AUTOMATED OPERATION OF HIGH-PERFORMANCE FIXED-WING DRONES: A POTENTIAL GAME-CHANGER FOR GREEN AERIAL SERVICES

Martin Spieck[1], Jan H. Binnebesel[2] & Jan Mehnen[2]

[1]Thelsys GmbH, Hamburg, Germany
[2]mb+Partner, Hamburg, Germany

Abstract

Authorities in Europe and the United States are currently creating the regulatory framework that unmanned aerial systems can routinely fly complex missions autonomously beyond the visual line of an operator. This will open up a new business sector for high-performance drones that can fly long distances or cover large areas in order to provide unmanned aerial services for the public and private sector that are not possible or economically feasible today. To fully exploit the flexibility and efficiency of these high-performance drones, it is not sufficient to fly unmanned, but to still depend on a ground crew to launch, retrieve and refuel the flight vehicle. Instead, the entire flight operations should be as "unmanned" as possible. The (proposed) paper presents technologies that enable fully automated and remotely controlled drone operations. The operating principle is explained by the application example of persistent monitoring missions for the early detection of wildfires. An outlook to the potential contributions such unmanned aerial services could make for a "greener", more sustainable future concludes the paper.

Keywords: unmanned aerial vehicle, drone, automated operations, BVLOS operations, wildfire detection, SAR

1. Nomenclature

ARC	=	Aviation Rulemaking Committee
B2B	=	Business-to-Business (market)
B2C	=	Business-to-Consumer (market)
CAGR	=	Compound annual growth rate
EASA	=	European Union Aviation Safety Agency
eVTOL	=	Electric vertical take-off and landing (aircraft)
FAA	=	Federal Aviation Administration
HFC	=	Hydrogen fuel cell
MTOW	=	Maximum take-ogg weight
SAR	=	Search and rescue
VTOL	=	Vertical take-off and landing
UAS	=	Unmanned aerial system (UAV including software, payload, pilot and communication systems)
UAV	=	Unmanned aerial vehicle (often denoted as drone")

2. Introduction

Aviation and air transportation is under tremendous pressure to meet the challenges of tomorrow: ensuring mobility of people and goods and providing new (digital) services while being environmentally neutral. Unmanned aerial vehicles (UAV), or drones, are seen as an answer to the challenges which

aviation is facing today: to provide and even enhance mobility and aerial services, at low costs, while protecting the environment and minimizing the effects on the global climate. Drones, with their flexibility, their efficiency and their low environmental footprint, are expected to gain an important role in tomorrow's aviation. They are even seen as a transformative technology for aviation that will support the shift of the sector from a linear "brown" to a circular, green economy.
"Drone" is a general, colloquial term for an unmanned aerial vehicle (UAV) or an unmanned aerial system (UAS): these are pilotless aircraft which are remotely controlled or fly autonomously using software-controlled flight controllers.
There are two main types of drone platforms: rotary-blade drones like multicopters, and fixed-wing drones which, as the name implies, are aircraft with wings as lifting devices. Like aeroplanes and helicopters in today"s civil aviation, those two main types of drones serve different purposes and perform different functions. A third, cross-bred type, the hybrid drone, does not have a real counterpart in today's civil aviation. These are aircraft that fly like an aeroplane with the lift of the wings, but can take off and land vertically, either by means of additional rotary-blade devices or by tilting the cruise rotors or the entire wing. The only manned hybrid air vehicle produced in significant numbers is the Bell Boeing V-22 Osprey for the military market, while for passenger transport the Leonardo AW609 is expected to receive civil certification by FAA and EASA in 2025.

- Rotary-blade drones are suitable for comparatively small areas and short distances, and are the vehicle of choice for flights within the operator's field of vision. They are also required for special operational conditions which require hovering or vertical take-off and landing. Their strength is their flexibility to operate in confined spaces and the low threshold to perform a mission.

  Rotary-blade drones like multicopters have already established a sizeable market. A great driver in the early phases was the consumer-market for recreational use of drones. Rotary-blade drones are also used for commercial and industrial applications, where they usually perform their mission in the vicinity of the operator.

- Fixed-wing drones are necessary for applications that require higher levels of flight performance. They are suitable for large areas, long distances, high payloads and long flight times. Their deployment is generally more complex, as typical mission profiles require them to operate beyond visual line-of-sight (BVLOS) of the drone pilot or flight monitor.

  The regulatory and technical preconditions to fly such high-performance drone missions have only partly been established in the last few years, while major parts remain under development. This means that these drones are only at the beginning of commercial utilisation.

- Hybrid drones try to merge both worlds: the eVTOL capability of the rotary-blade drones and the efficient cruise of a plane. This makes them easier and more flexible to operate than fixed-wing drones. Their disadvantage: design constraints, additional weight and increased power requirements lead to lower flight performance and limited payload, compared to "proper" fixed-wing drones.

  Most variants are fully electric, which already limits the available range and endurance, and require a proportion of the battery capacity for vertical take-off and landing, which additionally eats into the usable performance values. Developments with a combustion engine as a cruise engine possess higher flight performance, but still have the aerodynamic and weight-related disadvantages of their eVTOL capability.

Rotary-blade drones are not suitable for high performance missions, such as long range or long duration flights. And even hybrid drones are limited in their performance: though better than a multicopter, they fall short of the performance and operating costs offered by fixed-wing drones. These configurational disadvantages can sometimes be compensated for in today's dominant 25kg class by the simpler handling compared to conventional fixed-wing drones, but they become increasingly significant as the development moves towards higher take-off masses, and exclude this type from a large part of the high-performance market.

3. Market Sectors for High-Performance Drones

Drones have demonstrated their usefulness in military applications for more than 30 years. Expectations of their potential in the commercial market are correspondingly high. Here, rotary-blade drones like multicopters have already shown their advantages in small-scale operations (low payload, short range). For more demanding applications (higher weights, BVLOS), though, there was no legal framework for the operation of UAVs in civil airspace over longer distances until recently. This has proven to be an impassable barrier to the growth of the large projected market for commercial aerial services by high-performance drones.

However, the necessary legal frameworks are currently developing fast in Europe and the United States, clearing the way for new business opportunities. Here, high-performance drones will mainly serve the market segments "linear-long", "area-large" and "endurance-high", which translates into flying long distances, covering wide spaces or staying in the air for an extended period of time.

The authors are not aware of a standardised or at least common definition for these terms, and even the labelling is not uniform. Market research reports often refers to these segments with rotary-blade drones as a reference, and the corresponding performance requirements are not too ambitious. As an average of published market forecasts, we received the (rounded) values given in the table below. Applications for fixed-wing drones, however, will go far beyond the possibilities of rotary-blade UAV. The market segments "linear-long", "area-large" and "endurance-high" of high-performance drones start at a multiple of these values, with hundreds of miles of range and several hours of operating time. In our research of the market for high-performance fixed-wing drones, we are concentrating on applications which justify the use of this type of vehicle. Our numbers for the respective market segments are given in the table as well as a suggestion.

market segment	market forecasts (rotary-blade)	high-performance fixed-wing
linear-long	distance > 5 km (3 mi)	distance > 40 km (25 mi)
area-large	area > 1 km^2 (250 acres)	area > 100 km^2 (25.000 acres)
endurance-high	flight time > 30 minutes	flight time > 2 hours

Without the need to carry humans, drones have the potential to minimise the costs and the environmental footprint of flight missions, and allow for new operational areas and applications, [1]. This opens up a new, increasingly developing market which is expected to become much larger than that for rotary-blade drones and their applications. Examples of high-performance, high-value applications for fixed-wing drones are monitoring large areas for hazards or environmental damages, supporting emergency services, operating high-altitude platforms for observation or communication services, and substituting aircraft or helicopters for the inspection of large infrastructures such as pipelines, power lines and railway tracks.

Figure 1 shows relevant markets for BVLOS missions. Of those, especially the sectors of energy, infrastructure and emergency have demands which are very challenging in terms of flight performance and operational costs. Examples are the inspection of pipelines, power lines and railway tracks (linear-long), the monitoring of large, remote areas for detecting natural hazards and environmental changes or wildlife conservation (area-large), and providing a flying platform for situation assessment and communication in natural disasters (endurance-high).

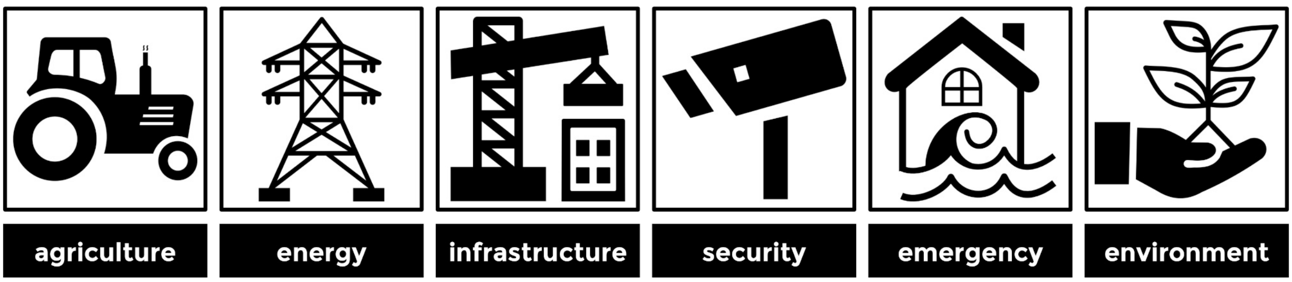

Figure 1 – Most relevant market sectors for high-performance drones

4. The Need for Automated Drone Operations

Prospective clients want to use drones to facilitate their business. The main interest is to receive information, in particular aerial views and/or sensor readings, respectively data derived and processed from those sources. It sound trivial, but it is the (sometimes neglected) cornerstone of any commercial drone activity: The vested interest of the potential buyer is to get the desired information faster and cheaper than by other means.

This defines the customers' needs: aerial services by high-performance drones have to deliver exactly the information the client wants (on demand, real-time or post-processed), at much lower costs and with the same reliability as the solution they are to substitute. Depending on the area of application, drone missions can replace manned flight, patrols by road/off-road vehicles or even on foot, watch towers, distress calls by the public, satellite imaging - it may even be that no economical solution exists so far.

There are two major customer groups for this kind of service: the public sector and the private B2B sector. From our market research and interaction with potential users and buyers, it becomes very clear that both customer groups do not want to be involved in any part of the drone operations, but expect "all-round service". The only notable exception are some SAR deployments in which emergency or relief services want to execute direct or indirect control of the aerial vehicle in the "hot phase" of the mission, either to have a better insight or to use expert competences, or because of legal or liability reasons.

A major bottleneck for commercial UAV services is the need for ground support. Drones can fly without a pilot on board, but they still need a ground crew on site for launching the drone, for retrieving it after landing and for preparing the next flight. This is a major cost factor, and it severely limits the range of potential applications, such as persistent operations or emergency sorties. It also impairs the flexibility to address customer needs, and, at a fundamental level, contradicts the idea of “unmanned”. After all, the main promise, and the real UVP (unique value proposition) of UAV services is: being unmanned!

The key to overcoming this bottleneck is automation. To find customer acceptance, complex flight operations have to be performed without the need of personnel on site. Drones must be able to launch, fly their mission, land and get ready for the next flight in a fully automated process.

5. Economic aspects

Commercial high-performance drone services have two major customer segments:

- Customers who already obtain aerial services, e.g. inspections or search/monitoring/mapping missions by aircraft or helicopter, as a substitution to manned flights.
- Customers who can use aerial services for the first time, e.g. because of cost restrictions or mission requirements that so far could not be met by other aerial services.

Drones are forecast to reduce the costs for aerial services by up to 90%. This would be a game-changer for aviation, and future market development is predicted by analysts and market researchers to be particularly dynamic once BVLOS missions become commonplace. But things are not so easy as these reports as these reports would have you believe. Manned aviation, in aircraft and helicopters, has seen decades of fierce competition and efficiency and cost awareness are highly developed. As a consequence, a simple light aircraft including pilot is astonishingly inexpensive as long as the objective is just to fly and watch the landscape.

The table below gives an approximate overview of current costs for aerial services by manned aircraft, i.e. aeroplanes and helicopters. The costs given are per flight hour (wet) with a pilot, from and to the airfield the aircraft are located and without contingency costs, ferry flights, observers, sensor equipment or any further extras. The actual hourly costs for commercial aerial services can be much higher, depending on the complexity of the mission, but due to their individual nature, it is not possible to compare them on a common basis.

It should be noted that the table contains only rough guide values at favourable, "no-frills" prices in the respective class. The aim is to show that commercial drone services will be under high price pressure from the outset, as long as they are competing directly with piloted aerial services.

Aircraft				
Category	Engine	Payload	Examples	Cost/h
Very light	Single e. piston	Pilot + 1 pax	Cessna 150, Liberty XL-2	200 €
Light	Single e. piston	Pilot + 3 pax	Cessna TTx, Cirrus SR22	350 €
Light	Twin e. piston	Pilot + 3 pax	Piper PA-44, Diamond DA42	600 €
Medium	Twin e. piston	Pilot + 5 pax	Beechcraft G58, Vulcanair P68C	1100 €
Medium	Single e. turbine	Pilot + 5 pax	Piper M500, Daher TBM 910	1800 €
Helicopters				
Category	Engine	Payload	Examples	Cost/h
Very light	Single e. piston	Pilot + 1 pax	Robinson R22, Cabri Guimbal G2	300 €
Light	Single e. piston	Pilot + 3 pax	Robinson R44	500 €
Light	Single e. Turbine	Pilot + 4 pax	Bell 206 JetRanger, Airbus EC120	1200 €
Medium	Single e. Turbine	Pilot + 6 pax	Bell 407, Airbus AS350	2200 €
Medium	Twin e. turbine	Pilot + 6 pax	Airbus AS355, Leonardo A109	2500 €

Feed-back from potential customers indicate that the unmanned aerial services become interesting when the costs fall below 30% of a comparable manned flight service. To demonstrate this in practice: The class of fixed-wing UAV for which BVLOS permits can be applied for most easily, i.e. drones of the 25 kg class, is primarily competing with very light aircraft, as their payload consists primarily of cameras and comparable sensors of low complexity which "replace" the eyes of the pilot or an observer. In this segment, aerial service providers should be able to reach a price level of 70 €/h, which is quite a challenge and only possible with streamlined processes, automated operations on-site and, as soon as it is permitted by regulation, the supervision of several UAVs by one remote operator.
After this sobering news: UAVs offer a wide range of options for enhancing customer value - and at lower additional costs than manned flight services. This market will be easier to develop as soon as civilian users can also utilise larger and more powerful drones in the high-performance market.

6. Operational aspects

6.1 BVLOS missions

In Europe, major steps towards BVLOS operations, and thus long-range/large-area missions, were the Commission's regulations (EU) 2019/945, [2], and (EU) 2019/947 in 2019, [3], which set the groundwork for aviation authorities to grant BVLOS permissions. Regulation (EU) 2022/425 then prolonged the transition period, [4], with (EU) 2019/947 becoming applicable from the 1st January 2024.
In 2020 and 2021, amendments were made in EASA guidelines, in particular by the Executive Director Decisions 2020/022/R, [5], and 2022/002/R, [6]. An important step was Annex II to the 2022 decision, which defines the process for obtaining an operational authorisation for BVLOS flight and gives the appropriate national and federal aviation authorities a guiding principle for issuing BVLOS licenses and permits for long-range missions.
In North America, the situation has not progressed as far. In 2021, the Unmanned Aircraft Systems Beyond Visual-Line-of-Sight Operations Aviation Rulemaking Committee (UAS BVLOS ARC) was established. The committee published their recommendations to the Federal Aviation Administration (FAA) for the regulatory requirements to normalise BVLOS operations in 2022. In 2023, the FAA called for public comments on the proposed rules for BVLOS flight, and is now in the legislative procedure of creating the required framework. It is expected, however, that once in force, implementation will be more straightforward than it is possible in the more heterogeneous landscape of Europe, so large-scale commercial BVLOS services will probably become reality on both continents at roughly the same time.
This does not mean that up to now, it was impossible to perform BVLOS mission. But the process to obtain a permission was complex, lengthy and often with an uncertain outcome. As a result, it was almost impossible to perform aerial services which required BVLOS flight as a routine commercial business.

In Europe, since 1st January 2024 there are four possibilities to operate a civil drone BVLOS in the Specific Category (medium risk).

- The European Standard Scenario STS-02 "BVLOS with Airspace Observers over a controlled ground area in a sparsely populated environment" is a low-threshold option for flying BVLOS, but the limits (up to 2 km with observer) do not permit any substantial commercial BVLOS activity.
- The Predefined Risk Assessments (PDRA) are operational scenarios for which EASA has already carried out the risk assessment. Most relevant for long-range BVLOS flights is PDRA-G02, allowing to operate drones up to 3 m max. dimension and not more than 34 kJ of energy in reserved/segregated airspace over densely populated areas, as far as a direct command and control link is ensured. PDRA-G02 is a well-suited option for BVLOS test flights, but does not allow efficient commercial activities. Additional PDRAs can be issued on the national level.
- A SORA (Specific Operations Risk Assessment) is a systematic classification of the risk posed by a BVLOS drone flight in the specific category and of the measures to mitigate the risk and ensure the safety objectives are met. SORAs are developed by the operator and approved by the responsible authorities. A 10 step methodology shall support operators to create a suitable risk assessment. SORAs are currently the predominant option for commercial BVLOS missions, but it is a substantial effort of work and time, and usually restrict the operator a to narrow scope of application.
- A Light UAS operator Certificate (LUC) represents an authorization for UAS operation in the special category. The requirements for issuing an LUC are significantly more extensive compared to an operating license. The associated rights are granted gradually in a step-by-step process and are based on the maturity of the UAS operator. The highest level is the permission to start operations in the specific category without needing an operational authorisation by the aviation authorities. Even the EASA sees the LUC as a "quantum change in the efficiency of drone aerial services" and thus the admission ticket to efficient commercial BVLOS operations. In Germany, the first LUC was issued in September 2023.

  For commercial activities which involve BVLOS, operators will have to develop the suitable SORA and, in the medium term, strive for obtaining an advanced LUC which allows them to fly missions flexibly and without delays due to administrative processes. Sorbelli et. al. elaborate associated challenges and solutions in more detail, [7].

6.2 Public Acceptance

Public acceptance of drones flying in the sky above its heads is an important issue for the future business performance and commercial success of unmanned aerial services. Germany, with its notoriously prudent if not critical citizens, is probably the best criterion with which to measure perception and possible reservations about the widespread use of drones.
A 2022 study of the Unmanned Aerial Vehicle Association (VUL), [8], a joint initiative of the German Air Transport Association (BDL) and the German Aerospace Industries Association (BDLI), suggests that for many purposes, there is a lot of scepticism concerning the widespread commercial use of UAV, see figure 2. The study was conducted in Germany, but recent research by Stolz et.al. indicates that the attitude towards drones is not fundamentally different between European countries, [9], so it can be reasonably expected that the perception across Europe with respect to the purpose of the drone mission will not deviate significantly from the German results as well.
According to the survey, that does not bode well for the market sector of fast urban deliveries of goods. The good news is that for purposes that are most relevant for high-performance applications, the values are at the upper end of the acceptance scale (shown in bold in figure 2). But it would be negligent to have a false sense of security that persistent or recurring operations might not suffer from complaints, protests and corresponding reactions of the authorities.
Mostofi et.al., [10], present a method to model public attitude towards drone operations, in this case air taxis, which can be applied to other mission types and market sectors, too. Other research aims

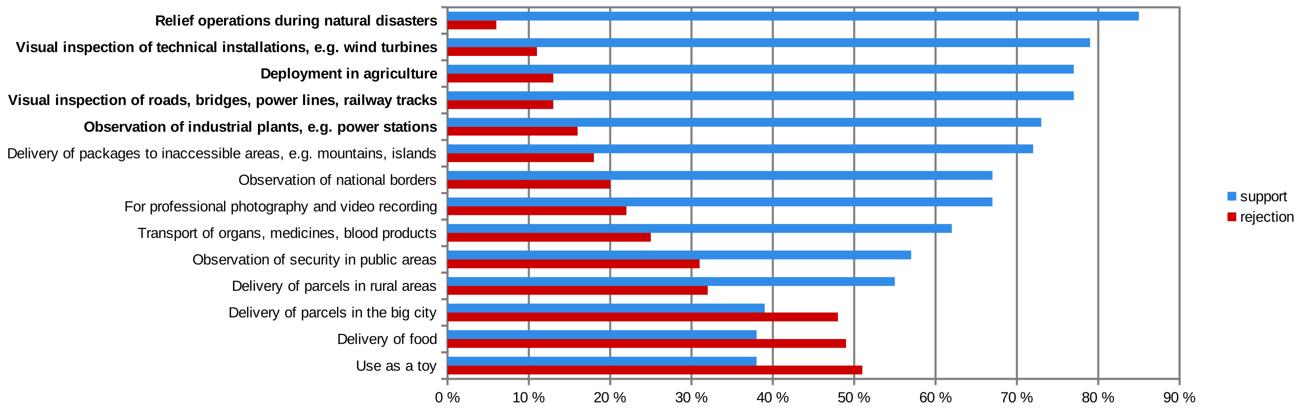

Figure 2 – Rates of support and rejection of drone operations with respect to the operation purpose

to address the most relevant factor for potential public disapproval: noise. As drones of the specific category are usually restricted to fly below an altitude of 120 m, the noise of a combustion engine arriving at ground level is often perceived as unpleasant and disturbing. UAV with electric propulsion have a more agreeable noise performance, but are limited in range, endurance and payload which prohibits their use for more challenging missions. Current research projects attempt to unite both worlds: drones powered with H_2-fuel cells are designed to combine the advantages of electric propulsion with the performance of petrol-driven UAV. Figure 3 shows the concept of a hydrogen fuel cell-powered class C3 drone from the German project "H2 FINITY"[1].

Figure 3 – The H2 FINITY concept of a silent long-range drone, powered by a H_2-fuel cell and electric propulsion

7. Technologies for Automated Drone Operation

Fixed-wing drones are remotely/autonomously controlled aeroplanes, and like their manned cousins they can take off and land on a runway. Manned and unmanned traffic, however, do nor mix well, and operating commercial drone services from existing airfields together with piloted aeroplanes is not a promising concept, and especially unsuitable if operations should be automated.

Advanced launch-&-landing systems aim at making operation of drones easier and smoother. But they have their limits. Concepts like the launch-&-recovery system of Zipline base on local distribution centres and offer little flexibility and prohibit mobile installations. Their launch-&-landing sites still require personnel on site and are not automated yet. Other solutions like the SkyHook recovery system develoed by Boeing Insitu are relocatable and more flexible, but need an entire team to operate the drones. Additionally, most of these systems can only accommodate a single type of drone, often an in-house design. This impairs the capability to address customer needs. There are

[1] H2 FINITY: Erforschung und Erprobung eines skalierbaren Wasserstoff-Antriebsstrangs für leichte und mittlere Fluggeräte (Research and testing of a scalable hydrogen powertrain for light and medium aircraft); http://h2finity.de

also limiting restrictions with respect to weight and payload of the flight vehicles that can be operated with these systems.
This makes commercial use of fixed-wing drones almost as expensive and cumbersome as operating manned aircraft - the actual advantage of “unmanned” is lost. It prevents a broad market introduction of flight services by fixed-wing drones, and are impeding the ability to tap the full potential of this new technology.

7.1 Automated Launch and Landing Systems for eVTOLS

The idea of operating drones in an automated process, without the direct intervention of humans, is not new. Automated launch-&-landing pads for rotary-blade drones, such as the ground station for the DHL parcelcopter, figure 4, allow fully unmanned operation of multicopters.
Manufacturers and operators of hybrid drones, like Gadfin of Israel and Beagle Systems of Germany, have adopted the concept for their vehicles, [11] and [12]. Flight performance and payload of their drones allows them to perform monitoring missions in the medium-performance market. With their Spirit-V and Spirit-X concepts, Gadfin is also aiming to develop larger drones with a payload of up to 150 kg, but it remains to be seen whether these developments will be fully realised and put into practical use.
For the large market share of missions with higher requirements than hybrid eVTOL drones can fulfil, conventional fixed-wing drones must be used. But automated operation is more challenging than for eVTOL drones. In principle, launching the fixed-wing drone is not difficult, and many operators use catapult devices to get the drone up to speed. The main difficulty is to recapture and retrieve the drone after the mission so that it can be automatically refuelled or recharged and prepared for the next flight.

Figure 4 – Automated eVTOL launch-&-landing pad of the DHL parcelcopter (left). DLR landing a fixed-wing UAV on a moving platform (right).

7.2 Automated Launch and Landing Systems for Fixed-Wing Aircraft

Early attempts to land fixed-wing drones on a moving platform were undertaken by DLR, the German Aerospace Center. In 2016, researchers from the Institute of Robotics and Mechatronics succeeded in landing a fixed-wing drone, the UAV Factory Penguin B, autonomously on a moving ground vehicle, [13]. Here, the landing platform was travelling at constant speed (with minor adjustments to support synchronisation) and the UAV had to navigate into the correct position. Supported by optical markers for positioning in the near field, the drone had to approach the landing area with an accuracy of 50 cm and was then touched down under computer control.
The main objective of this research was to develop a landing system that makes it possible to recover ultra-light solar-powered aircraft, which have no shock-absorbing landing gear due to their extremely lightweight construction and are easily damaged on touch-down. Further efforts to increase the level of automation have not been pursued, as it became apparent that in practical use, the manoeuvrability of the drone is not sufficient to compensate adverse effects like changing crosswinds and gusts.
A a system that takes the opposite approach has been developed by mb+Partner of Germany, figure 5. GROLAS, which stands for Ground-based Landing Gear System, synchronises actively with

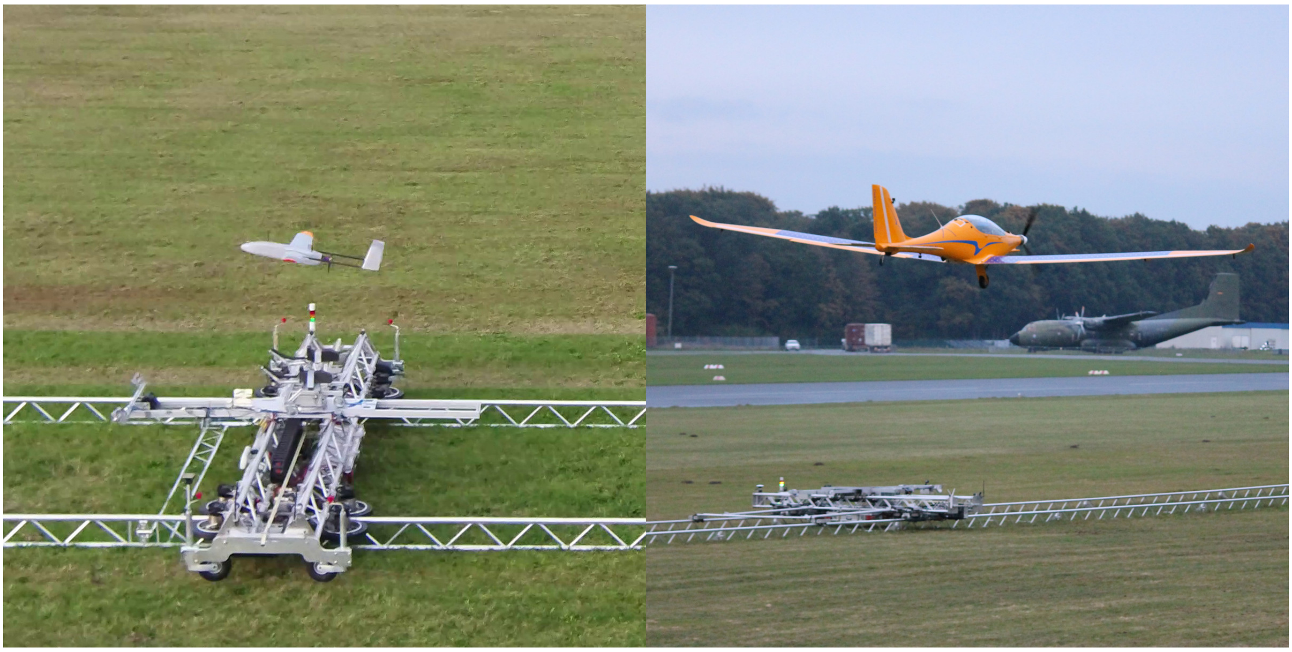

Figure 5 – Operating a fixed-wing drone from the GROLAS launch-&-landing system (left), synchronisation trails with Elektra One Solar, an optionally piloted / unmanned aircraft (right)

the approaching drone, which in turn has only to fly within its usual range of precision. As far as the authors are aware, this is the first system to enable fully automated landings of fixed-wing drones, see figure 6.

The central element of GROLAS is the launch-&-landing trolley which rides on a rail track of lightweight elements. The trolley is driven by electric motors and can accelerate and decelerate very dynamically. The fixture device for the drone is mounted on a slide which can move left/right and rotate for adjusting to the flight attitude of the drone. The track itself is easy to assemble and can be installed on unprepared ground.

To launch the drone, the trolley accelerates to take-off speed and releases the flight vehicle. For landing, the trolley synchronises precisely with the approaching drone, and the drone latches into the fixture device again. The slider with the fixture device adjusts for lateral and azimuthal deviations, so the drone is intercepted safely even when cross winds, gusts and other disturbances are present. This is a unique feature compared to competing solutions for landing fixed-wing drones, as the drone has only to fly within its normal accuracy range, and must not meet more stringent precision requirements, e.g. to hit an arresting rope or the centre of a net.

After coming to a standstill, the trolley with the drone on top returns to a maintenance position. Here, the drone is refuelled or recharged. Within minutes, the drone is then ready for the next mission. In case of very large data volumes or the need for high data security, data from the mission can also be downloaded from the drone and transmitted to central mission control while being served at the maintenance position.

A hangar at one end of the rail track offers protection against the weather and can be equipped with storage capacity for multiple drones. This option also allows operating up to 10 drones from one GROLAS system in parallel.

GROLAS can be configured for almost every type of drone that is within the (very wide) specification of the system. For example, GROLAS Type R150 can handle drones with a flying weight between 5 and 150 kg, and take-off & landing speeds below 25 m/s (90 km/h). This makes the system independent of the type of drone or a specific manufacturer.

The GROLAS system and the drones can be monitored from a central mission control room. Depending on the application, mission control oversees autonomous operations (e.g. patrol flights over woodland for wildfire spotting) or remotely controls GROLAS and the flight vehicle (e.g. fast-response search-&-rescue missions for people in distress at sea).

Figure 6 – Landing sequence of a drone on the GROLAS system. The time interval between the images is 1 sec.

8. Typical Application Area for High-performance Drones

Market research indicates that early adopters of fully automated, high-performance drone services will be emergency services and rescue services, as they have requirements for a variety of applications that can only be met by automated drone services. The two most relevant ones are

- **persistent operations**, i.e. the drones can provide seamless flight operations over a long period of time,
- **emergency scamble**, i.e. drones are ready to launch 24/7 on the press of a button from a remote mission control centre.

8.1 Application Scenario - Early Wildfire Detection

Wildfires cause immense damage worldwide, and both the number of incidents and their size are increasing all the time, [14]. In addition to the loss of human life, damage to property and the destruction of valuable nature, wildfires also cause an enormous amount of CO_2 emissions, releasing about 8 billion tonnes of CO_2 each year. This amounts to app. 10% of all global CO_2 emissions, more than all global traffic. Experts estimate that early detection systems and upgraded fire services could reduce wildfires and emissions significantly, [15]. Wildfire spotting by UAV is considered as a powerful approach to reduce the number and impact of wildfires, especially in remote and sparsely populated areas, [16].

To meet the requirements, drones have to patrol regularly large areas that are at risk and detect even small signs of danger. To do so at reasonable costs, standard operation must be automated: launch, monitoring flight, landing, turn-around, new mission assignment. On-board AI takes over the initial evaluation of images and sensor data, and contacts central mission control (CMC) in the event of anomalies. Operators at CMC make an initial assessment of the situation, take over control of the drone for close-ups if necessary, and initiate the next appropriate steps, such as alarming the emergency services. The fire brigade can analyse the images in real time and determine the exact location, type, extent and dynamics of the fire. Firefighting can thus be much faster and more targeted - important in wildfires, where any loss of time leads to exponentially greater damage. Figure 7 shows the schematic process of effective early wildfire detection.

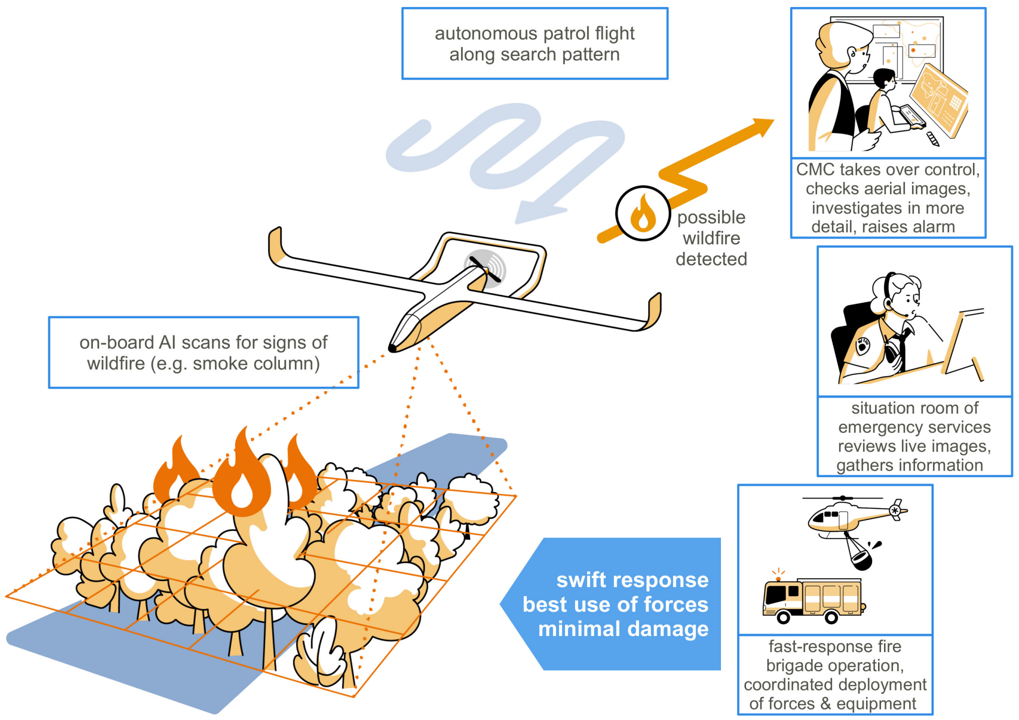

Figure 7 – Concept of early wildfire detection by high-performance, fixed-wing drones

8.2 Application Scenario - Fast-Response Maritime Search and Rescue

The responsibility for sea rescue lies with the country in whose internationally agreed zone the emergency occurs. search and rescue is a sovereign task carried out by government agencies such as the military and authorised organisations. There are frequent false alarms, especially in coastal areas: swimmers in distress turn out to be floating debris, and reportedly sinking sailboats and drifting kitesurfers can get themselves to safety before the rescue services arrive. This leads to high costs that have to be borne by the rescue organisations themselves.
On the other hand, the rescue services often arrive too late in the event of a real emergency:

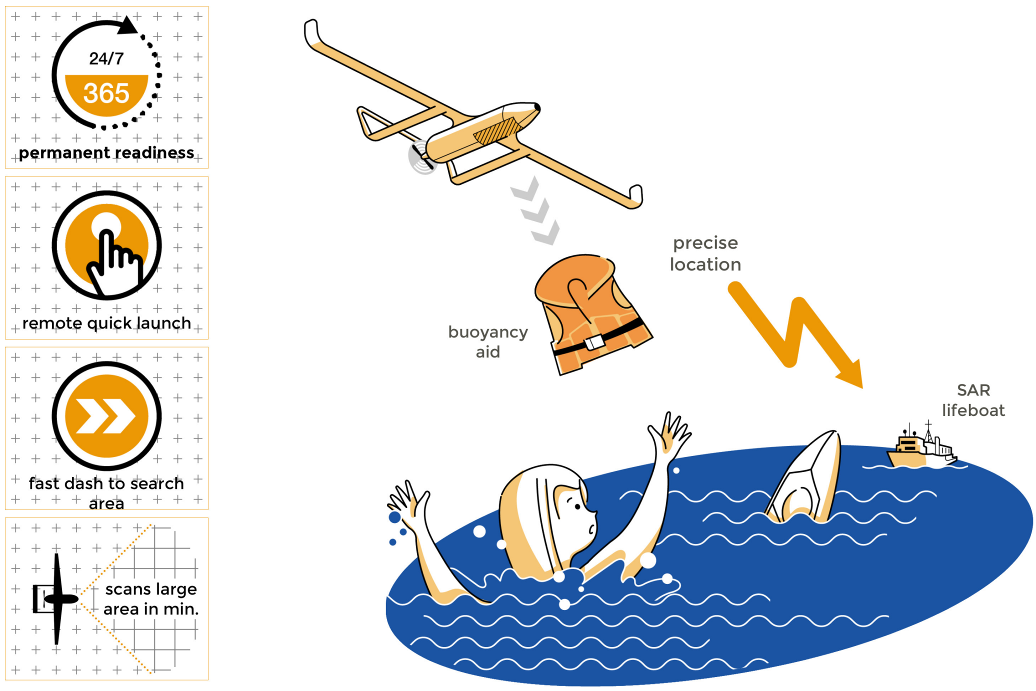

Figure 8 – Concept of fast-response maritime SAR by high-performance, fixed-wing drones

the exhausted swimmer goes under before the helicopter from a distant base can reach them, and the capsized rowing boat cannot be found quickly enough from the life boat in the sea of waves.
Small but performant UAV can make a difference here: they are fast, have a good overview and can quickly cover large areas. The small, comparatively cheap drones can be kept available in greater numbers and a closer network than expensive helicopters. Used correctly, drones can save costs, as rescue cruisers and SAR helicopters only have to be deployed in real (confirmed) emergencies. And they can save lives, because in a typical coastal emergency, there are usually only one or two people in distress, but they quickly need a buoyancy aid to keep them afloat until the rescuers arrive. Equipped accordingly, even a lightweight class C drone can drop inflatable life jackets with pinpoint accuracy, figure 8.

9. Potential Contributions for a Greener, More Sustainable Future

Unmanned aerial services by high-performance fixed-wing drones not only promise an exciting and growing market, but also tangible benefits for society. By replacing existing services with low-emission alternatives and enabling new, sustainable services, drones can contribute to strategic goals in the area of environmental and climate protection.
Below, selected supranational strategic sustainability goals are outlined in order to illustrate the diverse possibilities that this new technology offers.

9.1 Contribution to the European Green Deal

Applicable goals and objectives of the European Green Deal, [17]:

- 2.1.5. Accelerating the shift to sustainable and smart mobility

  Automated and connected multimodal mobility will play an increasing role [...]. The EU transport system and infrastructure will be made fit to support new sustainable mobility services that can reduce congestion and pollution [. . .] ramp-up the production and deployment of sustainable alternative transport fuels...

- 2.1.8. A zero pollution ambition for a toxic-free environment

  To protect Europe's citizens and ecosystems, the EU needs to better monitor, report, prevent and remedy pollution...

9.2 Contribution to A New Industrial Strategy for Europe

Applicable goals and objectives of the A New Industrial Strategy for Europe, [18]:

- 1.1.1 Pushing the frontiers of knowledge on adaptation

  The digital transformation is critical to achieving the Green Deal adaptation objectives. [...] We must promote the use of the latest digital technologies and climate services to underpin decision-making (for example remote sensing, smart weather stations, artificial intelligence and high performance computing). [...] Ocean measurements and observation will be also be further strengthened.

- 1.1.2 Fostering local, individual, and just resilience

  The Commission will support the local uptake of data, digital and smart solutions related to climate adaptation tailored to local and regional specificities.

9.3 Contribution to UN Sustainable Development Goals

Applicable goals and objectives of the UN Sustainable Development Goals, [19]:

- **Goal 6:** Ensure availability and sustainable management of water and sanitation for all

  6.3 By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally

  6.6 By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes

- **Goal 7:** Ensure access to affordable, reliable, sustainable and modern energy for all

  7.b By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States and landlocked developing countries, in accordance with their respective programmes of support

- **Goal 9:** Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation

  9.a Facilitate sustainable and resilient infrastructure development in developing countries through enhanced financial, technological and technical support to African countries, least developed countries, landlocked developing countries and small island developing States

- **Goal 13:** Take urgent action to combat climate change and its impacts

  13.1 Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries

- **Goal 14:** Conserve and sustainably use the oceans, seas and marine resources for sustainable development

  14.1 By 2025, prevent and significantly reduce marine pollution of all kinds [...]

  14.2 By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans

  14.a Increase scientific knowledge, develop research capacity and transfer marine technology [...]

- **Goal 15:** Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

  15.2 By 2020, promote the implementation of sustainable management of all types of forests [...]

  15.4 By 2030, ensure the conservation of mountain ecosystems, including their biodiversity[...]

  15.7 Take urgent action to end poaching [...] and address both demand and supply of illegal wildlife products

  15.b Mobilize significant resources from all sources and at all levels to finance sustainable forest management and provide adequate incentives to developing countries to advance such management, including for conservation and reforestation

  15.c Enhance global support for efforts to combat poaching and trafficking of protected species [...]

The authors would like to express their hope that this new, emerging technology of complex and performant unmanned flight missions will create a win-win-win situation: for the economy, for society and for the environment in which we live.

Contact Author Email Address

The contact author email address is mailto: martin.spieck@thelsys.de

Copyright Statement

Acknowledgements

The authors gratefully acknowledge that the proposed paper uses the results and support of several past and ongoing research and technology development projects:

- REALISE - Landebahn-unabhängiges automatisches Start- und Landesystem für unbemannte Luftfahrzeuge. KMU-NetC project co-funded by German Federal Ministry of Education and Research (BMBF). <http://realise.aero>
- 5G-Telk-NF. Co-funded by German Federal Ministry for Digital and Transport (BMDV). <http://en.5g-telk-nf.sh>
- ElektRail - Automatisches und landebahnunabhängiges Start- und Landesystem für einen solar-elektrischen Flugbetrieb mittelschwerer UAV. Co-funded by German Federal Ministry for Economic Affairs and Climate Action (BMWK). <http://elektrail.com>

References

[1] Politi, Elena; Rodosthenous, Panagiotis; dos Reis, Ricardo; Larsen, Morten; Varlamis, Iraklis; Dimitrakopoulos, George. (2024). *Analysis of the new market trends of UAVS for safe BVLOS operations.* Journal of Physics Conference Series 2716(1):012056. DOI:10.1088/1742-6596/2716/1/012056.

[2] European Commission. (2019). *Consolidated text: Commission Delegated Regulation (EU) 2019/945 of 12 March 2019 on unmanned aircraft systems and on third-country operators of unmanned aircraft systems.* Document 02019R0945-20200809. http://data.europa.eu/eli/reg_del/2019/945/2020-08-09

[3] European Commission. (2019). *Commission Implementing Regulation (EU) 2019/947 of 24 May 2019 on the rules and procedures for the operation of unmanned aircraft.* Document 02019R0947-20220404. http://data.europa.eu/eli/reg_impl/2019/947/2022-04-04

[4] European Commission. (2022). *Commission Implementing Regulation (EU) 2022/425 of 14 March 2022 amending Implementing Regulation (EU) 2019/947 as regards postponing the transition dates for the use of certain unmanned aircraft systems in the 'open' category and the date of application for standard scenarios for operations executed in or beyond the visual line of sight.* Document 32022R0425. http://data.europa.eu/eli/reg_impl/2022/425/oj

[5] European Union Aviation Safety Agency. (2020). *Executive Director Decision 2020/022/R.* http://www.easa.europa.eu/en/document-library/agency-decisions/ed-decision-2020022r

[6] European Union Aviation Safety Agency. (2022). *Executive Director Decision 2022/002/R.* Ref. Ares(2020)7628820 - 15/12/2020. http://www.easa.europa.eu/en/document-library/agency-decisions/ed-decision-2022002r

[7] Sorbelli, Francesco; Chatterjee, Punyasha; Das, Papiya; Pinotti, Cristina. (2024). *Risk Assessment in BVLoS Operations for UAVs: Challenges and Solutions.* Conference: 20th IEEE International Conference on Distributed Computing in Smart Systems and the Internet of Things (DCOSS-IoT 2024), Wi-DroIT Workshop. Abu Dhabi, UAE.

[8] VUL - Verband Unbemannte Luftfahrt (Unmanned Aerial Vehicle Association). (2022). *Was denken die Deutschen über Advanced Air Mobility? (What do Germans think about Advanced Air Mobility?)* http://www.bdli.de/sites/default/files/2024-05/VUL-Markststudie_2023_DE_f_-1.pdf

[9] Stolz, Maria; Papenfuß, Anne; Dunkel, Franziska; Linhuber, Eva. (2024). *Harmonized Skies: A Survey on Drone Acceptance across Europe.* Drones 2024, Volume 8, Issue 107. http://doi.org/10.3390/drones8030107

[10] Mostofi, Hamid; Biehle, Tobias; Kellermann, Robin; Dienel, Hans-Liudger. (2024). *Modelling public attitude towards air taxis in Germany.* Transportation Research Interdisciplinary Perspectives 24:101045. DOI:10.1016/j.trip.2024.101045

[11] Ball, Mike. (2021). *Autonomous eVTOL Drone Delivery Technology to Launch in UK.* UnmannedSystemsTechnology.com (UST). http://www.unmannedsystemstechnology.com/2021/09/autonomous-evtol-drone-delivery-technology-to-launch-in-uk

[12] Drones Magazin. (2021). *Drohne, sofort vor Ort: Beagle Systems startet mit erster Station eines deutschlandweiten Netzwerks (Drone, immediately on site: Beagle Systems launches the first station of a Germany-wide network).* Wellhausen & Marquardt Medien. http://www.drones-magazin.de/presse/drohne-sofort-vor-ort-beagle-systems-startet-mit-erster-station-eines-deutschlandweiten-netzwerks/

[13] Locher, Fabian; Muskardin, Tin; Kondak, Konstantin. (2016).*DLR-Press release - Video - autonomous landing at full speed.*

[14] Biddle, Nicholas; Bryant, Colleen; Gray, Matthew; Marasinghe, Dinith. (2020). *Measuring the economic impact of early bushfire detection.* ANU Centre for Social Research and Methods, Australian National University.

[15] Bandara, Sahan; Navaratnam, Satheeskumar; Rajeev, Pathmanathan. (2023). *Bushfire Management Strategies: Current Practice.* Fire, Volume 6, Issue 421. http://doi.org/10.3390/fire6110421

[16] Partheepan, Shouthiri; Sanati, Farzad; Hassan, Jahan. (2023). *Autonomous Unmanned Aerial Vehicles in Bushfire Management: Challenges and Opportunities.* Drones, Volume 7, Issue 47. http://doi.org/10.3390/drones7010047

[17] European Commission. (2019). *The European Green Deal.* Document 52019DC0640. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52019DC0640

[18] European Commission. (2020). *A New Industrial Strategy for Europe.* Document 52020DC0102. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020DC0102

[19] United Nations *Transforming Our World: The 2030 Agenda for Sustainable Development* https://www.un.org/sustainabledevelopment/development-agenda/