Rough and tough – Drones for Australia's industry

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How to select a drone for multiple industrial applications

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WHY READ THIS WHITE PAPER?

As drone technology evolved significantly in 2013, it became a game-changing solution for several industries. In the meantime, national aviation authorities have prepared stable regulatory frameworks for realizing UAV operation and today almost every industry is deploying UAVs to increase productivity and safety.

Especially in the mining, construction and infrastructure industry the technical solutions are mature enough to enable almost fully automated UAV operation, to provide data in the same or better quality in significantly less time compared to traditional methods from ground or by plane or satellite.

This white paper explains how this strong tool offers a real alternative and includes following insights:

- The economic benefits and added-value of UAV deployment
- Regulatory framework
- Understanding the requirements for a successful UAV workflow
- Comparison of service provider capabilities

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1 INTRODUCTION

1.1 Executive Summary

In the last 20 years China and India almost tripled their share of the global economy. Global competition and price dumping lead to challenges in cost and quality for the world's 13th largest economy – Australia (Department of infrastructure and regional development 2014).
Utilizing UAVs commercially provides high potential for optimizing costs, quality, time and safety across several industries. The UAV market alone is expected to grow to $127 billion in 2020 (PWC 2016).

UAVs truly are a game-changing technology making an impact specifically in low-margin industries. Collecting data via UAV improves data quality, increases work security and makes results accessible much faster. There are many application specific solutions available today covering tasks like inspection, mapping, surveying and many more.

Many different sensors (optoelectronical, electrochemical, temperature or radio sensors, etc.) have been modified to work with UAVs to acquire data close to the ground and at low speed – this increases result quality and operational safety while reducing costs and downtimes.

Unmanned aerial systems are very complex – improper handling (flight planning, hardware set-up, analytics, etc.) can lead to dramatic loss in quality. Professional service providers can ensure the required quality, especially when it comes to very complex use cases.

1.2 Challenges and perspectives of Australian industries

Before understanding the potential of UAV solutions it's important to understand the need of change in certain industrial verticals. Although innovative changes are part of continuous improvement, game-changing methods offer a tremendous leap in productivity. In the table below, challenges of several key industry sectors, with essential economic impact across Australia, are listed:

Industry	Core challenges	How UAVs can assist
Construction	▪ The complex value-chain often leads to megaprojects cost overruns and delays (Mc Kinsey 2015) ▪ Construction labor costs are growing stronger than in other industries (Deloitte 2016)	▪ Time and cost-efficient aerial operation can control increasing costs and time schedule
Mining	▪ The fall of commodity prices and the transition towards renewable energies leads to new pricing strategies ▪ Remote accessible mining sites have high impact on work safety	▪ Time and cost-efficient / automated operation ▪ Less hazardous operation and lower impact on work safety
Energy/Utilities	▪ Less network investment led to ageing assets and higher maintenance costs (Australian Energy Regulator 2015) ▪ Work safety for vertical and powerline inspection needs to be improved	▪ Advanced data analysis and information systems (asset management) ▪ Less hazardous operation and lower impact on work safety

Exhibit 1: Challenges of Australian industries – a snapshot

By looking at the possible solutions to handle the challenges of these industries it appears that a UAV alone is not the magic formula. But it's a tool which complies with all technological demands towards digital transformation, cost-control and the ecological changes and therefore requires special consideration

1.3 Commercial UAV operation in Australia

In Australia, the technical evolution of UAVs has progressively gained speed since 2013 allowing UAVs to secure an important role in several industries and service sectors today.

Since small and light-weight sensors became available at further descending price aerial applications continuously brought on-site operations to a higher level of efficiency and safety.

Several new applications in the heavy industry and the agriculture sector powered by application-specific software are literally taking off.

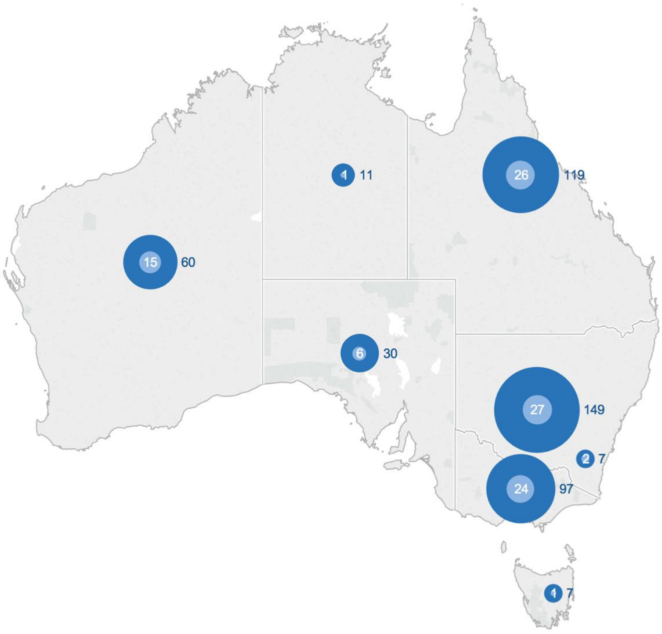


Exhibit 2: Regional growth of new UAV operator licenses since 2015 (Source: CASA)

Over the last couple of years, there has been an increasing demand for UAVs, which is strengthen by the exponential growth of UAV pilot licenses in Australia. Today, the commercial UAV market has reached a certain maturity in technology and operational experience empowering UAV service providers to offer very good tailor-made solutions to customers across the country.

2 WHY UAVs ARE A REAL ALTERNATIVE

As UAVs are getting more and more popular, the use of them must be handled thoroughly. There are challenges of unexpected operational drawbacks to overcome – compared to all traditional methods the advantages are still groundbreaking.

2.1 Traditional methods and operational challenges

UAVs have become an essential tool for surveyors and inspectors across the world for mapping the environment or construction sites, allowing to inspect vertical/horizontal infrastructure and helping farmers to efficiently monitoring crops.

"Advantages in costs, quality, time and safety are the primary reason why the construction, mining and infrastructure industries count on UAVs as an alternative solution."

The core question is: "Are UAVs providing the same or better results with less effort compared to traditional methods in the field?" The answer is: they do – many industries have the need to reduce costs for surveying and inspection processes, currently performed from ground, via helicopter or satellite.

Besides improving project planning, site-assessments, reducing downtimes of plants or construction sites, UAV applications help to:

- increase work safety and productivity
- reach remote or areas hard to access
- extend and automatize capacities
- save resources and increase flexibility
- increase the frequency of quality assessments

EXAMPLE:

A construction company requires three days of traditional ground-surveying of a 50ha site. This consequently leads to a downtime of the site. For safety reasons, no one can move equipment or continue during the surveying jobs. By using a UAV, the time of site-surveying reduces dramatically (direct savings) and the downtime for man and machine can be reduced as well (indirect savings) or even completely avoided. This combination make UAV technology a very attractive solution – not just in a safety critical environment.

2.2 More than just filling in the gap

As mentioned, UAVs supplement traditional methods by filling the gap between large-area satellite images and time-consuming ground operation. They can operate at lower altitude, less speed and higher resolution compared to manned aircraft. Operation is much more flexible due to a high degree of automation and pre-programmed routes making the repetition of the same job very easy.

Ground operation offers the highest accuracy, but as many case studies have proven, the required accuracy lies within the industry specific tolerances and UAVs usually fulfil these criteria.

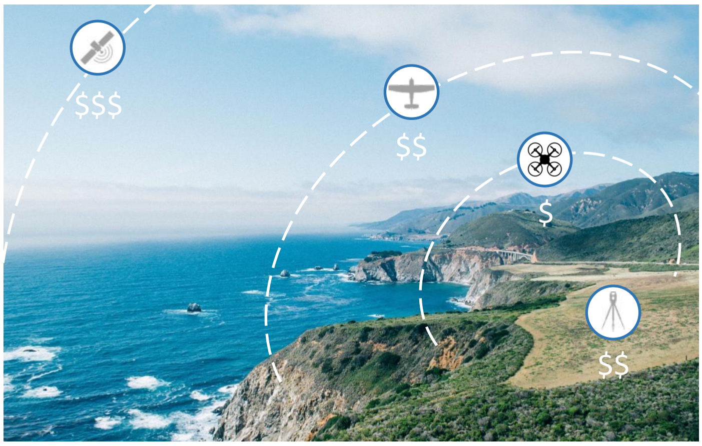


Exhibit 3: Filling in the gap – a new way of accessing data at low operational costs

In addition, UAV operation provides not only cost and time savings, but they often offer an unexpected added-value and an increase in quality and safety along the entire value-chain.

This additional benefit can be seen in aerial surveying and inspection applications, enabling multifunctional use in cross-sectional businesses and services.

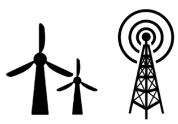
Industry	Added Value
	▪ Infrastructure before and after comparison ▪ Progress monitoring & reporting ▪ Liability (insurance documentation & claims) ▪ Lead time and flexibility
	▪ Asset lifecycle inspection ▪ Asset and engineering audits ▪ Clients assurance ▪ Emergency and disaster management

Exhibit 4: Added-value by using UAVs

"We are not looking for UAVs, we are looking for multi-applicable tools to increase efficiency in multiple use-cases" – UAV Project Engineer at a Mining company.

2.3 The impact of regulation on UAV businesses

UAVs open doors for new and promising business models with great potential of growth. Regulators around the world are now challenged to quickly establish comprehensive regulatory frameworks for this new and very dynamic market.

The Australian government already created a clear regulatory outline to allow commercial UAV operation. In a global comparison, the Australian Civil Aviation Safety Authority (CASA) regulations offer a comprehensive framework:

3 UNDERSTANDING THE UAV ECOSYSTEM

If UAVs shall be operated at scale, buying a random platform will not get anyone very far. The synergy of all used components has essential influence on the results. Choosing the right platform, sensors, software and training for the staff are challenging and very different between industrial applications. Another way to go is to hire a professional "Drone as a Service" (DaaS) provider who will collect the requested data for you.

Country	Altitude limit	Commercial operation permission	Operation up to 150kg MTOW[1]	UAV pilot certificate required	BVLOS[2] operation	Night operation	Operations manual required	e-application
Australia (CASA)	120m (400ft.)	✓	✓	✓	✓[3]	✓[3]	✓	-
Canada (TC)	90m (300ft.)	✓	✓	✓	✓[3]	✓[3]	✓	-
Japan (JCAB)	150m (400ft.)	-	-	-	✓[3]	✓[3]	✓	-
USA (FAA)	120m (400ft.)	-	-	✓	✓[3]	✓[3]	-	✓

Exhibit 5: Comparison of standard UAV regulation for commercial applications by country

The impact of the current Australian regulation allows automated operation beyond visual line of sight (BVLOS) under special conditions and after the completion of an exemption application process.

Documentation requirements in general are quite complex and not easy to manage for unexperienced UAV companies.

UAV regulation is quite new, hence many important technological standards need further development and global harmonization. Nevertheless, Australia was one the first countries to regulate UAVs when it published the Civil Aviation Safety Regulation 1998 (CASR) Part 101 in 2002 – a solid framework for business models.

Creating aerial footage by UAV is done seamlessly and quickly – extracting actionable information with high accuracy, is not.

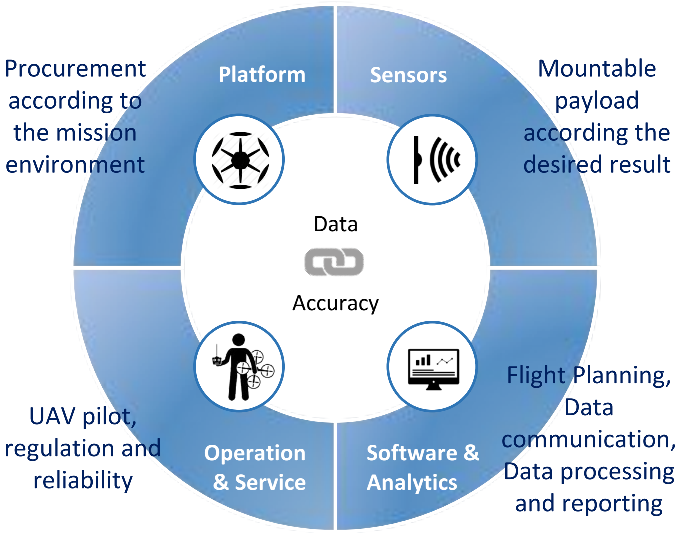


Exhibit 6: End-to-end workflow

[1] MTOW = Maximum Take Off Weight
[2] BVLOS = Beyond Visual Line Of Sight
[3] Exemption/Waiver permission and operation under special conditions

3.1 Accuracy of aerial data

No matter how high the savings are in time and costs, without the required accuracy of georeferenced data all savings will be consumed by the re-work of errors. For some applications, the accuracy of UAV acquired data exceed the current standards (stock pile volumes, mining, etc.) for other applications additional high-technological efforts are necessary to get close to conventional methods (surveying, etc.).

The accuracy of an UAV depends on many variables. The most important ones are the platform itself, the sensors and the software.

The Platform

To know the UAV's exact position during flight is essential. Not just for remote controlling but also to get precise georeferenced data. Georeferenced data sets are the assignment of digital data to GNSS coordinates. "Mission accuracy" defines the required quality of this data and describes the proximity of measurement results to the true value. In practical terms – the quality depends on the correction of GNSS deviation. Goal is to minimize the level of GNSS inaccuracy which can be done in multiple ways:

- UAV configuration (copter, fixed-wind, hybrid)
- Optimized altitude, speed and flight path
- Fixed/portable Ground Control Points (GCP),
- Real Time Kinematics (RTK)[1]
- Differential GPS (DGPS)[2]
- Additional post processing techniques (e.g. GNSS local base station post processing)

[1] Typical nominal accuracy for these systems is 1 cm ± 2 parts-per-million (ppm) horizontally and 2 cm ± 2 ppm vertically.
[2] Est. error growth of 0.22m to 0.67m per 100 km distance

The Sensors

There are several sensors available on the market – to date the two most popular sensor types for aerial surveying and inspection are optical and laser-based (LiDAR[3]) sensors.
The use of these sensors usually depends on the required result and the vegetative environment of the respective location.
Optical sensors are cost efficient and an easy to deploy. Almost every small UAV is capable to carry an optical high-quality (full format RGB) sensor. The combination of an optical sensor and commercial photogrammetry software provides big advantages for many applications according costs and quality today.

	Advantages	Limitations
Optical Sensors	High resolution at low price	Operation during night or bad weather conditions
	Density and accuracy of generated point-cloud	No/very little penetration into vegetation
	Most available UAVs are equipped with optical sensors	Inaccuracies due to vibration of lenses and chip

	Advantages	Limitations
LiDAR	Independent from light and vegetation conditions	No orthophoto possible
	Efficient flight patterns possible	Highly skilled personnel required for processing
	Faster decisions due to real-time point-cloud stream	Limited prevalence due to high costs
	Prospected price drops triggered by automobile industry	No texture possible without additional RGB camera

Exhibit 7: Summary of optical and LiDAR sensor capabilities

LiDAR sensors are a great tool in the hand of qualified professionals. The nearly unlimited and highly accurate use under almost all vegetative and daylight conditions makes it unique solution today. Nowadays, LiDAR scanner are particularly adapted for power-line inspections or land surveying in large areas and with or without dense vegetation. The typical accuracy (1 sigma) of less than 4cm along the XY axis and less than 2cm along the Z axis, is opening a large field of applications.

[3] LiDAR = Light Detection and Ranging

The Software

Besides flight-planning and flight-operation software, the analytics software has the biggest impact on result accuracy. Nonetheless the combination of all three is making the difference.

Flight planning software is commonly provided by the manufacturer of the UAV platform. For inspection and surveying tasks routes can and partly must be preprogrammed to reach the desired data or can switch to manual flight control when an object needs special inspection details.

To enable safe and efficient low-altitude operation, it is necessary to manage access into airspace and monitor the entire flight to avoid collisions with buildings, aircrafts or other obstacles. Today, there is no established standard by the governments for how to manage unmanned traffic. Advanced UTM[1] software helps to fill this gap.

Analytics software brings it all together – point clouds, aerial triangulations, DSM[2], DTM[3], orthophotos and orthomosaics can be created, presenting the results of aerial surveying.

The UAV software market offers Software-as-a-Service (SaaS) and customized end-to-end solutions from established industry provider like Autodesk, SimActive or Trimble as well as UAV-specific analytics software from Pix4D, Propeller.Aero or Dronedeploy.

Latest state-of-the-art software solutions provide additional capabilities allowing to combine LiDAR point clouds with an ortho-photos or to combine satellite data, terrestrial data and drone-acquired data. These sources are connected subsequently to industry specific analytics software (see above).

[1] UTM = Unmanned Traffic Management
[2] DSM = Digital Surface Model
[3] DTM = Digital Terrain Model

3.2 Make or Buy

Generating aerial data can be done in two ways: Either by in-house UAV operation or by hiring a professional service provider.

The decision (make or buy) however depends on a lot of business-individual factors:

Benefits "MAKE"	Reasoning
Control on the job	Acquired data is not a 'black box' – good for internal quality gates
Quality standards	Internal standard requirements define UAV operation
Data security	Safe transfer of (sensitive) data sets
Flexibility	Use the full scope of technological benefits anytime, anywhere
ROI	Increase the economic effect when using UAVs at scale

Benefits "BUY"	Reasoning
No overhead	No expenses for pilot training, certification or procurement
Cost flexibility	Pay the service per flight or project, no fixed costs
Hire the best	Appoint a service provider with the required expertise
Replacement costs	No ongoing investments in a rapidly changing technology
Assets	DaaS provider often offer to manage your assets and big data

Exhibit 8: Comparison of make or buy characteristics

UAV platforms often come with assisting functions (e.g. GPS, magnetometer and height-control) empowering unexperienced operators to qualify for a job. High-risk tasks (e.g. vertical inspection), however, strongly require a professional training and a lot of experience are to ensure a high accuracy of the result and a high operational safety.

The final decision depends on how big the impact of UAVs would be in daily operation – if collecting aerial data is part of the company's core-competency, operating an in-house fleet certainly is the preferred choice.

3.2.1 Configuring a UAV solution

Before starting to deploy an UAVs it's important to know how to combine and optimize hard- and software configurations as well as operational skills (training). As mentioned before, the careful combination of the different modules defines the required accuracy.

Following this approach allows to find different ways to explore the best solution. There are three ways to configure a UAV system:

1. Buy or lease a complete end-to-end solution from an OEM[1]
2. Buy a hardware and a software bundle
3. Configure all modules individually

The decision strongly depends on what's important for the respective business model and the required quality. Going into detail and configuring each piece of the whole puzzle can pay off perfectly but requires a lot of time and costs (learning curve).
Another factor is pilot expertise, which includes training and operational expertise. Especially for LiDAR operation the pilot's qualification is the primary success factor for accurate data.

3.2.2 Using a service provider

Professional service provider usually offer comprehensive packages to their customers. They can be found across all industries and in an increasing number. The biggest advantage is the expertise and short time for UAV deployment. Certified and specifically trained providers offer highly effective data acquisition from day one and often offer access to asset management tools.

3.2.3 Comparing key service provider solutions

Correctly assessing existing service provider is an essential requirement to successfully buy UAV services. Provider selection strongly depends on the scope of products and services along the entire workflow and how these match the desired mission results.

Some service provider offer an extremely wide range of services, others focus on one or two specific verticals.

The listed service providers are offering the major parts of the UAV-supported workflow. When assessing providers for a project or long-term relationship, it is necessary to understand the providers partnership network. A strong partnership network of the provider (hardware, software, services) allows to cover all parts of the value-chain.

Please find a comparison of the services of five service providers on the next page.

[1] OEM = Original Equipment Manufacturer

	Workflow capability	Explanation	Australian UAV	CYBERHAWK	TERRA DRONE	HELImetrex	Airmap3D
Platform	VTOL	*Platform configuration to vertically take-off and land*	✓	✓	✓	✓	✓
	fixed-wing	*Configuration to cover long distances. Take-off and landing space required*	✓	✓	✓	✓	✓
	Hybrid	*Configuration to take-off and land vertically and change into a fixed-wing horizontal flight*					
	Double GNSS	*Accurate platform positioning by minimizing the GNSS tolerances*			✓		
	RTK/PPK	*Real Time Kinematic/Post-Processing Kinematic for accurate positioning data*	✓	✓	✓	✓	✓
Payload	Optical Sensor	*Optical camera installed combined with a GNSS source*	✓	✓	✓	✓	✓
	NIR	*Optical camera installed operating in the near infrared band*		✓			
	Thermal	*Infrared camera installed combined with a GNSS source or live downlink*		✓	✓	✓	
	Multispectral	*Multispectral camera installed combined with a GNSS source*				✓	
	LiDAR	*Laser scanner installed combined with a GNSS source*	✓		✓		
Software	Flight planning	*Software to select flight pattern and upload it to the platforms autopilot*	✓	✓	✓	✓	✓
	Traffic control (UTM)	*Safe integration of UAV traffic in the uncontrolled airspace as well as supply of airspace maps and no-fly-zones*	✓		✓	✓	✓
	Data analysis	*Software to merge pictures/point clouds with geo data to create terrain models, distances, volumes, etc.*	✓	✓	✓	✓	✓
	Asset Management	*Track the condition of your assets over time. Compare similar datasets to find patterns and trends*	✓	✓			
Com.	Cloud storage	*Upload collected data to an online storage directly from the platform or via ground station*					
	Live downlink	*Optical, LiDAR image data*		✓	✓		
Application	Small area surveying/ mapping	*UAVS specifically designed to fulfill smaller area (< 1sqm) tasks in the construction and mining industry by photogrammetry or laser-scanning*	✓	✓	✓	✓	✓
	Large area surveying/ mapping	*UAVS specifically designed to fulfill smaller area (>1sqm) tasks in the mining industry by photogrammetry or laser-scanning or for large mapping projects*	✓		✓	✓	✓
	Inspection vertical/point	*UAVS specifically designed to inspect vertical structures like cell-towers, facades, or bridges*	✓	✓	✓	✓	
	Inspection linear	*UAVS specifically designed to inspect linear structures like train tracks, pipelines or power-lines*	✓	✓	✓	✓	
	Inspection indoor	*UAVS specifically designed to inspect ballast-tanks of ships, horizontal tunnels (mining) or pipelines from the inside*		✓	✓		

Exhibit 9: Capabilities of key drone as a service providers

Case study – UAVs in utilities

UAV-based powerline inspection

50km range	300.000 points/sec	2 hour return flight time	25m altitude above power lines

The Task

The goal is to inspect 50km of powerline network. In the past crews in helicopters carried out this job, which led to very high operational costs. To reduce these costs and to lower the operational risk at the same time, an alternative solution is required.

The Operation

The challenge to cover such a long distance while ensuring high data quality, a fixed-wing platform in combination with a LiDAR scanner and an optical sensor is required to generate a point-cloud and ortho-photos simultaneously.

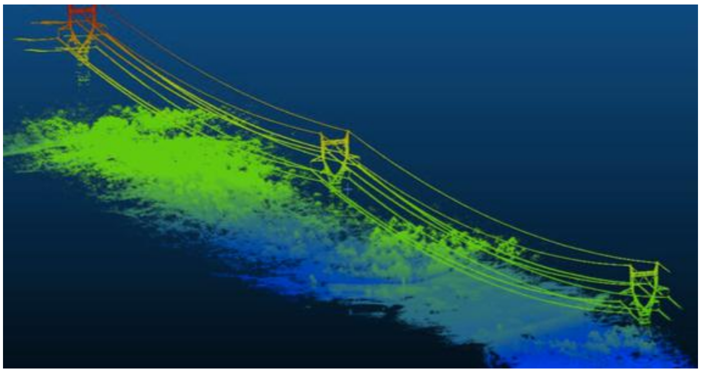
Preparation time including flight planning and local set-up takes about 3 hours. After take-off the platform is able to fly for two hours while capturing

300.000 points/sec. During a flight beyond visual line of sight (BVLOS), a stable communication link between pilot and platform must be ensured to maintain control of the platform. In this case a 4G network connection is used to overcome the limitations of the regular communication links.

Post-processing of the collected data requires around 3 days and creates a highly accurate point cloud combined with ortho-photos.

The Results

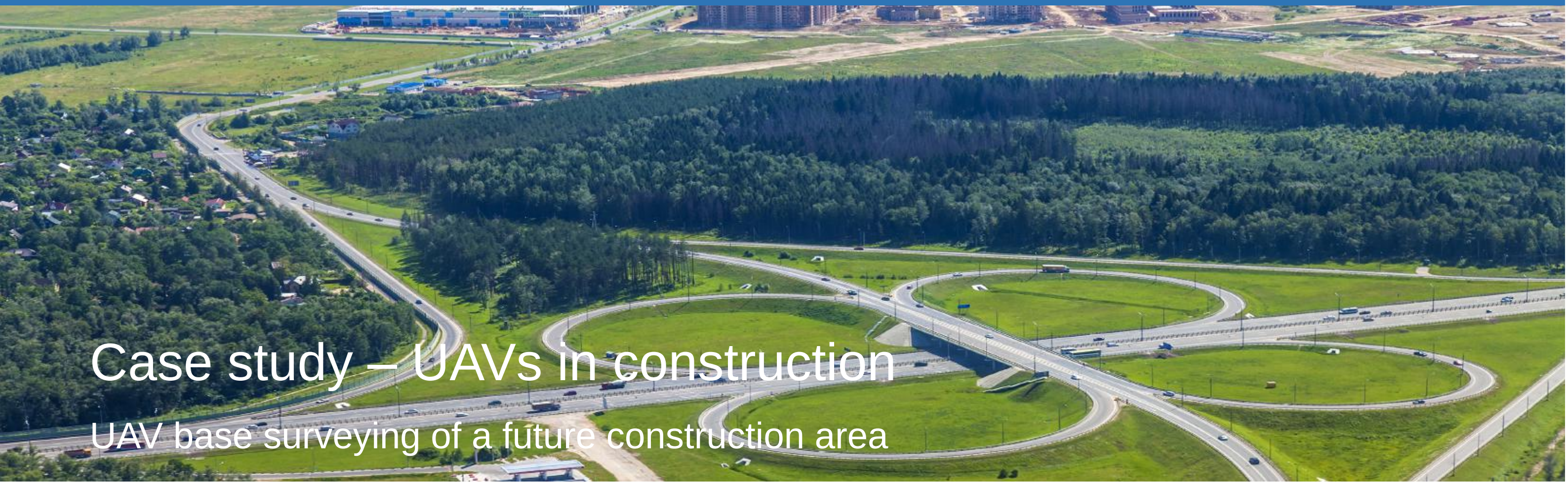
The final 3D model offers a 3cm overall accuracy. Depending on the clients request a comprehensive inspection report is available within 5 working days after assignment.



The Conclusion

Powerline monitoring via UAV is a safe and very cost-efficient alternative to helicopter-based inspections – the right technology and network coverage provided.

Using LiDAR technology, especially when it comes to data processing and integration into clients systems, requires a lot of expertise. Using a professional drone service provider might be something to look into to ensure the quality of the results.



Case study – UAVs in construction

UAV base surveying of a future construction area

200 ha area size	1.000.000.000 data points in total	7 flights	50m flight altitude

The Task

A construction company needs surveying data of a 200ha (2sqm) big area for planning a construction site. In this use case satellite and airplane imagery can not provide the required data quality due to dense vegetation. A 3D point cloud and Digital Terrain Model (DTM) is the desired result.

The Operation

Compared to photogrammetry LiDAR scanners are able to scan areas with high vegetation.

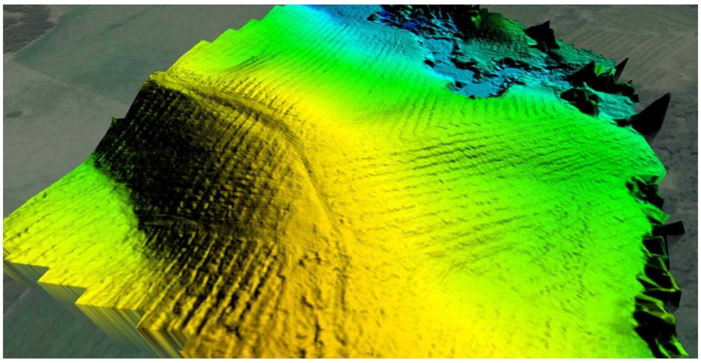
To cover the full area seven flights with a multirotor UAV are required. Each flight at a speed of 18 km/h is fully automated except for take-off and landing. With this settings the ideal point cloud density of 500 points/sqm can be captured. UAV-based LiDAR systems offers the possibility to directly reference the point cloud with geo- information. Optionally these data-sets can be referenced to ground control points to further increase accuracy.

The applied RTK-GPS and DGNSS systems plus the high-quality Inertial Measurement Unit (IMU) ensures a total position (x,y,z) accuracy of ~3cm.

For the whole area approximately 10 hours of operation including stops for battery changes is required. All gathered information are uploaded to a cloud storage, allowing to it to instantly share these information with multiple people.

The Result

The point cloud allows to generate a DTM with standard surveying analytics software. To process the collected raw-data to the required LiDAR based point cloud, standard surveying analytics software can be used. Besides from position, point clouds do not contain any further information. To provide true color picture information an ortho-photo (taken with an additional optical camera) can be overlaid.



The Conclusion

In many scenarios photogrammetry provides a more cost-efficient solution. LiDAR-based surveying increasingly provides great data quality especially in areas with dense vegetation. The preparation (technical set-up, flight planning) and data analysis, however, are key to great accuracy and mission success.

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