings) with a UAV (using lasers, video, acoustics and other NDT techniques – *Non-Destructive Testing*, and information on autonomous maintenance, e.g. lubrication and heating activation),
- Built-in monitoring (measurement) of switch and cross dynamics using accelerometers and other sensors with intelligent processing algorithms,
- Monitoring (measuring) train dynamics and correlating with data obtained from the infrastructure,
- Built-in system start-up monitoring,
- Error-tolerant cross and switch inspection.

These data streams, with their closely related interaction, form an autonomous system. The UAVs used in these applications are generally designed to activate sensor and actuator components in addition to standard manoeuvring and positioning systems.

Although there are concerns about the use of UAVs on the railway as an inspection platform, the growing number of studies and examples of applications suggests that this direction will develop rapidly.

An example of a new measuring device mounted on a UAV is the system for checking a rail section (Fig. 5).

This hybrid, armed with cameras enveloping the sides of the rail, has the ability to remotely land on the track and ride along the rail using vision-based 3D reconstruction developed using CAD software – *Computer-Aided Design*. The system has a flight and landing speed of 5–10 m/s and can hover for about 20 minutes.

Thanks to the MVS algorithms (*Multi-View Stereo)* one can reconstruct 3D geometry from several images obtained by the UAV, with accuracy comparable to that obtained by 3D laser scanners. The study compared MVS reconstructions with a CAD model using the ICP method – *Iterative Closest Point*. The shape accuracy of each section was compared with the actual 60 E1 rail shape.

The comparison shows that the section shape of the reconstruction result and the ICP result are almost the same with a minimal RMS https://pl.wikipedia.org/wiki/Język_angielski*(Root Mean Square)* error of 0.67 mm. This is an error determined by summing up the squares of individual errors, then dividing the sum obtained by the number of included values and determining the square root of the quotient obtained. It is also worth noting that ICP results can be used as a measure to evaluate the wear condition of the rail head. The RMS error scale increases as rail wear increases. This shows the strong potential of 3D reconstruction, which uses only a few images to complement traditional manual or automated (laser) rail head section measurements [38].

In autonomous UAVs for railway inspections, great emphasis was placed on computer vision, algorithms of data processing, machine learning, deep learning and artificial intelligence. This is based on autonomous IT platforms [6].

4. UAVs safety analysis on railways

The use of UAVs above a railway line can be associated with considerable danger, risk and serious operational challenges. UAVs first of all require navigation

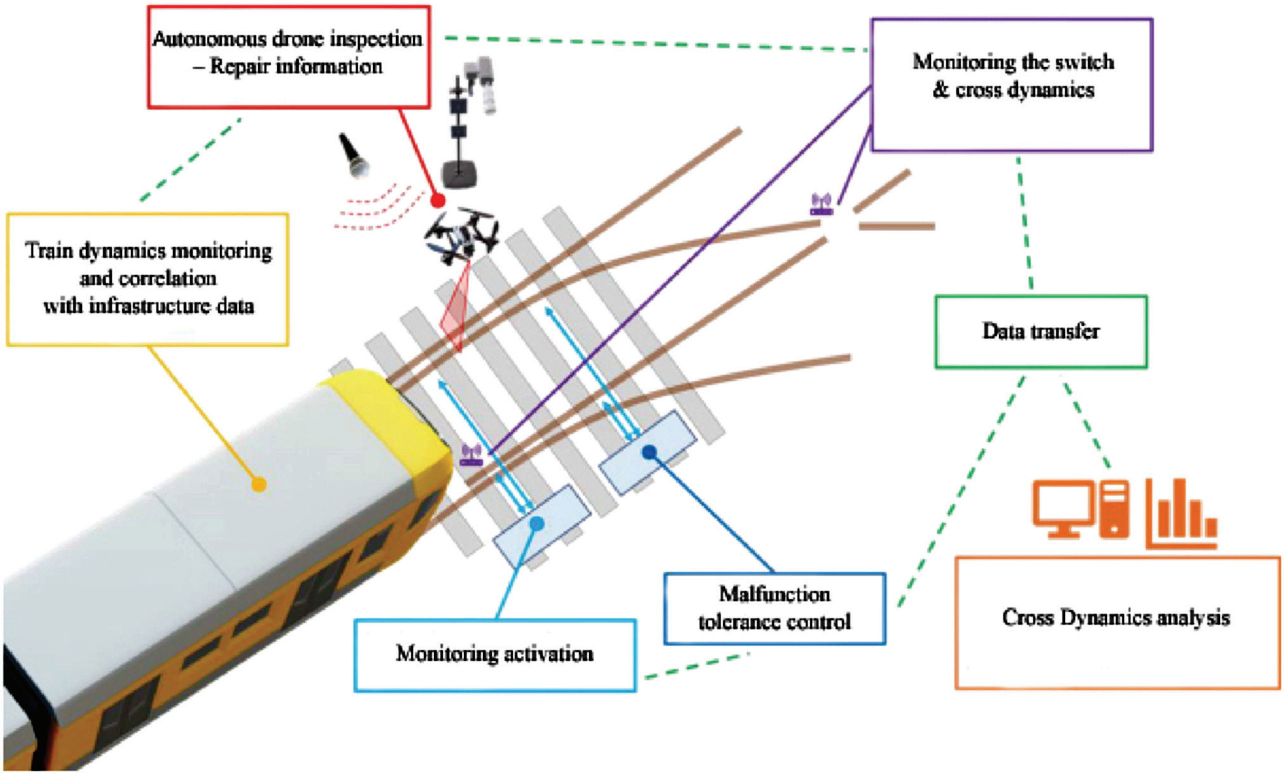

Fig. 4. An autonomous UAV-based inspection and maintenance system [5]

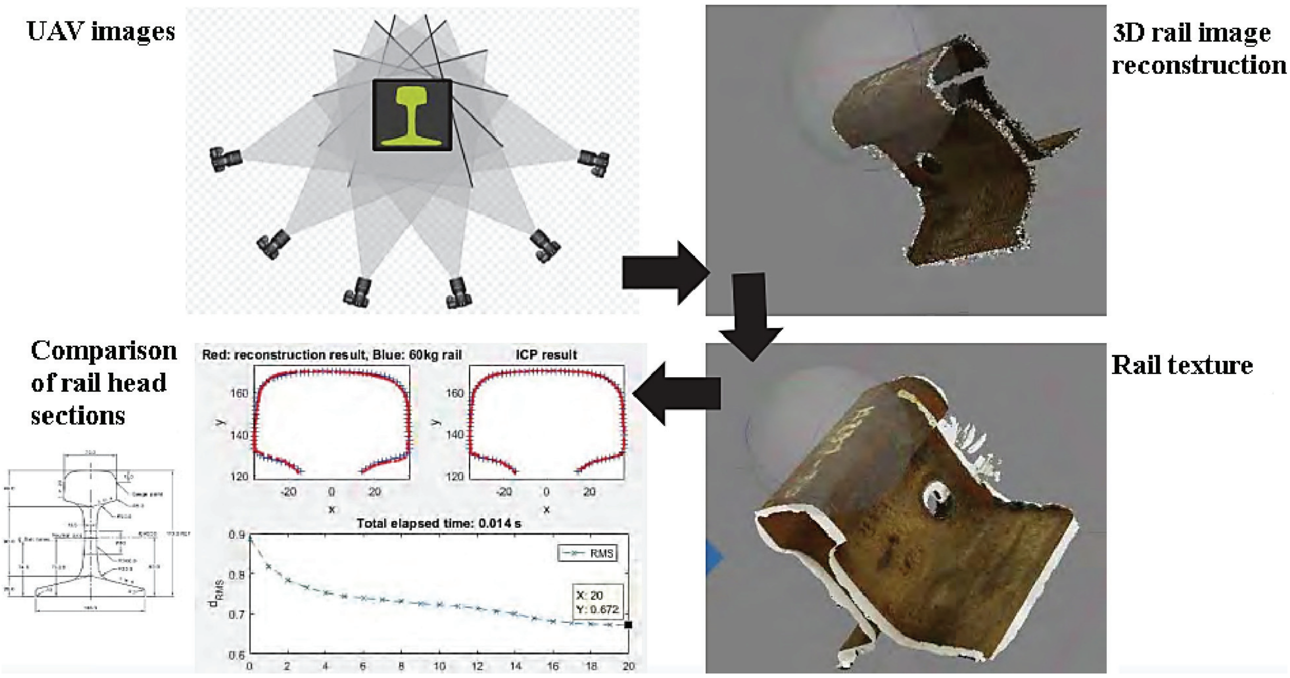

Fig. 5. Rail head section measurements with a UAV [30]

on long track sections. However, there are some disruptions to the GPS (*Global Positioning System)* from the environment, such as bridges, viaducts, vegetation and similar obstacles that limit the view of the sky and thus cause unexpected signal loss, which can lead to unpredictable UAV behaviour.

UAV navigation should be avoided near BTS stations (*Base Transceiver Station*) used in wireless communication systems, including GSM, equipped with electromagnetic wave antennas, usually on a high mast. Moreover, so-called solar storms, sudden and intense changes in the Earth's magnetic field, significantly interfere with the GPS signal. In addition, there is a short flight time of 20–30 min., which can translate into problems returning "home" in the event of any interference.

In confined spaces (tunnels), there are strong air flows that must be taken into account. The system selected should be able to hold its position in the strongest air gust to prevent accidents. Moreover, most UAVs do not tolerate physical collisions, so the risk of collision must be properly managed to avoid damage to both the UAVs and the infrastructure. There is a common risk of collision with overhead lines, track-side equipment, rolling stock and buildings. Managing these risks is difficult. Flight below the traction line may cause interference with the compass on board the UAVs and risk collision with rolling stock. The risk of collision when operating UAVs beyond visual line of sight (BVLOS) is also increased.

Many countries have rules on the minimum distances over which UAVs can fly. For example, in the UK, flying a UAV within a radius up to 150 m from a rail line or a station is illegal. To cross these limits, consent from supervisory authorities, additional training and further risk assessment are required. From an operational perspective, a camera failure or loss of the video link forces the operator to visually inspect and manoeuvre, which can be difficult or sometimes even impossible in an area of numerous railway facilities.

Traditional aviation concepts are based on the "see and avoid" principle. In the case of UAVs, this rule can be observed only during operations carried out within line of sight or using appropriate technology by extending this line. However, even then the risk of collision is not completely eliminated. It is important to be aware of blind corners and areas with limited visibility (especially in adverse weather conditions) which are commonly encountered within the railway infrastructure.

UAV operations on the railway beyond visual line of sight are hypothetically possible with currently available technology. Therefore, the railway network is beginning to develop its own set of standards and requirements to achieve its inspection objectives. Furthermore, use of advanced obstacle detection techniques, automatic landings or an emergency parachute can be considered.

However, such operations require height awareness. Flight planning with UAV equipment would have to be able to calculate the flight path. A better approach may be to activate the flight site tracking function. Progress in the field of sensors, microcomputers, control and aerodynamic theory is utilized here. However, the specific construction of UAVs and their rich instrumentation poses some dangers to the environment. The reason is the small size of microelectromechanical sensors (MEMS – *Microelectromechanical Systems*), which are temperature and vibration-sensitive, and being embedded in an integrated housing are therefore difficult to isolate from these vibrating effects. Another problem that occurs with such small UAV structures, usually less than one metre long, is stability and strength in an unpredictable railway environment.

Therefore, global research centres, in cooperation with railway network managers, are investigating the unique challenges associated with the use of UAVs in railway infrastructure inspection and maintenance operations. This research involves gathering knowledge about the experiences and concerns of railway operators and other people working in this environment. It is expected that the test results will help to formulate safety requirements for unmanned aerial vehicles in railway areas and to analyse the applicable rules and procedures governing their operation.

5. Conclusions

Growth forecasts for the UAV market indicate a huge potential for the railway industry in terms of exploiting their commercial opportunities for railway infrastructure.

Infrastructure inspection and accident investigation are two key areas where railway undertakings can greatly benefit from the implementation of UAV technology.

In addition, the development of autonomous UAVs equipped with Artificial Intelligence (AI) technology will provide significant opportunities to reduce research personnel, costs, time and risk. Beforehand, however, one should take into account any technological limitations, such as:

- Short flight time due to battery capacity, about 20–30 minutes,
- For operational safety reasons, at least two trained staff members, one operator and one observer, are often needed,
- The exact positioning of UAVs along the line must be ensured to perform valuable research analyses,
- For fully autonomous inspection, a tightly integrated UAV control system with a general infrastructure monitoring system is needed,
- Fully autonomous UAV operation requires access to the local environment (i.e. environment mapping and collision control).

One possible solution to address some of these constraints would be to create a UAV based on a periodic inspection system, combined "home" location which would release the UAV only after receiving notification from the signalling system that the track is not occupied.

If the signalling system reports an approaching train, the UAV will be called "home". Once released, the UAV would use standard operating paths and combinations designated by the GPS signal, based on the vision of a precision positioning detection system at a defined initial location.

It is also worth indicating further directions of UAV implementation by PKP PLK S.A. for railway infrastructure inspection. In the author's opinion, the field of action here is extensive, and the selected proposals cover:

- Electrical traction, including inspection of the technical condition of steel structures (deformations and corrosion), traction wires as well as contact tests with the pantograph (within columns), and thermal vision tests on insulators (electrical leakage),
- Railway viaducts and bridges, of differing structures (displacement dynamics), and damage especially in places difficult to access,
- Railway track – inventory and acquisition of technical condition (sleepers, fixations and rail bonds), switches and cross (dynamics, geometry and heating – thermovision), and gauges (also in tunnels),
- Landslides, trees posing hazard to a line, and overgrowing vegetation (including spraying)
- Stations (buildings, signal and command boxes), platforms (shelters) and traffic control equipment,
- Monitoring railway accidents,

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