SESAR
JOINT UNDERTAKING

European Drones Outlook Study

Unlocking the value for Europe

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Contents

NOTE TO THE READER

The SESAR Joint Undertaking has developed insights related to the use of 'drones' which refers to unmanned aircraft systems (UAS) or unmanned aerial vehicles (UAV); this includes, as a subset, remotely piloted aircraft systems (RPAS).

Unmanned aerial system (UAS), of which the unmanned aerial vehicle (UAV) is the airborne component, comprising two fundamental types: Remotely-Piloted Aircraft Systems (RPAS), a class of UAS which has a ‘pilot’ operating the Remotely-Piloted Aircraft (RPA) from a Ground-Control Station (GCS); and UAS with no remote pilot, or autonomous air vehicles. In this document, the term ‘drone’, essentially a layman’s term, refers to all types of UAS.

This forecast extends to 2050 and, as such, includes a number of assumptions that carry uncertainty. As a result of the inherent uncertainty, all figures have been rounded and should be interpreted in terms of their order of magnitude. Additionally, the forecast has been developed as a starting point for Europe on the topic and is not expected to be exhaustive of all potential forms of drones. Special attention was paid to the operation of drones within European skies and, as a result, missions and drone types that are designed for use inside industrial and residential facilities are not forecasted. Additionally, all monetary figures are nominal and do not include adjustments for the effects of inflation. All economic indicators and drone unit totals indicated in this report are reflective of European demand and do not reflect potential export into the broader global marketplace.

In order to increase the validity of assumptions used in developing the forecast, a number of stakeholder discussions and workshops have been conducted. Developers of drone technologies, operators that manage drones in bringing services to businesses and consumers, policy makers involved with the governing regulation of drones and industry leaders across a number of relevant domains that are anticipated to be end users of drone capabilities were consulted. Additionally, analysis for the study was supported by The Boston Consulting Group. The study's forecasts do not represent any specific organization or stakeholder and, instead, represent a set of publically available facts collected by the study and supported by trends and themes that emerged across the entire set of experts.

The SESAR Joint Undertaking thanks all those stakeholders that supported the development of this study, including the OECD for their continued support in regards to the economic impact.

EXECUTIVE SUMMARY

Drone market and capabilities expanding rapidly – in Europe and also globally

'Drones' have been instrumental in providing new capabilities for European defence and have demonstrated significant growth as a consumer leisure product. Drones are offering public safety and security authorities new capabilities much in the same way they have for the military and are transforming commercial businesses. A core component to these new capabilities and transformations is the collection of data from strategic vantage points that have been either inaccessible or too expensive to be economically viable today. This core area of data processing is being extended to include the efficient transport of urgently needed goods within a local community or industrial site with longer term aspirations to transform large commercial vehicles for both cargo transport and also, someday, passenger transport.

Europe – with a strong mix of leadership in aerospace and defence, innovative forces developing both drone products and services and industrial leaders finding new ways to impact their businesses by leveraging the technology – is helping drive what is becoming a global industry. Many of Europe's Member States have been progressively establishing legislation that extends beyond exemption-based protocols to provide drone operators the opportunity to create local operations. As a next step, EASA has proposed a risk based approach to settle a performance-based framework for regulation related to drones. This work is nearing completion and could provide scale opportunities for market players. In addition to these regulation efforts, initial investments are being made into developing European capabilities, including SESAR, in order to drive forward technology and support the large array of increasing private investments.

Europe is not alone in its strong efforts to generate value from drones. The United States (US) and China are two key States that are significantly investing into technology and innovative businesses that currently exceed the level of total European investments. In particular, the US is the leader in producing defence drone systems – followed by Israel – and China is the leader in producing leisure units that tend to be more and more used for professional purposes.

The use of drones in many sectors creates significant benefits that should be pursued

The growing drone marketplace shows significant potential, with European demand suggestive of a valuation in excess of EUR 10 billion annually, in nominal terms, by 2035 and over EUR 15 billion annually by 2050. The impact of civil missions by (either for governments or for commercial businesses) is expected to generate the majority of this value as related services are anticipated to represent more than EUR 5 billion of annual value by 2035, highlighting their importance within the marketplace. The other main sectors, defence and leisure, will continue contributing to this marketplace and remain the largest sources of value in the near-term. Both together represent nearly EUR 2 billion in annual product-related turnover in Europe over the long term.

The development of the civil drone industry is dependent on the ability of drones to operate in various areas of the airspace, especially at very low levels that today are generally defined as being below 150 metres. In aggregate, some 7 million consumer leisure drones are expected to be operating across Europe and a fleet of 400 000 is expected to be used for commercial and government missions in 2050. Commercial and professional users are expected to demand drones in both rural and urban settings and will be reliant on beyond visual line of sight capabilities to be permitted. Examples of some of the most influential missions, in terms of the potential number of drones and economic impact, include the following:

- Agriculture sector where over 100 000 drones are forecasted to enable precision agriculture to help drive increased levels of productivity that are required
- Energy sector where close to 10 000 drones limit risk of personnel and infrastructure by performing preventative maintenance inspections
- Delivery purposes where there is potential for a fleet of nearly 100 000 drones to provide society with some kind of urgent service capabilities, such as transporting emergency medical supplies, and “premium” deliveries
- Public safety and security where a forecasted fleet of approximately 50 000 drones would provide authorities like police and fire forces the means to more efficiently and effectively locate endangered citizens and assess hazards as they carry out civil protection and humanitarian missions

Included in this demand are also thousands of new types of aircraft that are expected to impact more conventional areas of airspace. In the near term, robust certified systems are expected to support border security, maritime surveillance and other government authority missions. In the longer term, unmanned larger commercial vehicles are gradually expected with initial versions of optionally piloted systems estimated for sometime after 2030 – first impacting cargo transport and then moving slowly towards transport of passengers. The feasibility of such solutions will require significant societal acceptance as well as a number of critical advancements in technology and regulation.

Re-assessment of EU support levels required to fortify Europe's position at global level

Unlocking the full potential of the market and maintaining the high standards of safety of EU aviation will require increased levels of European support. Indeed, the market is likely to be operated by many firms pursuing multi-national scale and/or conducting cross border missions (e.g., border security and maritime surveillance). Setting up a single competitive EU drone market would improve connectivity, as well as allow economic growth and the creation of jobs. This EU drone market would also support the EU aviation strategy by embracing a new era of innovation and digital technologies and helping maintain the high EU safety and security standards. Indeed, support of a single drone market through the combination of an enabling legal framework and R&D efforts that foster a myriad of new services has been supported by the EU since 2014[1].

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[1] COM(2014)207

Further actions taken at the EU level will need to occur rapidly given the pace of global development in drones, especially as the US and China are already the leaders in different forms of production and investing more heavily into scalable capabilities. Much of what still needs to be done include technology (detect and avoid, datacom), air traffic management, security & cyber reliance along with the availability of authorised & safe testing environments. As a main finding of the study, and based on the expectations of the market to unlock demand and global competiveness, these improvements need to be completed within a window of opportunity limited to the next 5-10 years. Completion within such a time span requires that an ecosystem is created at an EU level around both technology and regulation to ensure a proper 'home' for drones that brings all key public and private stakeholders together. Key stakeholders on the private side will need to incorporate the talents of leading aviation players together with the variety of new entrants into aviation that include new ventures and also industrial leaders exploring the impact of drones on their current businesses.

EU funding levels into research and development need to be re-assessed to stimulate this emerging marketplace and establish an EU level ecosystem . An estimated total of at least EUR 200 million in additional R&D over the next 5-10 years, based on expectations of the market, is required to address remaining gaps related to Very Low Level (VLL) activities that represent the majority of future drone operations. This boost in R&D capabilities would complement on-going efforts for the integration of drones into controlled airspace. Priorities related to the successful integration into controlled airspace continue, as previously forecasted in the SESAR RPAS Definition Phase, to require close to EUR 150 million over the next 5-10 years, of which the SESAR 2020 programme is presently addressing EUR 40 million due to budget constraints.

Required additional investments should be supported by a mix of both public and private stakeholders reinforcing the importance of an EU level ecosystem for R&D. This same mix of stakeholders will also be needed to ensure fast implementation of comprehensive regulation. Speed will be essential for Europe to obtain a global leadership position, especially as the value in services remains in the early stages of development in all markets. It is therefore also critical that R&D coordination at EU level results in leveraging and bringing together numerous initiatives that are presently fragmented across Member States and industry stakeholders.

Near term efforts to stimulate R&D will have transferrable benefits for many years to come. Drone technologies will impact both manned and unmanned aviation of the future and EU level coordination of innovation will ease the ability for international cooperation. The long term implications of unmanned aviation will require such international cooperation and maintaining safety will be positively impacted if European standards are globally consistent and accepted.

Air traffic management related technologies are the key

The demand of drones on all areas of the airspace highlights the critical nature of air traffic management. Overall, the potential exists for drones to represent the majority of total flight time across the entire airspace. Drones will create new forms of traffic especially at very low levels of airspace with high demand in densely populated areas where risk levels will be increased. The impact is also significant in more conventional classes of airspace, including controlled airspace where approximately 20% of flight time is expected to be remotely or optionally piloted by 2050.

As a result, appropriate new and adapted procedures along with the development of technology related to the management of airspace are a "must-have" for safely unlocking growth. The current investment in SESAR of EUR 40 million highlights how this is already a formal priority following the last update of the European ATM Master Plan and provides a foundation to build on, together with critical investments coordinated by other EU bodies such as the European Defence Agency. The seven pillars of research, as described in the SESAR RPAS definition phase document; into detect and avoid, human factors, command and control datalink, security & cyber resilience, contingency, demonstration & validation activities and airspace access & airport operations, all remain essential for the safe integration of drones in all airspaces.

However, indications that these categories of technology require an estimated EUR 200 million of R&D investment to develop technological solutions relevant at very low levels of the airspace highlight that a gap remains to be closed, especially when markets like the US and China are investing more. Increased investment on this end would serve two purposes:

- Create an EU unmanned aircraft traffic management (UTM) system supporting the cohabitation/sharing of airspace of manned and unmanned systems. This need represents a critical enabler to support economic value related to the use of drones that has not yet been addressed at the European level. This new traffic management system requires an estimated EUR 100 million in R&D over the coming 5-10 years, a magnitude that is in line with on-going US investment levels in excess of EUR 20 million annually related to UTM.
- Develop distinct versions of the technologies already in progress under SESAR that are relevant at very low levels. In total, these adaptations require an estimated additional EUR 100 million of R&D investment based on a number of factors that include, but are not limited to, the smaller size of the drone, the type of propulsion, a separate concept of operations and the need for more cost effective solutions.

In a nutshell: Drones represents a genuine opportunity which requires immediate EU actions

The drone market has started bringing significant benefits all over Europe and the continuation of that growth appears to be a matter of not if, but when. Europe has the opportunity to obtain a significant role in this rapidly evolving global marketplace – especially in relation to services that are expected to generate the greatest sources of value. In order to unlock this value through the creation of a single market, while ensuring high safety standards already demonstrated by EU aviation, a series of immediate actions must be taken at the EU level to both boost innovative capabilities and implement comprehensive regulation that creates a single drone market. The SESAR PPP already plays a significant role in the modernisation of EU ATM, and could help in playing a pivotal role; indeed, bringing together public and private stakeholders is necessary to ensure that the social and economic benefits created by drones are effectively enabled.

Figure 1 below summarizes the main outcomes of the study.

Figure 1: Key figures associated to the main outcomes of the study

1 | SNAPSHOT OF THE EVOLVING 'DRONE' LANDSCAPE

1.1 'Drone' Industry Races Forward – Types of Use Expanding Rapidly

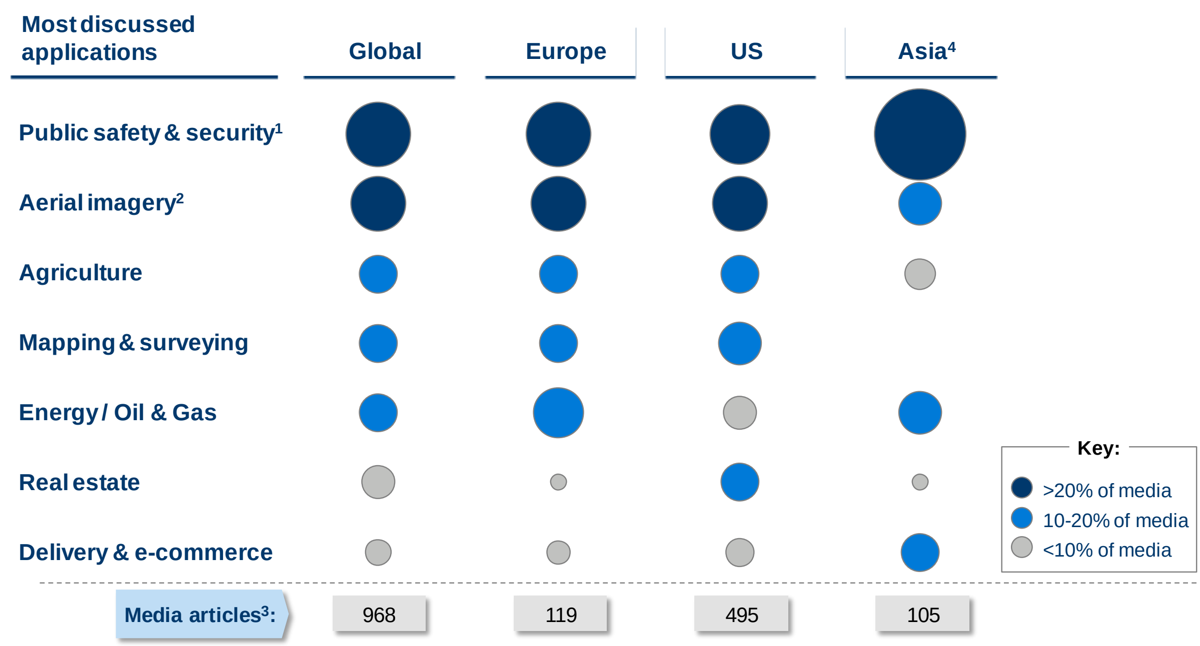
'Drones' have seen an increasing amount of attention as an evolving industry. Up until recently, drones were mostly used for defence. The game has changed now with leisure drones already selling in the millions. This development of small and cost effective drones has led to a variety of uses that businesses and public institutions are starting to leverage to reduce risk, optimize processes and drive new forms of customer and societal value.

The area of filming was among the first commercial applications and uses in imaging have rapidly expanded for mapping, surveying and inspections. Among the numerous applications being discussed in the media are:

- Inspecting industrial infrastructure, such as flare stacks of an oil refinery, to limit expensive shutdowns and avoid placing personnel in hazardous conditions
- Patrolling of pipeline, electricity power-lines and railways to detect physical abnormal activity like encroachment or intrusion
- Mapping and surveying of mining and construction sites to perform tasks such as stock pile management, pre- & post-blast data collection and vegetation change tracking
- Analyzing crop health and conducting topographic survey to support agriculture
- Delivering emergency medical supplies such as defibrillators for cardiac arrest
- Transferring real time data from fire and emergency scenes to fire-fighter and police forces on the ground in order to assess danger and locate at-risk person

The figure below showcases the variety of applications being discussed globally based on a review of English-based articles from different markets.

Figure 2: Applications by region based on media attention



1. Includes use by law enforcement to fight criminality, monitor borders, catastrophe and emergency management, environment study and protection (e.g., poaching); 2. Includes both consumer and professional applications 3. Sample size excludes any overlap with regulatory or social topics (e.g., discussion of FAA as it relates to Amazon's Prime Air); 4.Includes India
Note: Based on English speaking database of articles over last year (Feb-15 to Jan-16); does not represent all media in all languages
Source: Quid, BCG analysis

Drones traditionally used for defence purposes are also being used more in a support-to-civil government authorities role, performing activities such as:

- Observing border areas, supporting maritime surveillance and conducting other observations for fisheries and forestry
- Responding to and prevention of a natural disaster such as an earthquake, flood, hurricane or forest fire

Drone technology also supports the development of new solutions such as the provision of communication access using drones in category of HALE (High Altitude Long Endurance) or/and HAPS (High Altitude Pseudo Satellite). Other specific applications that are being developed include the provision of wind energy using drones attached to the ground.

However, before all of these uses can grow in practice, a number of questions still need to be answered around technology, regulation and social readiness.

1.2 Today's Evolution depends on Technology, ATM, Regulation and Societal Acceptance

The increase of automation up to potential of robotics in our skies is not brand new; however more robust technology is still required before many applications are commercially viable and accepted. Additionally, regulation and societal concerns related to privacy and safety remain constraints for some applications already feasible from a technical perspective.

In terms of regulation, a new framework around the operations of drones is proposed by the European Union as a common basis to harmonise regulation across Europe and enable more applications[2]. On the whole, European Member States have already been at the forefront of regulation with over 15 Member States holding legislation related to drones. Included in this legislation are initial permissions for beyond visual line of sight (BVLOS) drone operations that are critical for many of these operations to be economically viable opportunities. Examples of such BVLOS permissions include Spain allowing BVLOS for drones under 2 kilograms (kg) and France allowing these flights for drones under 2 kg with no lateral limitation and additionally for drones under 25 kg that operate within 1 kilometre (km) of the remote pilot. The above examples also begin to indicate the remaining opportunity for harmonisation across States in order to unlock future potential. A detailed listing of regulation by Member State is included in the annex.

The United States (US), in comparison, continues to only allow for visual line of sight civil & commercial flights having recently passed new rules that replaced exemption-based licensing[3]. Other countries offer examples of allowing more progressive operations around BVLOS including Australia and Japan that require case by case permission and Switzerland which requires a total hazard and risk assessment.

Even though EU countries have been at the forefront of legislation, regulation still, on the whole, limits the extent to which drones can operate on their own and the ease of to which operations can expand across countries using the same drones and certifications. Critical parts of the evolving regulation will be the extent to which drones can be operated BVLOS, in populated areas or/and without a dedicated pilot per each drone (i.e., allowing a single pilot to operate or monitor more than one drone at the same time).

Furthermore, societal worries on privacy and accidents create an additional barrier drones must overcome in order for regulators to allow flights in populated areas. These concerns over safety are magnified by the fact drones are bringing aviation capabilities to a group of new users – consumers and businesses alike. The "newness" of aviation to these users increases the number of issues regulators must consider.

Traffic management solutions associated to required drone technologies (e.g., detect and avoid, datalink, geofencing) are key enablers for safety, and it is essential they together demonstrate safety performance in-line with the high standards of the aviation industry. The ability to address how drones will be safely integrated into European airspace and also how cybersecurity threats will be mitigated will be factors in determining the pace at which the industry will grow over the coming years.

Additional technology advancements will also be important to increase the value drones generate for end users. 'Big Data' analytics related to services such as industrial preventative maintenance,

[2] COM(2015) 613 final; EASA Advance Notice of Proposed Amendment 2015-10

[3] FAA Part 107

precision agriculture and research purposes are still in their early phases of development and must continue to evolve for drones applications to successfully transform businesses and processes. Components and systems related to engines, propulsion and batteries will be needed to achieve required levels of reliability and durability performance that commercial users demand. High-precision navigation, like that in development as part of the EU's Galileo and EGNOS satellite navigation systems, could also be considered for drones to improve reliability and support their integration in non-segregated airspace.

The progression of regulation, ATM procedures, technology and societal acceptance will likely continue to take shape rapidly – both in Europe and in other global markets. It is therefore the right time to examine Europe's position in helping determine where focus and investment should be placed.

1.3 Scaling Operations & Further Investment Critical to Fortify Europe's Position in a Global Marketplace

Today's drone technology and market development includes both familiar and new faces to the world of aviation. Leading aerospace and defence players are investing into military-grade systems and related services that are also transferrable for civil uses by government authorities and, at a later stage, to commercial aviation. At the same time, new players emerging from start-up and academic settings are driving growth in leisure drones and many early forms of commercial missions. These start-ups are joined by a variety of other established companies that are investing in drone-related capabilities, as evidenced by recent publicised drone demonstrations from the likes of DHL, Maersk and SNCF. Finally, a host of service companies, focused on software, analytics and/or more general piloting are starting to be established.

Europe is actively involved across all of these domains with assets to support the design, production and operation of government contracted, commercial and leisure drones. Assets supporting the operation of drones extend into data processing and 'Big Data' analytics. Additionally, Europe has started investing into the integration of drones in the airspace as evidenced by being an area of focus in SESAR 2020.

In general, the efforts of Europe have been focused on designing automatic flying capabilities (including the related hardware), building integrated platforms to manage drone flights and also to analyze information captured via drones. These efforts have attracted significant capital, on the range of multi-billion euros in defence, R&D programs and private investments.

The developments of these industry players in producing leisure, military, government/civil and commercial drone products and services are further supported by national and regional authorities focusing on safety issues and traffic management. A list of past and on-going programmes in the EU from Eurocontrol shows over 450 initiatives related to drones, with EUR 150 million still to be invested in on-going programs over the next few years, including almost EUR 100 million in programmes coordinated by the EDA. Additionally, Europe also has active a EUR 100 million per year MALE program[4] and a EUR 200 million per year joint military drone program for France and the UK[5]. Investments are also being made into new and growing businesses with private equity investments, public private partnerships (PPP) and even recently public stock issuances, together creating a foundation for growth in Europe. For example, Parrot, a global player in leisure and commercial drones attracted a EUR 300 million stock issuance at the end of 2015.

Although Europe continues to progress in investing in new products and service capabilities, the US and China are the leaders in terms of overall investment and are global leaders in terms of production for defence systems (US) and leisure units (China) respectively. Current commercially used systems more closely resemble leisure units, making China the leading producer with Europe as another leader (primarily driven by Parrot Group as it stands today). Services remain in the early stages of development globally and none of these markets are significantly advantaged in terms of innovation and in terms of building experience.

The US in particular has committed significant funds for defence development as the global leader in producing military drone solutions, as highlighted by the proposed 2017 Presidential Budget that includes EUR 1.4 billion specifically for research & development over that year. NASA and FAA are also spending in excess of EUR 20 million annually focused on air traffic management[6,7]. This investment compares to under EUR 10 million per year currently allocated to the SESAR programme out to 2020 (Horizon 2020) addressing the integration of drones in non-segregated airspace. Finally, new venture funding has been more accessible in the US than in Europe, highlighted by over EUR 500 million in funding out of the US in comparison to under EUR 100 million coming from Europe (excluding stock issuances). The proximity of new venture funding with the renowned Silicon Valley for technology development positions the US to become a global leader in drone services and integrated platforms.

China is also investing heavily in drones and has taken a leadership role in hardware for leisure and commercial drones. The figure below demonstrates that across different types of hardware, including navigation, propulsion systems / battery and attached payload components like cameras and sensors, China is a major player. Chinese player DJI is a global market share leader in leisure drones and also in commercial drones, excluding complex government solutions, and has attracted investment exceeding EUR 100 million (with speculation that the total could be above EUR 500 million). China is also now also exporting defence technologies, indicating their potential to be an influential player in all forms of future drones and joining the US and Israel in terms of defence system leadership.

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[4] Program expected to last 10 years to develop European MALE drone and to cost EUR 1B according to industry players (feasibility study ongoing)

[5] 1.5B GBP program from 2017-2025 as communicated by both governments

[6] FY 2016 Budget Estimates of FAA by US Department of Transportation

[7] $15.6M by NASA per AINonline (ainonline.com/aviation-news/aerospace/2015-09-17/nasa-faa-discuss-formal-collaboration-small-drones) as part of NASA's Aerospace Operations & Safety Program expected to increase to $159M in 2017 per FY 2017 President's Budget Request

China has already a strong position in leisure and commercial drone hardware. An appropriate way to maximise value within Europe, appears to be leveraging European assets to design automatic flying capabilities, high performance safety features and build integrated platforms. Given the US seems to be pursuing a similar strategy (high-end designs, integrated platforms, value added service capabilities as evidenced by global proportion of integration & software patents), it will be important for Europe to be efficient with its investment.

An equally important factor will be the ability for the European market to gain experience with operations and appropriately determine how to safely integrate drones into all areas of the airspace. This dimension of experience is one that all markets, including heavy investors like the US and China, are still grappling with. Europe is positioned to play a significant role in shaping the future globally if it is able to enable safe drone operations in the near-term and prioritise the most relevant areas of research and regulation.

2 | How the Market Will Unfold – A View to 2050

2.1 Setting the Stage – Framework to Assess Benefits in Numerous Sectors

The role of drones is likely to expand still for many years, thus driving the need to understand mission types that are being established today and also those yet to come. To examine different mission types and provide new insight into the rationale, as well as benefits and parameters for growth, a variety of industry sectors were profiled in-depth. Sectors selected for in-depth profiling attempt to balance multiple factors including addressing the most relevant topics in today's society, identifying what kind of new sources of value could be generated and providing a glimpse into future mission types given the study's horizon extends out to 2050. Profiled sectors illustrate the opportunity drones have to transform how businesses operate, increase Europe's global competitiveness, provide new jobs and deliver both economic and environmental benefits. These sectors, shown together with some of societal benefits drones may generate within each, are as follows:

- **Agriculture:** Drones could help enable precision agriculture that will be critical to meet productivity needs for Europe and support greener farmer practices that are a focus of the EU Common Agricultural Policy (CAP) of 2020
- **Energy:** Drones may reduce a variety of risks including to personnel performing hazardous tasks, to the environment by properly maintaining assets and to the infrastructure overall by limiting the amount of downtime to Europe that already is a heavy importer of resources and pays higher energy prices than other regions
- **Public safety and security**: Drones could be used by a variety of authorities to better assess and monitor hazardous situations, complete search and rescue missions, gather evidence for investigations and detect and prevent other crises
- **E-commerce and delivery:** Urgent packages, including medical supplies, could be completed in a fraction of the time and online retailers could benefit from increased accessibility in both urban and remote areas
- **Mobility and transport:** The infrastructure of today, i.e., railways, may be monitored and kept secure and future forms of passenger aircraft could someday operate safely without the requirement of on-board pilots

As such, drone missions span many more sectors that will also benefit from drones. These industries – such as mining, construction, telecommunications, insurance and other research by the likes of universities – are also introduced.

A summary of these sectors and mission types is highlighted in the following figure.

Figure 3: Framework to assess Government & Commercial demand

	Sectors profiled in-depth					Other growth sectors included in study			
Mission types	**Agriculture**	**Energy**	**Public safety & security**	**Delivery & e-commerce**	**Mobility & transport**	**Mining & construction**	**Telecom**	**Insurance**	**Others**
Localized Surveying (primarily VLOS)		✓ Infrastructure sites	✓ Police & fire, in-vehicle units			✓ Bridge, crane & buildings	✓ Cell tower inspection	✓ Roof & site inspections	✓ Real estate, private security, media, indoor
Long range Surveying (primarily BVLOS)	✓ Crop & livestock monitoring	✓ Pipeline & power lines	✓ Police & fire, disasters, wildlife		✓ Railway inspection	✓ Site surveying	✓ Cell tower inspection	✓ Disaster impact	✓ University & research; especially wildlife
Light load movement (primarily BVLOS)	✓ Crop spraying / pellet application			✓ Parcel, medical supply, delivery		✓ Transport light critical material			✓ Ports, Indoor light goods movement
Long endurance Surveying (primarily ≥ 150m)	✓ Large land monitoring	✓ Pipeline & power lines	✓ Border control, maritime, environment surveillance						✓ University & research; especially wildlife
Unmanned aviation				✓ Cargo planes, air freight	✓ Passenger planes, & rotorcraft				
Others		✓ Tethered wind energy prod.					✓ Connectivity provision		

Public safety also includes prison surveillance and examples for environment include poaching prevention; University and research examples include animal breeding monitoring, geological studies

Growth within the government & commercial space is anticipated to be certainly significant. At the same time, growth factors at a European level are also considered for leisure drones that act as consumer electronics and for military applications.

The combination of these profiled government and commercial domains together with already established (but still growing) markets for leisure drones and defence assets remains a conservative estimate of potential demand given the likelihood new mission types and new domains will continue to emerge. Based on the rapid evolution over recent years, unforeseen missions may in fact act as a significant multiplier to the value and demand depicted in this study. Furthermore, while the study focuses on drones in European skies, there are already an expanding set of incremental indoor use cases that also demonstrate the conservative nature of the study's forecasts out to 2050.

2.2 Meeting the Hype – Growth Expected Across Leisure, Military, Government and Commercial

Overview of key assumptions used in demand forecast

Potential demand for drones remains reliant on advances in technology, regulation and societal acceptance, especially as it relates to government and applications. The study's forecasts are meant to examine the potential of the marketplace and thus estimates assume successful enablement of different drone mission types over time. The following assumptions have been made by the study in regards to this market enablement:

- Military drone missions will only increase driving new forms of uses. At the same time, the size of the manned aviation fleet will continue to slowly decline. Current R&D levels in defence technologies globally suggest such increases in military drone missions.
- The pace of technology will continue to be rapid and will not be a constraint. For drones operating at very low levels (i.e., today defined as below 150 metres), BVLOS capabilities will be robust and complete after approximately 5 years. Future optionally piloted or unmanned aircraft for cargo and passenger transport can be implemented by 2030. The rapid pace of technology will be enabled with accepted performance requirements and a concept of operations that provides for VLL activities. EASA's new framework on the operation of drones and the expectations by the market on technology development form the basis of these potential timelines.
- Regulation for BVLOS missions will be friendly, including in urban environments over time and relatively consistent across European markets. Near-term harmonisation, before 2020, is assumed for BVLOS missions in areas with low population density and by 2025 for BVLOS in densely populated settings. Initial permissions for BVLOS in Europe and the number of recent drone legislations demonstrate the potential for such advancement of regulation and EU aviation illustrates the potential for harmonisation across Member States.
- Included in future forms of BVLOS capabilities and regulation will be the enablement for multiple drones to be remotely piloted or monitored by a single operator. An operator is assumed to monitor all drone operations, even in conditions of higher drone autonomy. The start of adoption for such operations will require 5-10 years to account for progress that must still be achieved.
- Licensing, liability insurance and other administrative overhead will be at affordable rates that do not severely impact the underlying economics, including for operations with higher levels of autonomy.
- Society will accept drones over time assuming there are no significant events whereby the technology or cybersecurity fails. This includes future missions by large commercial vehicles for cargo and passenger transport after other forms of robotics, notably self-driving vehicles, are expected to be adopted in the marketplace. Specifically, aerial cargo transport is not expected until 2030 with first forms of passenger transport by way of optionally piloted vehicles occurring, at earliest, 2035. Current consumer interest for self-driving vehicles and indications by the industry that there continues to be a positive shift in society's perception of drone operations provide the basis for this assumption.

Scenarios for these assumptions are shared in showing a range of potential demand. The summary estimates, therefore, are not meant to represent the theoretical maximum potential for the drone market across the industries and missions known to-date. Development, regulation and adoption timelines may in fact be faster or slower than indicated. Furthermore, society may adopt these technologies to a greater or lesser extent and some missions may not come to fruition as a result of technology and/or regulation. Overall, the summary estimates are meant to reflect a pragmatic approach to the potential for drones in a set of industry sectors and for a set of drone missions that appear to be highly relevant for Europe.

Drones currently in operations

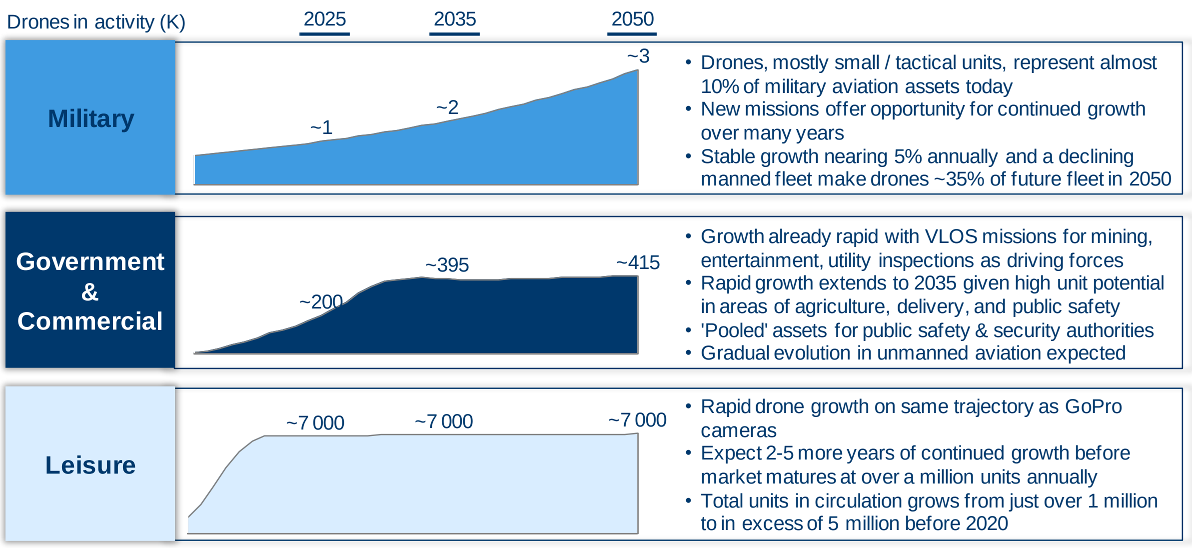
Europe today has just fewer than 1 000 military drones across its Member States. This includes mostly small and mini drones for surveillance along with a set of tactical drones and a few, approximately 40, medium and high altitude drones (MALE and HALE) that all together represent just under 10% of the total defence aviation fleet (including rotorcraft)[8,9]. In comparing only MALE and HALE drones to manned aircraft, drones still only represent a fraction of a percent of the fleet.

In the civil domain, the European market for drones includes an estimated 1-1.5 million consumer drones as leisure drones have enjoyed strong growth, over 100% per annum the past few years[10]. Additionally there are a lower number of commercial drones, estimated to now exceed 10 000 units based on operator registrations numbering in the thousands in multiple European Member States, that have to-date mostly been used for filming and surveying purposes. These commercial units have resembled more closely leisure units than complex military systems to-date.

Summary of demand forecast

Overall, growth in the number of drones in activity is forecasted for each of defence, government & commercial missions and leisure. Overall, in terms of order of magnitude, military defence assets are expected to increase from the aforementioned high hundreds to multiple thousands, leisure units from close to 1 million to approximately 7 million and, finally, government and commercial units from multiple thousands to hundreds of thousands. Leisure unit growth is expected to mature in the near term with defence, government and commercial growth continuing out through 2050. A summary of these forecasts is illustrated below with a description of each area following.

Figure 4: Total fleet size (Current through 2050)



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[8] Number of military drones based on EDA database provided February 2016

[9] Number of traditional military aircraft sourced from SESAR ATM Master Plan forecast

[10] Leisure based on global sales and average prices; Europe estimated at 30% of units

Looking ahead, defence missions are expected to increasingly rely on drones as evidenced by Europe's MALE programme, the recent UK and French military drones programme and global indications that today's aviation fleets could someday be partly replaced by drones or include optionally piloted systems. Over the long term, military growth of the total drone fleet size is expected to occur at a stable pace of approximately 4%. As a comparison, a view into the US Department of Defence (DoD) fleet size projections shows steady growth at this rate with the drone fleet across naval, armed and air forces representing approximately half of the fleet before even accounting for other potential optionally piloted systems by 2035[11]. Applying a similar standard to Europe would see the drones becoming approximately over a third of the fleet by 2050 and creating a fleet of 3 000 drones.

Although the number of military surveillance drones is rather small, these complex systems serve as the foundation for research and development and are expected to play a role in other areas of public safety and security (e.g., maritime, forestry and border protection) along with future mobility and transport.

Civil government missions and commercial uses are expected to increase the number of complex certified drone systems by 10 000, representing only one portion of the approximately 400 000 drones anticipated overall in this area of civil missions. This increase includes commercial solutions for mobility that are likely to begin in the form of optionally piloted systems for today's cargo aircraft and rotorcraft before being used by scheduled airlines. At this level of growth that is expected to occur gradually and not begin until at least 2030 approximately 20% of cargo aircraft, business aircraft, rotorcrafts and scheduled airlines in the civilian domain would be fitted with some form of ground-control capabilities in 2050. Before market adoption of such mobility systems begins, near term potential exists for strategic drones used by government authorities. These systems represent a dual use opportunity of defence technologies. They will support border security and maritime surveillance along with a host of related missions such as forestry assessments (including fires) and disaster relief. Units for these purposes are estimated to remain near approximately 100 in total across Europe given their ability to fly at speeds in excess of 300 kilometres per hour over many hours.

A summary of these advanced drones in mobility, public safety and security (excluding all drones primarily for very low level altitudes) along with all defence systems in comparison to the rest of the aircraft fleet is depicted in the following figure highlighting that unmanned systems must be successfully integrated into the airspace as they may represent nearly 25% of aircraft by 2050 (excluding general aviation).

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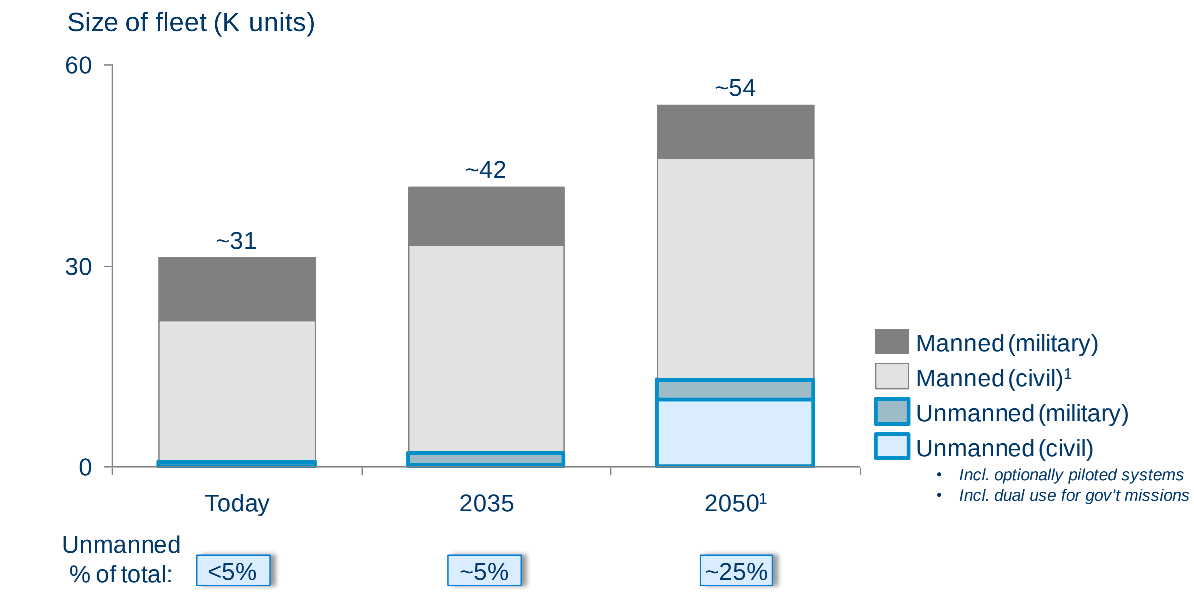
[11] Volpe National Transportation Systems Center, "Unmanned Aircraft System (UAS) Service Demand 2015 - 2035: Literature Review and Projections of Future Usage"

Figure 5: Comparison of defence and certified drones vs. manned aircraft (excluding general aviation)

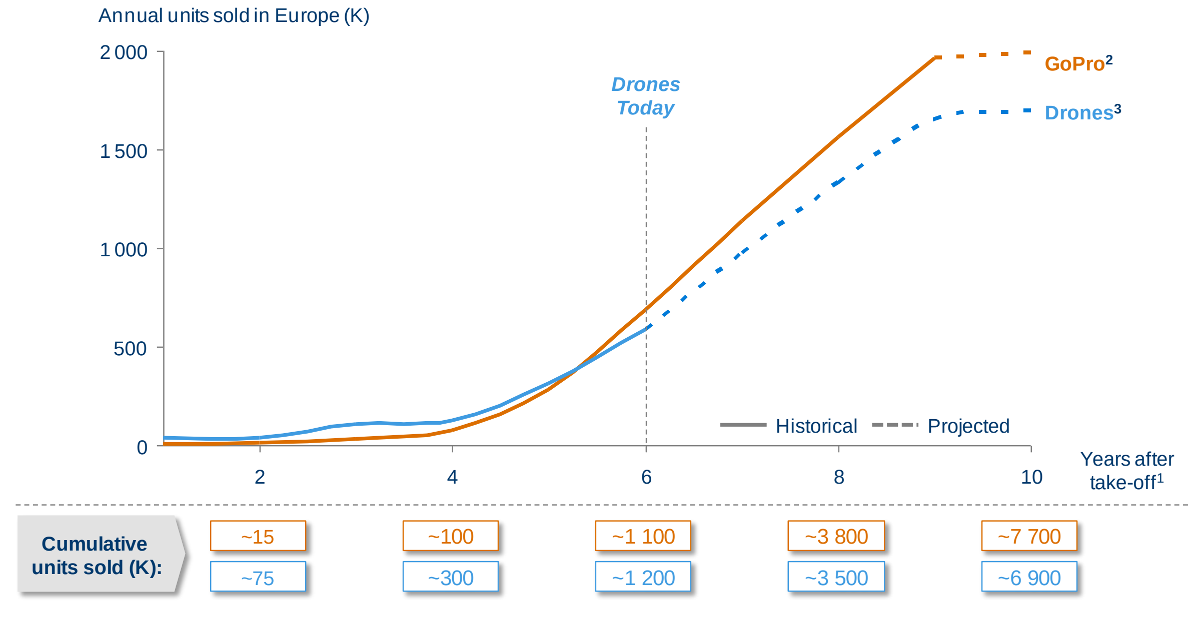


1. Growth rate from 2015-2035 held stable through 2050 for individual aviation categories (scheduled, business, rotorcraft, military transport, military rotorcraft, military IFR/VFR and combat); unmanned aviation, including optionally piloted systems, for cargo, mobility and military replaces civilian manned fleet units beginning near 2035; Manned civil excludes general aviation
Source: SESAR ATM Master Plan research, EDA estimates for current drones, BCG analysis

Although government and commercial demand will greatly increase the number of complex systems impacting conventional airspace by 2050, the majority of demand will be at lower levels of airspace, today primarily indicated as being at or below 150 metres. This growth of civil-aimed government missions and for commercial activity is only at its beginning. By 2035, there is potential for in excess of 400 000 drones with the majority flying beyond visual line of sight and many, including for delivery purposes, being demanded for in populated settings at these very low levels of airspace. It includes impact across a great number of industry sectors – including agriculture, energy, first responders for public safety and security, e-commerce and delivery, railway, mining, construction, insurance, telecommunications, film and media and professional and academic research. An overview of the impact drones will have in each of these sectors is included in Section 2.3 with additional details available in the annex.

For leisure drones also operating at very low levels of the airspace, continued annual unit growth is expected for another 3 years that would increase the total from just over 1 million units sold to nearly 7 million (with annual sales exceeding a million units). The recent history of action based cameras, led by GoPro, provides a comparable case to highlight these expectations, especially given filming and imaging are a leading driver of consumer usage. GoPro is expected to reach maturity of its annual unit sales this year after a period of 9 years of growth, of which the first 6 were a near identical match to drones (see following figure). After 2-5 more years of annual sales growth in drones, the total consumer base should remain relatively stable for a significant period, especially as buyers replace obsolete units and uses such as racing maintain niche attention.

Figure 6: Comparison of Growth in Leisure Drones to GoPro Action Cameras



1. Take-off year defined as first year with sold units >10k i.e. 2007 for GoPro and 2010 for drones; 2. Units based on total turnover and pricing statistics. Year 10 stability based on Morgan Stanley estimates for declining sales and assumes a 5-10% pricing discount on units vs. last year; 3. Units based on total turnover and pricing statistics using similar 30% regional split for Europe
Source: Company annual reports, Natixis investor research, Morgan Stanley investor research, Goldman Sachs investor research, Forbes, Wall Street Journal, CNBC, BCG analysis

Key takeaway	Drone market is still at the beginning of a long term growth path

2.3 Closer View of Civil Missions Highlights Use in All Classes of Airspace

The following section describes the demand estimates within government and commercial along the two main dimensions of the framework as described in section 2.1: mission types and industry sectors. Additionally, the annex includes a more complete breakdown of demand parameters in the different industry sectors.

Overview of demand forecast by mission type

Today's government and commercial users and corresponding operators are growing rapidly. Most of this growth today is in the form of multicopter drones that are used to perform local surveying, including mapping (2D and 3D) and inspections (for example inspecting a flare stack in domain of oil and gas).

The use of drones for local surveying that is mostly within visual line of sight (VLOS) has the potential to increase rapidly as result of energy infrastructure inspections (solar farms, wind turbines, power plants, dams, refineries, oil platforms), public safety and security (police and fire response using in-vehicle units), mining and construction (both quarries and industrial construction sites with the potential for residential surveying in future), insurance (property inspections) and media (new coverage) among other. Together there is estimated potential for over 100 000 drones by 2035 and 2050. These drones have a relatively low regulation hurdle to overcome as many of these operations can be performed within visual line of sight. However, as exemplified by police and fire missions, these drones will need to be able to fly in densely populated areas to reach this forecasted potential.

Beyond visual line of sight capabilities yield even greater potential. For mapping and surveying alone, 180 000 drones are estimated for 2035 with fixed wing drones being the primary operating type. This includes agriculture remote sensing of crops and livestock, inspection of power line, pipeline, and railway networks that currently require expensive helicopters. In the future they could be used by public authorities to operate drones directly from each station and could complement or replace VLOS units carried in vehicles. Media drones used to cover traffic conditions or sporting events such as cycling are also opportunities along with use at larger construction and mining sites and for conducting new forms of research by universities and other institutes.

The majority of light load drone missions are also expected to operate beyond visual line of sight with 90 000 drones forecasted by 2035 mostly for delivery purposes and flying at low altitudes. This includes emergency medical deliveries, lightweight industrial deliveries (e.g., from a port to a vessel or transfer of tools across a large industrial construction site) and completing traditional forms of delivering parcels and couriers to businesses and consumers. Agriculture chemical spraying and seeding represents a smaller portion, approximately 25 000, of the estimate for light load drones flying at these low altitudes.

More complex certified drones are expected primarily in public safety and security and mobility sectors. Drones with longer endurances and flying well above 150 metres are expected for border security, maritime surveillance and other environment assessments (e.g., forestry and national park surveillance). As a result they will likely be acquired by national and regional authorities and represent a low volume (a fleet size close to 100 units in total which could reach a few hundred over the time). These capabilities are likely to be in the form of technology transferred from the military. Other longer endurance missions include research into the use for telecommunications, although this is more applicable to less developed markets and even if used in Europe would represent a very small number of units (a US report estimated the entire country could be covered by 8 such drones including capacity for redundancy)[12].

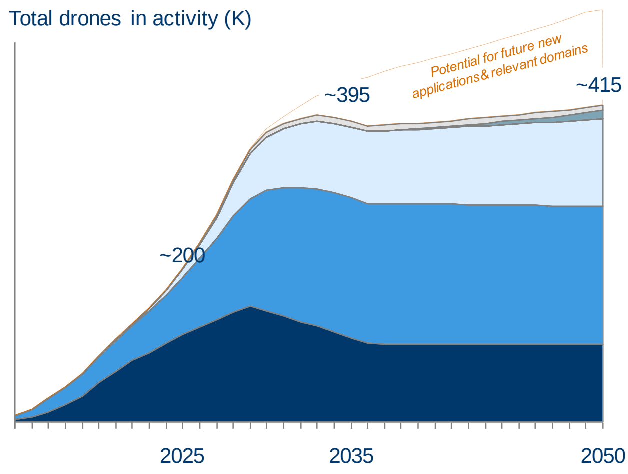
Complex certified drones also encompass remotely piloted or highly automated aviation capabilities for today's aircraft fleet - including rotorcrafts and commercial airlines. As profiled earlier on key assumptions (section 2.2), public acceptance will be essential along with ensuring robustness of the technology which is likely to come from the military. A gradual shift towards systems with no pilot on board over multiple decades is expected to occur according to the evolution of the society with regards to automation. Therefore estimates are inclusive of optionally piloted systems. Approximately 10 000 units are estimated in 2050 on the basis of the market starting first for cargo aircraft sometime after 2030 and then for human transport at earliest 2035, representing a lag of at least 10 years from after the launch of fully autonomous self-driving vehicles anticipated for 2025.

A summary of the demand outlook per mission type is shown below.

[12] Volpe National Transportation Systems Center, "Unmanned Aircraft System (UAS) Service Demand 2015 - 2035: Literature Review and Projections of Future Usage"

Figure 7: Demand outlook by type of mission

Evolution of drone demand – view through 2050



Split between 'certified' and other, primarily 'specific', drones under EASA framework

	2035		2050	
	Specific	Certified	Specific	Certified
Others - tethered	--	~5	--	~5
Unmanned aviation	--	<1	--	~10
Long endurance surveying	--	<1	--	<1
BVLOS with light load[1]	~95	--	~115	--
BVLOS surveying[2]	~185	--	~180	--
Localized VLOS surveying[3]	~110	--	~100	--
Total	**~390**	**~5**	**~400**	**~15**
excl. tethered	*~390*	*~1*	*~400*	*~10*

1. Includes agriculture spraying and delivery drones; 2. Includes "more automatic long range surveillance" drones, e.g. centralized police drones, agriculture remote sensing, monitoring of pipeline, power-lines and railway; 3. Includes inspections for energy sites (solar, oil & gas, etc.), telecommunication towers, mining & construction sites, etc., and in-vehicle police & fire response units
Note: figures are rounded to the nearest 5K units; differences in totals due to rounding
Source: Press search, expert interviews with technology providers, operators, future users in each sector and policy makers, Eurostat, BCG analysis

A distinction is drawn between 'certified' drones and 'specific' drones in anticipating categories being defined as part of EASA's pending framework. 'Specific' drones, representing medium levels of risk, have been defined generally as being below 25 kilograms and flying near or below 150 metres. The 'certified' category was used for drones flying well above 150 metres – i.e., have impact on controlled airspace as well as uncontrolled airspace, including Class G – or of sufficient size to create more substantial risk. These categorisations should not be considered as absolute as weight and size are not specifically used for determining whether a mission is classified under the 'certified' versus 'specific' label and instead the risk assessment of individual missions (including their proximity to densely populated areas) will be the overall deciding factor. The 'specific' category has been used as a general rule for commercial applications over using the 'open' category, designated for low risk missions where training is not required. Portions of the 'specific' category could end up being classified as 'open' under the future EASA performance-based framework, especially those missions remaining within visual line of sight outside of densely populated areas.

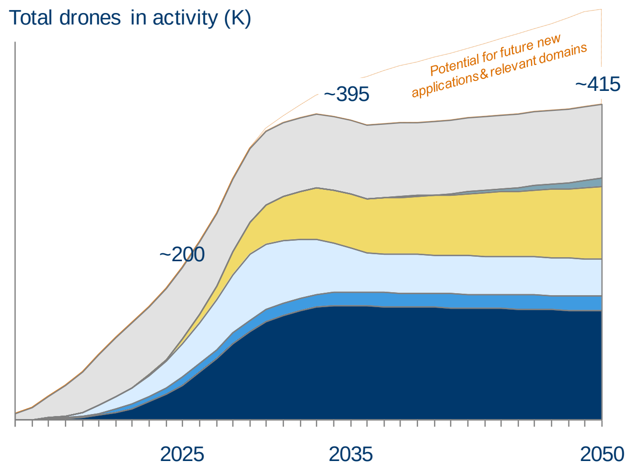
Key takeaway	The majority of government & commercial potential demand is for drones expected to perform beyond visual line of sight (BVLOS) missions

Overview of demand forecast by industry sector

Driving the study's estimates are the business cases and industry dynamics within each individual sector. A breakdown of how different sectors impact the forecast is depicted in the exhibit below with 'other growth' being the combination of mining & construction, media, insurance, telecommunications, real estate, university & research domains. Following is an overview of the demand parameters within each sector with additional details available in the annex.

Figure 8: Demand outlook by industry domain

Evolution of drone demand – view through 2050



Split between 'certified' and other, primarily 'specific', drones under EASA framework

	2035		2050	
	Specific	Certified	Specific	Certified
Other growth	~100	--	~100	--
Mobility	<1	<1	<1	~10
Delivery	~70	<1	~95	<1
P.S.S.¹	~60	<1	~50	<1
Energy²	~10	~5	~15	~5
Agriculture	~150	--	~145	--
Total	**~390**	**~5**	**~400**	**~15**
excl. tethered	*~390*	*~1*	*~400*	*~10*

1. P.S.S. is public safety & security; first response visual line of sight drones carried in vehicle and beyond line of sight operated from central stations categorised as 'Specific' with long endurance used by government authorities for missions such as border security categorised as 'Certified'; 2. Tethered drones used for wind production at high-altitudes (~450m) included as 'Certified' drones while all short and long range inspection included as 'Specific'
Note: figures are rounded to the nearest 5K units; differences in totals due to rounding
Source: Press search, expert interviews with technology providers, operators, future users in each sector and policy makers, Eurostat, BCG analysis

Agriculture demand

The driver for beyond visual line of sight surveying within agriculture is the ability for drones to benefit most of Europe's 175 million hectares across crops and livestock[13]. Given the market has already started with early adopting farms paying near EUR 10 per hectare for an individual service, the market is expected to be mostly service contracted as approximately 95% of Europe's 12 million farms are under 50 hectares[14] and most farms do not currently have a desire for more than 2-3 flyovers a year (equating to an annual willingness to pay of less than EUR 1 000 for most farms). Even with the number of small farms, the majority of land is likely to be drone covered as today's satellite offerings are constrained by clouds and low service levels unable to adapt to future needs for greater flight intensities. The combination of large farms with their own drone and service providers able meet customer requests within a week (important for harvest, fertilizing, etc.) and able to cover 500 hectares a day is expected to create the demand of approximately 125 000 drones by 2035.

Additional light load drones for spraying and seeding are expected on the basis of high value crops – wine, fruit and vegetables primarily. About 25 000 drones by 2035 are possible based on Europe holding 12 million hectares of these crops that are to be covered by low flying drones moving at slower speeds (coverage ratio is assumed to be 5 times less than fixed wing drones used in remote sensing)[15].

[13] Eurostat: agricultural census 2010

[14] Eurostat: agricultural census 2010

[15] Based on proportion of land covered by vineyards, fruit and vegetables in Germany (Statistisches Bundesamt), the UK (UK dept. of Food and Rural affairs), France (INSEE) and Poland (Central Statistical Office)

Energy demand

The benefits of using drones for infrastructure inspections are the reduction of personnel/environmental risk, facility downtime and overall maintenance costs as today crews need to hang from ropes or build scaffolding to conduct these activities – both a timely and costly operation. Additionally, long linear assets such as electricity grids or pipelines need to be serviced by expensive helicopters or slowly by teams travelling non-stop and thus prone to accidents. Drones have the opportunity to impact both types of surveying – local site inspections and long range – in order to provide cost-effective methods that increase the timeliness and quality of maintenance information.

Local site inspection is already happening in the area of oil & gas industry where specialised drone operators are coming to offshore facilities and refineries to condense what used to take multiple weeks into less than a week and do so at better rates. Over the longer term, and as drones can either be operated by local crews or more remotely, drones are likely to be located at most sites permitting more frequent maintenance cycles and better responsiveness to unforeseen events. These sites include oil & gas platforms/vessels, wind turbine 'farms', power plants, solar panel fields and hydraulic dams that are estimated to number nearly 10 000 by 2035 and thus requiring a similar number of drones if one is on site at all locations.

Utility lines and pipeline, currently inspected once every 3 to 18 months, would need under 1 000 fixed wing drones to inspect approximately 8 million kilometres of above-ground assets[16] up to 3 times per year given a single drone is likely able to fly 50 000 kilometres annually. This number could be closer to under a few hundred if these fixed wing drones fly at higher altitudes (well above 300 metres) given their increased range. The type of drone will depend on the cost of these higher altitude drones (requiring more complex data link and sensory equipment) in comparison to a limited crew able to retrieve and re-launch fixed wing drones flying at low altitudes that today represent near or below 150 metres.

Beyond inspections, tethered drones converting high altitude winds into electricity could emerge in European skies. The EU forecasts growth in wind energy production of approximately 600 terawatt hours (TWh) annually by 2035, a 225% increase to 2015. If drones, operating more effectively than turbines, account for approximately 10% of the additional capacity then some 5 000 tethered drones would be flying around 450 metres altitude.

Public safety & security demand

Drones are set to offer first response police and fire teams along with other national and regional authorities with new opportunities to acquire real-time aerial imaging in a cost effective way. They also help authorities better allocate their teams.

[16] Based on data made available by EU transport in figures, statistical pocketbook 2015; VERIVOX; Bundesministerium für Wirtschaft und Energie; Eurelectric, Power distribution in Europe, Facts & Figures; National Grid; RTE (Réseau de transport d'électricité - France); PSE S.A. (Polish Government Plenipotentiary for Strategic Energy Infrastructure) and BCG proprietary data

First responders, police and fire, will likely use small, low altitude drones as pooled resources to take in-vehicle on missions in the way vehicles are pooled today for officers of the same station. With an estimated nearly half million response vehicles across the region[17], demand for some 150 000 drones is foreseen (1 for every 2 fire trucks or 4 police vehicles). Adoption will likely take many years given budget pressures and distributed procurement responsibilities. This long cycle is likely to create an opportunity for new, common service models to develop as technology and regulation evolve. Station-based drones (with greater range than today's technology), separate for police and fire operations, could be used to respond to requests with much higher coverage than helicopters today and over time replace obsolete in-vehicle units that are utilized much less (1 station-based drone for every 4-8 in-vehicle units). In-vehicle units are expected to remain essential for specialized task forces and in more rural areas where a common coverage model may not be sufficiently responsive. Finally, other authorities beyond police and fire (e.g., prisons) that account for approximately 15% of the budget are likely to leverage these tools in a similar manner[18]. Overall, the combination of these types of drones is expected to reach 50 000 by 2050.

The dual use and transfer of more complex technologies originating from defence and military are also expected to be used in the area of public safety and security primarily performing missions around border security, maritime surveillance. Overall, approximately a hundred drones are estimated to cover over 100 000 kilometres of European borders allowing for two flights a day flights over non-Schengen borders (15 000 kilometres) and daily on the coastlines (70 000 kilometres)[19]. These assets are likely to also be shared for other critical missions related to search and rescue, disaster prevention and relief, and other environmental efforts (e.g., forestry assessment).

E-commerce and delivery demand

Drones able to avoid today's growing traffic on roads are expected to offer opportunities for faster, more customised delivery and increase access of communities in remote places. These opportunities are expected to be considered value-adding services that both consumers and businesses are willing to pay a premium for. A closer view at the economics of delivery today foster a view that today's standard deliveries are not likely to be impacted. Indeed, premium services – today the average premium courier or overnight delivery costs about EUR 10 – may be feasible if automatic flying capabilities of many drones (forecasted to upwards of 15 drones over the long term) are able to be controlled by a single operator: at full capacity, drones could complete 5 000-9 000 annual premium parcels providing a EUR 50 000-90 000 breakeven point that appears realistic as long as a single pilot is allowed to operate or monitor many high autonomy drones simultaneously)[20].

[17] Based on numbers of police vehicles in UK, Germany, Poland and France, scaled up by number of police officers (as provided by Eurostat)

[18] Based on budget spending in public safety as a whole excl. justice vs. budget allowed for police and firefighting (data provided by Eurostat)

[19] Based on the CIA world fact book

[20] European Commision: Digital Single Market & BIEK (Bundesverband Paket & Express Logistik): KEP-Studie 2015 - Analyse des Marktes in Deutschland

Today, around 10% of over 7 billion annual EU packages same day deliveries were considered to be part of the applications covered efficiently by drone capabilities[21]. Most of these packages, approximately 60% are less than 2.5 kg[22], are light enough for expected drone delivery. Drones are expected to provide the greatest competitive advantage in dense (sub-) urban areas. Overall, about 10% of same day premium lightweight packages are considered for potential drone services. This number of 'eligible' packages is expected to grow over the coming years as a result of drones increasing the access of goods such as pharmaceuticals, food, electronics, do-it-yourself items and clothing to consumers given e-commerce still represents a very small portion of overall retail. This growth, along with creating enough capacity to deal with peak periods of demand (e.g., Christmas holiday), drives a forecast of approximately 70 000 drones to deliver nearly 200 million parcels in 2035.

Drones are not expected to be viable for regular parcel deliveries based on current last mile economics that are estimated to only provide EUR 10 000 annual cost base for a single drone. However, it may be feasible for retailers with substantial scale to replace the "delivery middleman" by an owned drone fleet, although this applies to a very limited number of retailers given they are subject to the full cost with mark-up of a regular parcel.

In addition, Europe has over 300 freight aircraft, a number expected to grow to near 500 units by 2050, where ground-controlled operations may drive efficiencies[23]. Following the emergence of automated vehicles in the 2020's, it is anticipated that the first remotely piloted air freighters could potentially appear (as highlighted in key assumptions in section 2.2). This movement, estimated for near or soon after 2030, would result in a total conversion of these approximately 500 aircrafts by 2050 even with a maturity cycle of 15 years (see following focus on mobility & transport and the supporting annex for additional discussion on potential societal acceptance for large commercial vehicles such as cargo transport).

Mobility & transport demand

One of the critical questions for future of Europe's skies related to drones is how ground control capabilities could impact the future aviation fleet, including scheduled airlines. Current and developing aviation technology has already brought us high levels of automation on commercial passenger aircraft. However, despite how most parts of today's passenger flights are auto-piloted, supporting operations with no pilot on board will require significant evolution in technology, regulation and, most importantly, passenger acceptance.

Public acceptance for flights with no pilot on board is likely to be impacted by advancements in other sectors and technologies, notably by self-driving vehicles. Multiple commercial announcements have already been made for both partial and fully autonomous capabilities over the coming years with 2025 being targeted for fully autonomous vehicles[24]. These advancements at this

[21] BIEK (Bundesverband Paket & Express) : KEP - Studie 2015-Analyse des Marktes in Deutschland

[22] Barclays: The last Mile, Exploring the online purchasing and delivery journey, 2014

[23] Airbus Global Market Forecast 2015-2034; Boeing, World Air Cargo Forecast 2014-2015

[24] Mercedes has announced having fully autonomous vehicles on market by 2025

time are expected to create sufficient acceptance given recent studies indicate a majority of consumers are interested in purchasing these features, and most importantly, list increased safety as a leading rationale for their interest. If safety is linked with highly autonomous technology then aviation will become a natural extension gradually in the future, even though a distinction must be kept between the different sectors.

Current estimates are for the overall fleet of scheduled airlines, business aircraft and rotorcraft to grow from over 20 000 today and to in excess of 30 000 by 2035 and near 45 000 by 2050[25]. 10 000 aircraft are forecasted as part of unmanned aviation that includes optionally piloted aircraft based on a considerable lag of at least 10 years to self-driving vehicles and a gradual adoption cycle exceeding 15 years. The potential for unmanned aviation also serves as a natural opportunity for a transfer over from investments into defence and long endurance assets, especially since these estimates imply that 20% of the fleet could be equipped with 'drone' technology.

Additionally, drones could benefit the mobility sector through railway inspection (similar to pipeline inspection in energy). A few hundred units are estimated to be sufficient to monitor approximately 200 000 kilometres on a bi-monthly basis given the long range of fixed wing drones over an extended period of time.

Demand in other growth sectors

Many additional sectors will be and already are leveraging drone capabilities. Two areas that are influencing today's strong growth are media and mining & construction. The benefits of capturing film and photography have already made media a key user and we expect this growth to continue. Across film and channels for entertainment, sports, and general/regional news that are part of some 11 000 European channels[26], the number of drones could reach 30 000 (mostly small multicopter drones used near or below today's altitude restrictions of around 150 metres and operating within line of sight). For mining & construction, drones are being used mostly for civil surveying and site management. The market potential and business case is exemplified by large data processing contracts that can exceed EUR 10 000 annually for a single drone used across multiple sites in the form of a service. In the near term, mining is likely to drive significant growth with 7 000 drones expected across around 20 000 quarries and mines that are mostly small (i.e., 15 000 sites have approximately 3 employees)[27]. The number of drones in a variety of construction sites is likely to be much larger, estimated at 35 000, especially if and when drones can operate closer to populated areas.

Additional domains include the insurance and real estate industries, where drones complete property inspections or imaging, telecommunications for completing cell tower inspections more safely and efficiently, and in the academic setting where drones allow new methods of conducting research. Across each of these sectors there appears to be the potential for some 25 000 drones that

[25] Based on European ATM master plan projections until 2035; extended to 2050

[26] Mavise: Database on TV and on-demand audiovisual services and companies in Europe

[27] Based on Eurostat data on mining and quarrying

will mostly be multicopters remaining in visual line of sight. Academic research is the most likely exception as longer range survey drones will provide researchers the ability to access new environments safely – e.g., forests, volcanoes.

Overall, the combination of these other growth sectors will drive much of the growth leading into 2020. This is a result of missions for many of these sectors being potentially operated within visual line or sight and/or in low population density areas.

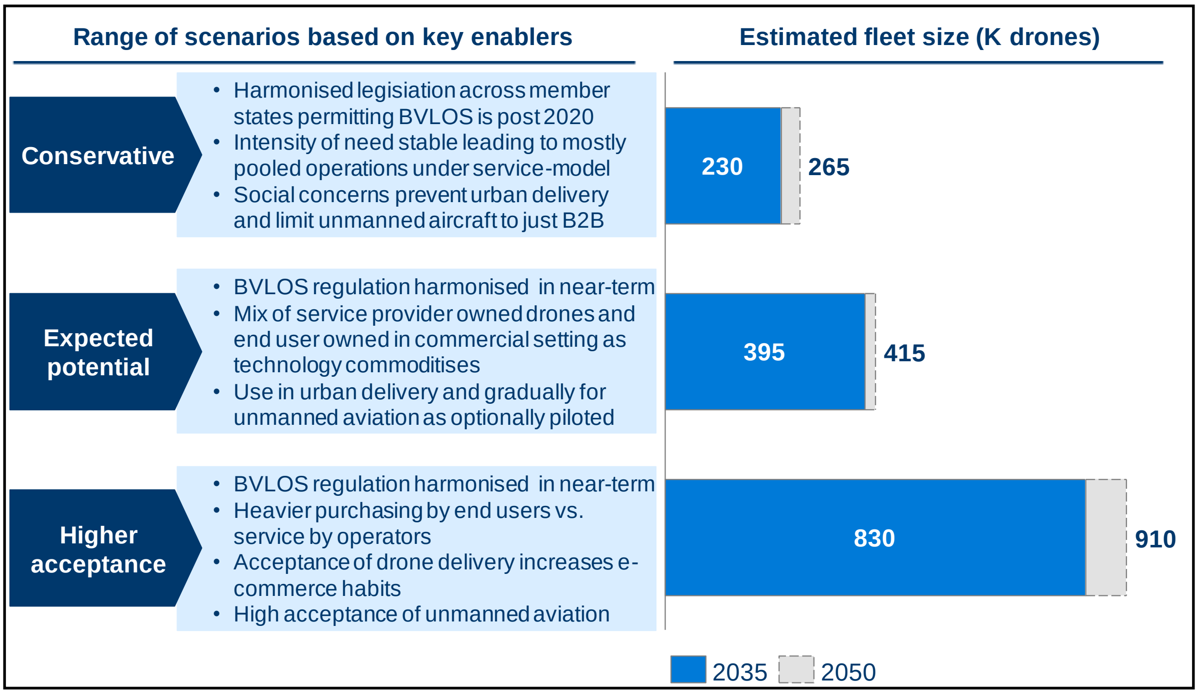
Key takeaway	Drones impact a variety of influential European sectors with no single sector corresponding to the majority of potential demand

Scenario analysis for government & commercial demand

The noted key enablers of beyond visual line of sight regulation, both in rural settings and around populated areas, along with more robust technology to permit safe beyond visual line of sight flights all have uncertainty. Given the uncertainty around these enablers, a variety of scenarios were developed for each individual mission type. The themes of these scenarios test how delays in beyond visual line of sight regulation, limitations on deliveries in densely populated areas, reduced public acceptance of drones for human transport, and slower development in technology such as detect and avoid impacts the number of drones in operation.

These scenarios for the missions and profiled sectors demonstrate, as summarized in the following figure, that growth is still expected well above 100 000 units by 2035 even under more conservative assumptions. On the other hand, if public acceptance is high then drones for government & commercial mission could near 1 million units.

Figure 9: Scenarios for government & commercial demand



Key takeaway	Growth still significant even under more conservative assumptions

2.4 Significant Societal Benefits for Europe Justify Further Action

Summary of economic valuation

The efficiency, cost and safety benefits brought by drones to businesses and government authorities will inevitably drive market growth, resulting in new employment opportunities and a positive impact on the European economy. This commercial growth extends what has already been a growing market in the areas of leisure drones as consumer electronics and defence capabilities.

An economic impact analysis of the entire value chain for each of the areas of demand revealed the potential for a European market exceeding EUR 10 billion annually by 2035 and further growing past EUR 15 billion annually by 2050 as unmanned aviation propels the market forward (figures represent nominal 2016 euros). Leisure and defence are expected to remain the largest markets in the next few years, however in the long run commercial & government is expected to be the greatest contributor of market valuation (overview of valuation in following sub-sections with further details available in the annex).

The development of a market exceeding EUR 10 billion also provides new job creation throughout all Member States, as each will need localised operations, pilots, maintenance contractors and insurers among other specific occupations. In summary, over 100 000 jobs are estimated to be at-stake with a market this significant, based on data of jobs per turnover from the OECD[28].

Additionally, there are indirect macroeconomics and societal externalities from a potential drone industry that should be considered. These include safety and environmental externalities such as increasing the success of search and rescue missions and preventing chemicals impacting natural environments through precision agriculture. Potential indirect economic areas include software developers creating applications for drones, new "drone racing" activities related to recreational use and the development of drone counter-measures that are also rising as an additional security layer around protected infrastructure. Adjacent industries, such as "computer and related activities", "electrical machinery and apparatus" and "motor vehicles", are shown by the OECD to have macro-economic multipliers factors ranging from 1.9 to 3.0 to account for these indirect benefits implying that the total (direct and indirect) impact of the drone industry could range between EUR 25 billion and EUR 45 billion in 2050, resulting in 250 000 to 400 000 additional jobs[29].

The direct economic potential for each area of demand is summarised in the figure below, highlighting the implication of services within the commercial and government domain.

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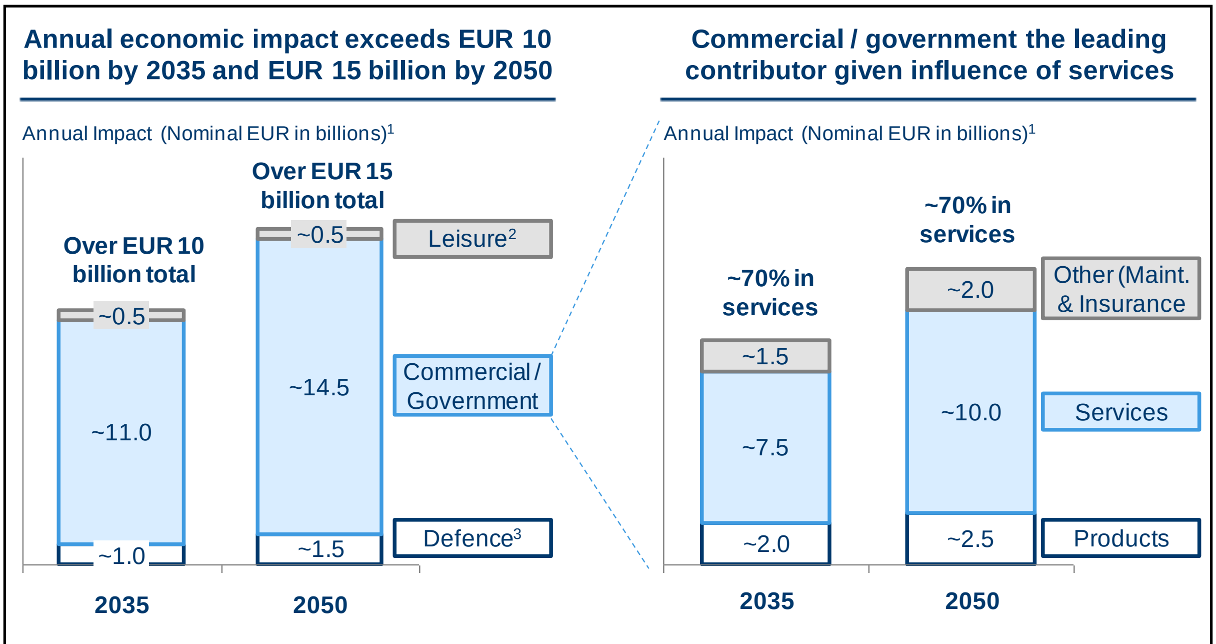
[28] OECD STAN Database for Structural Analysis (ISIC Rev. 4): For selected industries factor is determined by division of "Production (gross output)" by "Number of persons engaged (total employment)";

[29] OECD STAN I-O Inverse Matrix (Total), European Union, 2012

Figure 10: Value at-stake for European demand across entire spectrum



1. Represents long term steady state demand; nominal figures excluding inflation adjustment; figures rounded to the nearest 0.5B; represents Europe demand (i.e., excl. imports / exports)
2. 1-1.5M units at future prices expected on average to be below EUR 500 per unit given availability at this level of pricing today and expectation for overall average declines long term
3. Based on avg. of EUR 1.5-2.0M/unit with ~4% fleet growth & ~10% replacement factor (or ratio of US to EU fleet:10-15% of $1.78B growing YoY at ~5%); R&D at ratio of ~60% of procurement
Source: Industry reports, US Department of Defense, Selected companies' annual reports, expert interviews, BCG analysis

Key takeaway	Significant value is at-stake as European drone market worth over EUR 10 billion annually in 2035 and over EUR 15 billion annually in 2050

Overview of the drone market value chain

This evolution to government and commercial as the largest potential source of value for Europe is based on the importance of services beyond products. This service component is really relevant for the government and commercial sectors but not the defence and leisure markets that are shown for their product-orientated value.

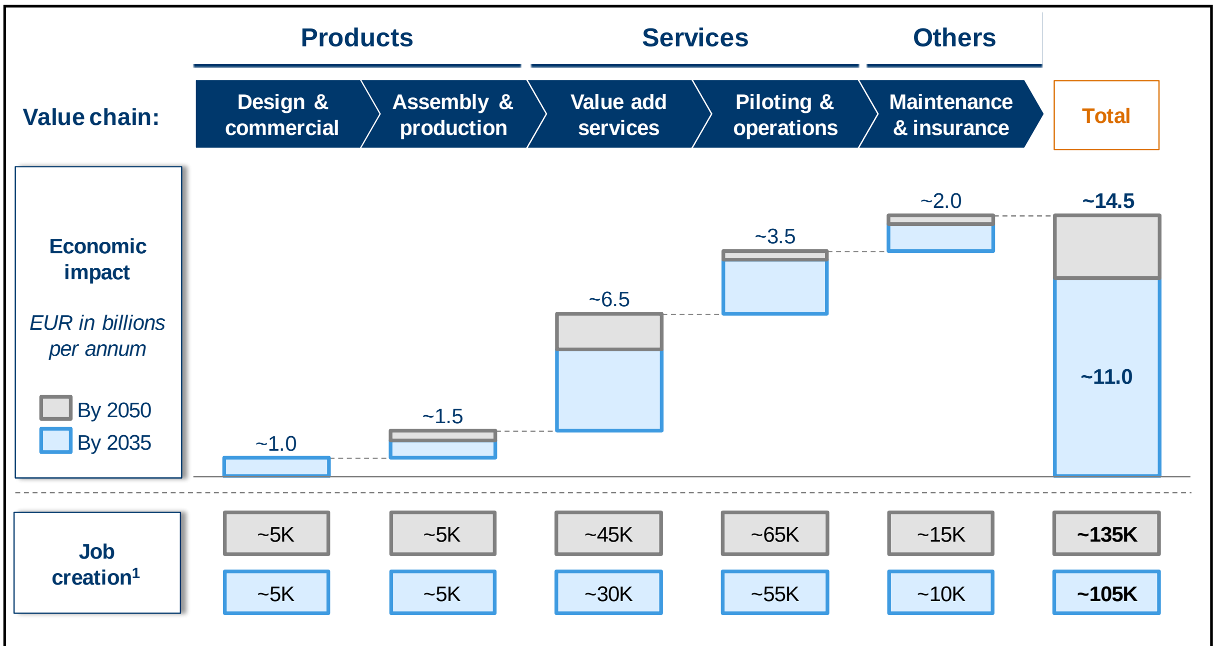
Some indirect activities will occur in the leisure domain– i.e., drone racing and product insurance – although these are expected to remain niche and are captured in the extended benefits of the drone market or, in the case of insurance, partially covered already in the production value as insurers replace broken units. The leisure market is estimated to have a long term annual sales volumes of 1 million to 1.5 million drones. Average prices are estimated to be under or near EUR 500 over the coming years given the today's already decreasing prices and likelihood that further unit growth as a consumer electronic will come more from lower priced drones that already can be purchased for a few hundred euros[30]. Together this calls for a market impact of approximately EUR 0.5 billion for European demand.

[30] Goldman Sachs, Drones flying into Mainstream

The area of defence is also predominantly product-based with procurement driving the valuation. Defence is expected to be and remain of even greater value than leisure drones especially if including the research and development contracts. Overall, a market valuation of EUR 0.5-1.0 billion is expected for procurement of the fleet of approximately 3 000 units in the long term. Higher annual figures are likely for years in which an increased number of complex systems are procured, for example at completion of the strategically important MALE programme. This estimate of EUR 0.5-1.0 billion aligns to Europe's fleet growing at nearly 5% year over year and being 10-15% of the U.S. fleet, which spends approximately EUR 1.5 billion annually on procurement today[31,32]. These drone assets also are leveraged over many years, limiting the number to be replaced in any one year. For example, tactical drones of today have already been used for around 10 years in many European countries such as Belgium, Ireland, Cyprus or Croatia [33]. Research and development also offers an opportunity for job creation in Europe and potential technology transfer opportunities into the entire aviation industry, and as a result, was noted in terms of its own potential. At a 50-60% ratio to procurement activities, this is estimated to represent an annual value of EUR 0.5 billion.

The European government & commercial drone market includes multi-billion opportunities in both products and services. However, the combination of value added services and other piloting and operations generate the majority of the valuation as depicted in the following figure that showcases the entire direct value chain for government & commercial demand.

Figure 11: Commercial & Government Economic Impact throughout the Value Chain



1. Trained end users, i.e. professional who will be trained to fly drones in addition to their current task set, are not included these figures
Note: All values in nominal Euros; Job figures rounded to the nearest 5K, economics to nearest 0.5B; excludes Electricity producing tethered drones
Source: Drone manufacturers commercial sites, Selected companies' annual reports; Goldman Sachs; Trusted choice; Expert interviews, BCG analysis

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[31] Volpe National Transportation Systems Center, "Unmanned Aircraft System (UAS) Service Demand 2015 - 2035: Literature Review and Projections of Future Usage"

[32] FY 2016 Budget Estimates of FAA by US Department of Transportation

[33] Based on EDA database of units acquired before 2006 in Belgium, in 2007 for Croatia and Ireland and in 2002 for Cyprus

The products portion of the value chain includes separating the design and commercialisation of drones and the assembly and manufacturing given parts of the process may in fact occur in different local or global locations. All drone units in government & commercial are anticipated to have multi-year useful lives, although the exact replacement cycles are anticipated to differ by industry domain based on intensity of use and capital availability. 'Certified' drones, based on similar lifecycles already being observed in defence, are expected to have much longer useful lives and may only be replaced every 20 years with on-going maintenance and updated sensory equipment as needed. Related pricing for the variety of drones is also expected to evolve with decreases over time anticipated to be 2-4% per annum. Price decreases are especially relevant for drones where a major portion of the cost is sensors that may gain scale throughout a variety of industries thus increasing the rate of commoditisation. In general, 'specific' drones are still in the tens of thousands euros, including sensory, and in most cases 'certified' drones rates are in the millions of euros (a complete listing of pricing and replacement rate utilisation is included in the Annex).

A near 50/50 split is estimated for the value of products between design & commercialisation and assembly & manufacturing for smaller units categorised as 'specific' in the demand estimates (see section 2.2 and 2.3) on the basis of the current cost structure of leisure drone manufacturers[34]. For 'certified' drones, a 30/70 split was assumed based on military equipment producers and aviation electronics and navigation manufacturers[35].

Value added services are expected to represent the largest market opportunity in the value chain. "Drones-As-A-Service" and the insight procured by leveraging drone technologies is the real intention of commercial users. Reports and data tools for crop health, energy leakage, etc. represent this service component to the drone industry. Willingness to pay is inherently directly connected to these sources of value and therefore dependent on the specific application and domain versus the type of drone used.

These value add service providers may choose to operate their own fleet of drones or contract out with local pilots given their expertise will likely be data processing. They may also be the drone provider themselves as companies look to maximise their upside in the market. Economic valuation for this portion of the value chain is represented by the total willingness to pay after removing the production value of drones, piloting operations and other on-going costs related to maintenance and insurance that are required to deliver the service. In some cases, the willingness to pay is already being defined – e.g., in agriculture where farms pay in excess of EUR 10 per hectare on each flyover and by energy companies that pay contracts in the tens of thousands for site visits. In other cases, the market for these services is still to be defined and thus assumptions have been made around potential savings the drone-service could bring to a business or based on forecasted public spend on drone operations (further details by industry are included in the annex). This includes unmanned aviation where the level of artificial intelligence will dictate whether 'drone' technologies for cargo and passenger transport end up fully as products or as a service solution.

[34] Consumer/Civil based on Parrot annual report

[35] Military based on Lockheed Martin, Aerovironment and General Dynamics annual reports, Aviation electronics based on Rockwell Collins and Honeywell Automation and Control Solutions annual reports

The scalable nature of data processing and analytics means leaders in this area will have export opportunities as well. Overall, the benefits presented by these value added services and their geographic scalability should be prioritised to unlock growth.

The impact of services is also displayed by drone piloting and operations which are suggested to represent half the job opportunities. These operations, especially for near term missions mostly completed within visual line of sight, highlights another area for Europe to prioritise as for the drone market to reach its full potential many pilots still need to be trained to operate drones safely. Most of these trainees will not represent new job creation as drone responsibilities will simply be an extension of an existing role (e.g. land surveyors).

Finally, insurance and maintenance represent additional extensions to the commercial and government drones market. Similarly to other vehicles and aircraft, drones will need to be maintained and repaired and must be insured for liability purposes against potential damages. The aspects related to maintenance and insurance of drones create a marketplace in excess of EUR 1 billion. The maintenance portion of the valuation is varies by industry based on the intensity of use with a range of 25% to 75%[36] of annual depreciation an estimated for smaller 'specific' drones and between 30% and 40%[37] for the more expensive 'certified' drones. Insurance plans covering limited liability for 'specific' units are assumed to be around EUR 1 300[38], whereas insurance premiums for certified operations are forecasted to range in the multiple tens of thousands of euros based on current spend by airlines[39]. Jobs will also be created as both extensions of existing insurance providers and localised mechanics (e.g., automobile mechanics) and new business opportunities more specific to drones.

Key takeaway	Services must be prioritized within the drone market as they account for the majority of the economic impact across the entire value chain

Job creation assessment

Job creation forecasted throughout the value chain is expected to be primarily incremental in the long run based on that most of the drone impact creates new forms of value or provides relief to capacity-constrained roles. This includes:

- **Agriculture:** The sector faces capacity constraints both in terms of personnel available to support growth and means to increase productivity. Drone services, as a key enabler of precision farming, help address these concerns and therefore direct industry job creation is incremental for Europe.

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36 Based on car running costs: maintenance/depreciation ratio for 15K & 50K km yearly

37 Based on Ryan Air Annual report

38 Goldman Sachs, Drones flying into Mainstream

39 Based on airlines insurance cost & rate of accidents due to piloting errors. Lower premium for rotorcrafts & private jets. Premium for Long endurance surveying & monitoring drones covers all accidents: Lufthansa 2015 Annual report (Insurance premium for flight operations / # non leased aircrafts) and Trusted Choice Causes of Fatal Commercial Airplane Accidents

- **Public safety & security:** Drones provide new forms of insight and service used together with the forces supporting responses and security. This includes manned aircraft operations, such as helicopter services, that will persist in the future. Many trainees will be incremental responsibilities to existing roles as well so only a portion of piloting operations is counted as incremental job growth.
- **Delivery & e-commerce:** Initial drone services are expected to be first piloted in areas with very low accessibility and thus act as new growth versus displacement. In the longer term when drones operate in more urban environments, the proportion of packages delivered, 1% of parcels, is such that very low displacement will occur, especially given most of the services correspond to new packages now ordered as a result of faster premium options becoming available. The general growth of the industry, especially in standard deliveries, should support today's entire workforce plus many future opportunities.
- **Mobility & transport:** Growth in the overall size of aviation fleet will demand many more pilots than available today. Even under the forecast that 20% of the fleet could be optionally piloted or unmanned, more pilots will be needed in the future than today. The gradual adoption within the industry also suggests that any long term transitioning in the pilot force will occur as a result of natural retirement and turnover.

Finally, for where some displacement is happening in the areas of energy and for some other inspection purposes, the majority is for dangerous jobs that will also be partially converted into drone operator roles. Hazardous inspection jobs, where inspectors must climb down offshore platforms or up high on cell towers, will be the ones displaced with those impacted as likely candidates to assume drone operator roles. These industries – primarily energy and railway, insurance, and telecommunication for cell tower inspections with only minor impact expected in mining & construction – represent less than 5% of overall drones in operation and thus the total incremental job creation is expected to remain near or above 100 000 in the long term, especially after factoring in the jobs created by military and leisure drone products.

Key takeaway	Jobs potentially created by the drone market would be primarily all new opportunities for EU citizens

Safety and environmental externalities

The safety implications as it relates to preventing hazardous occupations and fatalities are a core societal benefit of the drone industry. This safety benefit includes and extends beyond industrial inspections, as shown by the following examples:

- **Safety by limiting dangerous occupations:** Drones keep workers from hazardous inspections that lead to multiple deaths a year and protect our first responders and the victims they assist. Inspections also translate into residential safety, including safeguarding insurance claims conducted on residential rooftops and residential construction sites.
- **More lives saved & protected:** Search and rescue operations will become more effective, resulting in more successful searches. First responders – police and fire brigades – and government authorities will have a richer view of any situation, resulting in a more targeted manner to resolve issues and prevent incidents. Emergency deliveries of medical supplies in

a timelier fashion further protect lives and reduce risk of losing valuable life-saving assets (e.g., blood transferred to a hospital).

Safety is just one of the broader set of societal benefits, as evidenced by how drones are viewed as a new tool to reduce Europe's carbon footprint and protect our natural resources. Examples of such impact include the following:

- **Reducing CO2 emissions:** Drones are a substitute to CO2 emitting vehicles, thus limiting time on road by consumers and commercial vehicles while also reducing the number of traffic incidents
- **Protecting wildlife and historical sites:** Drones have the opportunity to improve maintenance in order to prevent pollution and also to monitor and protect our resources
- **Accelerating our ability to use renewable energy:** Drones help optimize solar panel networks, improve wind turbine maintenance and offer new forms of potential wind energy
- **Reducing use of soil contaminating chemicals in agriculture:** Drones help meet our need for increased agricultural productivity with reduced use of chemicals

Although drones offer numerous benefits for society, it is important to note that obstacles and risks remain to society. Drones must avoid creating new levels of noise pollution, especially as to not disturb populated settings. Further, the capabilities of drone flights must be preserved for beneficial purposes, meaning risks associated to privacy violations, flights in protected environments and cybersecurity aspects must be properly managed to avoid negative impacts to society.

Global trade implications

The estimates of a market in excess of EUR 10 billion by 2035 is representative of demand within Europe, and represents only a piece of the global marketplace for drones. Not all European spending related to the commercial use of drones will flow to the local economy. Yet, if Europe successfully manages to establish its position in the global marketplace, not only is it possible for the majority of the “value at stake” to remain in Europe, but incremental export potential may further grow the benefits of a drone market for European citizens.

The production segment of the market is likely to have the highest trade implications. The value in manufacturing and some areas of design are least likely to remain fully European generated given the comparable advantages of production in markets such as China that are also investing into the industry. This extends into the sensory equipment that is important for drones and will also likely include some imported value. However, the importance of services also suggests that Europe's focus in producing high-end hardware around automatic flight capabilities, including artificial intelligence, are well placed to capture value as these areas of focus will be the platforms connected to value adding data processing capabilities (e.g., similar to a mobile device's or computer's operating system being connected to programs and installed applications). These high-end designs represent an export opportunity for European businesses as well – for example to markets such as Africa, the Middle East and South America.

The impact of these global considerations on the proportion of product-related value to be generated in Europe further demonstrates the importance of prioritising services and operations. Trained pilots and operators are likely to perform multiple tasks related to commercial activities and support functions and thus offer long term value within European Member States. The complexity of data processing and analytics and the close connection they must have for each industry also means that value added services are an opportunity for local actors. However, the scalable nature of such platforms and the fact that the relevant domains for Europe remain consistent in other leading regions – notably the US – drives a need for near term action if investments are to successfully generate positive benefits for the region.

This prompt action is accentuated by the differences in investment between the US, China and Europe. The overall disparity requires Europe to successfully prioritise its investments and remain coordinated across Member States to provide industry participants with the scale opportunities for both products and services that will be needed to ensure appropriate return and job opportunities for European citizens.

Key takeaway	Immediate actions are required to secure value for Europe, especially with markets like the US and China investing much more and already being market leaders in defence (US) and leisure (China) production

RECAP: Key takeaways on "why we need to act"

The snapshot of today's evolving drone market and the view of demand implications out to 2050 highlights that drones represent a genuine opportunity for Europe. The following is a summary of main findings related to why continued action should be pursued by Europe:

- **Drones create value for many influential government & commercial sectors** in expanding on the growth already occurring in defence and leisure. Overall, estimates are for hundreds of thousands of government & commercial drones to go along with thousands of defence drones and millions for leisure purposes. Long term growth is anticipated for both defence and government & commercial demand while growth in annual unit sales for leisure is estimated to reach maturity in the next 3 years.
- **Significant value is at-stake in Europe** with the potential for multi-billion production and service industries over the long-term. By 2035, in nominal figures, a drone marketplace exceeding EUR 10 billion annually is expected with growth to over EUR 15 billion by 2050 creating over 100 000 new jobs. Government & commercial is forecasted to be largest contributor to the overall valuation based on the importance of services that should be prioritised by the European market, especially given no global market has developed a significant competitive advantage in services yet.
- **Immediate actions remain to secure value for Europe in global marketplace**, especially with markets like the US and China investing much more and already being global market leaders in defence production (US) and leisure production (China).

3 | Unlocking Potential Value of Drones Safely – The Role of European Level Support

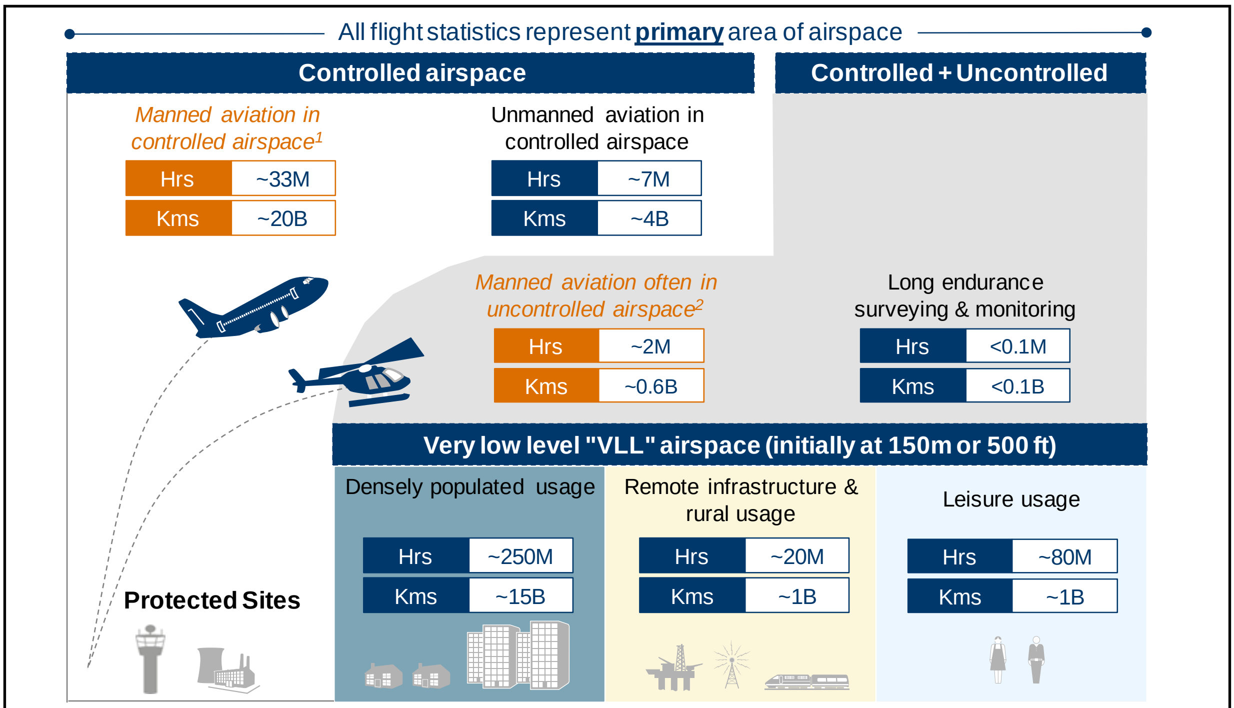
3.1 Variety of Innovations Required to Safely Integrate Drones in All Areas of the Airspace – Air Traffic Management Related Technologies are the Key

Airspace impact assessment

The potential for drones across many different settings in the years to come has considerable implications for airspace management. Future forms of optionally piloted and unmanned aircraft for mobility purposes are estimated to represent approximately 20% of the future fleet (see section 2.3 for details) meaning that air traffic management would need to account for 5-10 million hours of such flights in controlled airspace that travel just under 5 billion km by 2050. The safe integration of these drones in ATM will also need to encompass ground operations particularly in airports where automated taxiing capabilities are required.

In addition, recent media coverage of incidents involving small drones generating risk near airports highlights the importance of considering where and for how long all forms of drones will be flying to assess the risk. The following figure provides estimates of flight statistics – both duration in hours and distance travelled in kilometres – for drones in their primary setting.

Figure 12: Impact on airspace of drones measured in flight hours and distances



1. Includes business aircraft and scheduled airlines; 2. Includes rotorcraft and general aviation flight time statistics; however these aircraft do utilise all areas (incl. VLL) such as rotorcraft landing on buildings and hospitals that would be impacted by VLL drone traffic
Note: Flight distance (kms) and time (hours) for 2050
Source: ATM Master Plan, BCG analysis

Leisure drones, while increasing dramatically in number, are still on average only flown for a few hours annually. Beyond visual line of sight operations, including above the VLL, may impact all classes of airspace and have a much greater impact on the airspace than leisure drones given they will likely fly multiple hours a day. This is expected to be especially true in the long term for delivery and public safety & security drones operating in urban environments. First responders leveraging the technologies routinely as they respond to situations, including potentially with station-operated beyond visual line of sight drones, will need to safely operate alongside manned aviation and delivery drones in dynamically changing locations. In total, all operations that are primarily performed at very low levels are estimated to represent the majority of flight time to be accounted for and thus require additional technology to support safe operations.

Key takeaway	More robust technology and an accepted concept of operations to incorporate VLL activity is required given drones significantly impact all areas of the airspace

Research & development priorities for Europe

Enabling successful safe operations beyond visual line of sight are the core of commercial & government market potential; this will require the availability of a variety of technologies. Further, many of these technologies will require multiple forms to account for the various types of missions being performed at very low levels and also in controlled and uncontrolled airspace (i.e., different development to prevent a collision with a static building than a collision with a fast travelling manned aircraft). Several of these technologies are suggested to require European level support to effectively bring them to market in context of the global marketplace. This set of technologies is further detailed below individually:

- **Detect and avoid** (D&A) capabilities are seen as a key enabler for drone operations in all classes airspace and are expected to have a positive impact on safety and social acceptance.. Depending on the flight rules: in IFR the D&A system performs the collision avoidance function against cooperative and non-cooperative traffic; in VFR/VLL drones will need to be able to detect and avoid cooperative and non-cooperative traffic and multiple types of obstacles (power lines, buildings, trees, birds etc.). Although some investments to develop solutions supporting the safe integration of drones in non-segregated airspace have been made in EDA programs (MICAS, ERA) or scheduled in SESAR 2020, detect and avoid capabilities applicable to smaller drones necessary especially for VLL operations, still requires large investments to bring performances to the required level. Lower levels of investment in detect and avoid for very low level operating drones are also impacted by the remaining gap of a clear vision on the future concepts of operations and regulatory framework, making it risky to invest and difficult to align players towards industry standards and hence the development of appropriate solutions. As the concept of operations is defined it will also be important to take into account technologies like geofencing that will be used to define the geographical envelope of drone flights.
- **Datacom and spectrum** issues are critical to enable BVLOS and long endurance surveying missions to happen in safe conditions. Appropriate datalinks are necessary for command and control (C2) as well as potentially for communication with air traffic control (ATC) or future forms of VLL drone management. The biggest challenges when it comes to datalinks are the identification, allocation and protection of the necessary spectrum. There is also some R&D about the satellite communication such as DESIRE II, that contribute to research on Datacom and spectrum for certified drones, have been set up by EU institutions. Specific solutions adapted to BVLOS operations occurring in VLL, especially in urban areas, are currently more fragmented and require further exploration of several alternative communication means such as the use of mobile phones network (4G, 5G etc.).
- **Security and cyber resilience** is a priority area of development to mitigate the risk that drones could be subjected to malicious or accidental takeovers of datalinks leading to accidents, theft or deliberate use of the aircraft to damage infrastructure or hurt civilians. Those issues could have a severe negative impact on public acceptance. Private initiatives are exploring potential solutions such as digital identification but clear concepts of operations, requirements and standards are needed to drive research into a more advanced and coordinated phase.
- **Human factors and training** will need additional R&D efforts to ensure that the situation awareness for pilots of drones matches that of pilots in cockpits. Additionally, there will be a requirement to manage the transition from remotely piloted drones to more automated drones that are only monitored. In order to achieve those goals, effective solutions regarding contingency, failure management etc. will need to be put in place. Harmonisation of the operator’s environment is likely to lead to more appropriate training and higher safety. Training and qualification is an underlying topic that requires immediate action from

the EU to provision new, well trained pilots. Achieving EU-wide accepted pilot licenses would accelerate the creation of drone service companies.

- **Validation and demonstration** will be important to increase public acceptance of drone operations and will support the regulatory work. Although some validation exercises are performed at national level, broader authorised and safe testing environments to perform integrated demonstrations involving different systems (manned and unmanned operating simultaneously) will be needed. In addition to that, EU level coordination on the allowance to let some pioneer applications operate will be of high importance. Indeed, pioneer applications that would be allowed under a risk-based logic would enable the collection of data and observations to further refine concepts of operations and regulation while increasing public acceptance.
- Finally, the critical area of **air traffic management ("ATM")** requires further research and development. All previously mentioned R&D topics depend on how ATM will integrate drones in all classes of airspace. The basic principles of drone traffic management as defined by the concepts of operations will lead to precise requirements on which industry standards will be developed, thereby assuring a strong basis for future investments and partnerships across private industry players and public member states and stakeholders.

Key takeaway	Several R&D priorities related to ATM require EU level support to successfully and efficiently integrate drones into all areas of the airspace

Overview of differential R&D for Very Low Level airspace

Research around the integration of drones in controlled airspace is expected to be partly covered by SESAR 2020 programme and supported by other programmes coordinated by EDA such as MIDCAS, ERA and DESIRE II. In order to maintain high levels of safety similar to manned aviation, multiple technology areas are being taken into account, which are highly aligned to these same categories as D&A, datacom & spectrum, human factors, security & cyber resilience and validation & demonstration are all included and represent direct synergies with ATM.

The issue, as introduced in the individual overview of technology needs, is that in the lower levels of airspace, i.e. uncontrolled airspace and very low level airspace, the road to safe integration of drones is even more challenging and currently less addressed than in controlled airspace. Drones in those types of airspace will need to be able to cope with non-cooperative air traffic, multiple sorts of obstacles and aircrafts operating under visual flight rules (VFR). The safe integration of unmanned aviation at those lower levels is likely to require a new drone management system and approach. The exact shape of this drone management system is yet to be defined and will likely require EU level coordination and harmonisation of all stakeholders.

Furthermore, the advances under scope in SESAR must be complemented to address the D&A, datacom and human factor elements more specifically associated with these very low level operations. It will be essential to build support in some manner for the entirety of these operations.

Key takeaway	SESAR needs to be further complemented, in particular in regards to managing very low level operations (i.e., unmanned aircraft traffic management – UTM)

R&D investment requirement

Supporting the growth of a market with the potential to exceed EUR 10 billion per annum (see Section 2.4 for details) in the long term will require continued investment. Current levels of investment that are already being measured in the hundreds of millions across public and private stakeholders (even after excluding defence) highlight the significant price tags of robust technology (see section 1.3 for details).

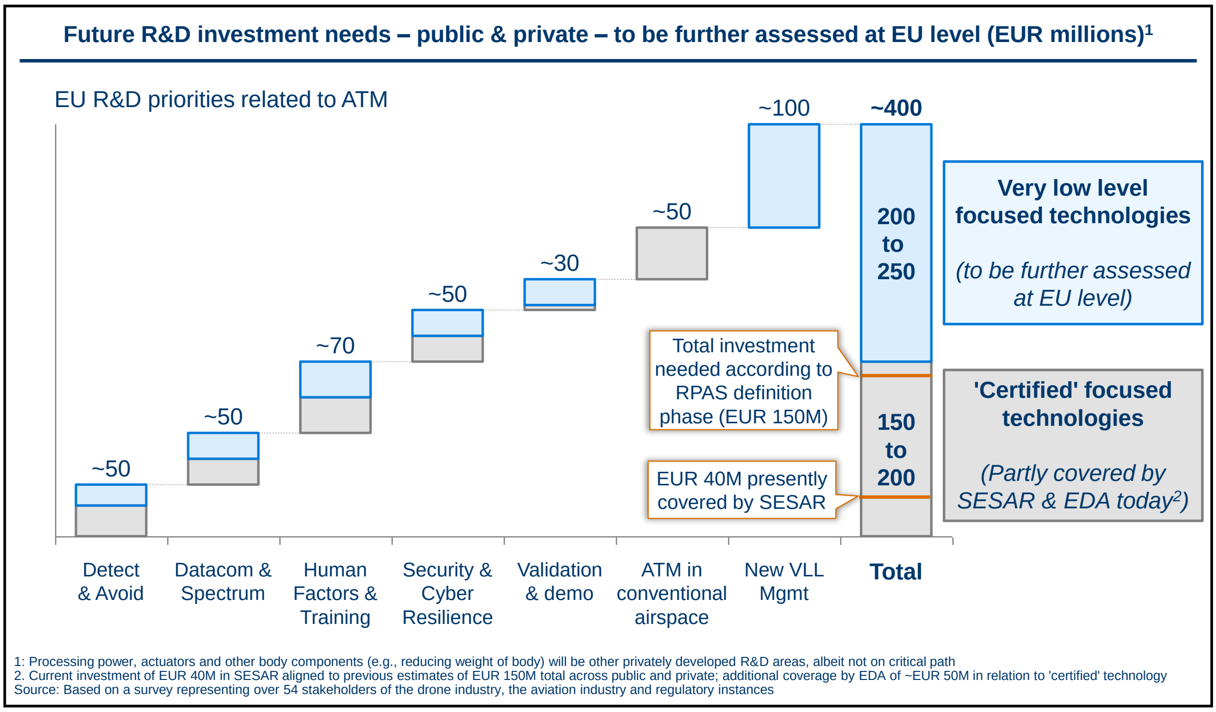
SESAR currently includes a budget of EUR 40 million on the topic of drones, equating to under EUR 10 million annually, that represents an initial foundation to progress on many R&D priorities. Additionally, recent investments of approximately EUR 50 million associated with the EDA further the support of priority areas such as D&A. These investments are primarily focused on complex 'certified' solutions that will impact the more conventional classes of airspace in the future. Altogether, 'certified' systems are suggested by the industry to demand between EUR 150 million and EUR 200 million to be leveraged in the coming 5-10 years. This figure is aligned to initial SESAR estimate of EUR 150 million for drones that required integration into the airspace that was used to drive the allotment of EUR 40 million currently budgeted within the existing PPP.

Additional investment needs will still have to be assessed at EU level, for complementary R&D activities. This includes the set up of specific ops and tech requirements that would drive complementary research at least on D&A capabilities, and appropriate C2 link that represent between EUR 100 million and EUR 150 million to be addressed by both private and public stakeholders.

R&D for a new very low level management system represents additional new investment requirements suggested to be on the order of magnitude of EUR 100 million over approximately 5-10 years. The investment levels by the US related to their equivalent unmanned aircraft traffic management (UTM) programme of over EUR 20 million suggest this to be of credible scale. In sum, very low level management appears to require in excess of EUR 200 million and is a remaining gap not primarily addressed by SESAR and other EU level support (including the EDA). Supporting such development through a PPP seems to be appropriate considering it would increase the effectiveness and the efficiency of the development cycle and would benefit from the sharing of investment responsibilities across public and private stakeholders.

The trailing figure summarises these investment areas for research and development on topics benefitting from European level support, as suggested by the industry. The total increase in the investment required over past estimates exceeds EUR 200 million as a result of very low level focused technologies. The increase is a result of how very low level technologies are rapidly expanding beyond just being used for visual line of sight operations in remote areas. The increase in drone operators, involvement of industrial leaders in drones and expansion of capabilities by leisure drones now used commercially have demonstrated the forthcoming impact such drones will have on the airspace. It is also critical to note the need for swift action across all R&D priorities with the industry projecting that much of the technology investment should and must be completed in the next 5-10 years. The push by markets like the US and China suggest expectations for the next 5 years are in fact a limited window of opportunity for Europe to consider.

Figure 13: Summary future R&D needs to be further assessed at EU level



The urgency of these R&D efforts suggests that investment must be made before completion of programmes such as SESAR 2020 in complementary fashion, especially as each acts as a "must-have" requirement for acceptable performance of drones missions representing significant value.

Additional investments and development will also be required in other forms of technologies that can be primarily privately funded, especially since they act as intellectual property industry players use to compete in the marketplace. Included in this set of R&D topics are the propulsion systems (including battery) to increase the range of drones and the applications and algorithms around data processing and analytics.

Key takeaway	EU support levels for R&D need to be re-assessed to enable the safe integration of drones in all classes of airspace

3.2 Ecosystem for R&D Requires EU Level Coordination to be Globally Competitive

EU level support and progress towards a more efficient market will be critical to unlock the potential of over EUR 10 billion in annual value. Such EU support would create a single competitive drone market able to improve connectivity, growth and jobs just as has been done in EU aviation. A single market will be especially critical to ensure Europe is globally competitive with opportunities available for attractive scale. Furthermore, boosting innovation and regulation in a manner that matches or outpaces that of the global marketplace needs harmonisation and coordination. The numerous initiatives on drones remain fragmented across industry participants and Member States such that it is important that increased coordination and pooling is urgently put in place. Facilitating cooperation and public private co-developments is a role best orchestrated at the EU level and it will be critical in doing so to develop an ecosystem that that welcomes the full range of relevant public and private stakeholders.

In defining a holistic ecosystem for R&D in Europe, a variety of private institutions should be considered and involved, including:

- Current partners of SESAR JU and instrumental stakeholders in the development of 'certified' drone capabilities for long endurance surveying and future unmanned aviation
- Designers and producers of 'specific' and 'open' drones such as Parrot as the recent recipient of EUR 300 million in stock issuance funding and the European leader in turnover related to leisure drones
- New venture service providers, including both those conducting visual line of sight operations and also those developing the initial beyond visual line of sight experience to be shared broadly
- European and global technology innovators involved throughout the value chain in terms of developing drones and the operating systems (including options for very low level UTM solutions)
- European telecommunication providers able to assess and recommend options for alternative solutions for data communications
- European and global industry domain leaders experimenting with the use of drones to create new businesses and transform existing ones. Examples of such firms include DHL, Maersk and SNCF that have also shown interest in drones through publicised demonstrations of drone applications

Public involvement must also be expansive and extend beyond only European level institutions and authorities, including the following:

- Universities and academic institutions to support priority research efforts and to stimulate the training of the future workforce across the entire value chain – including design, commercialisation, legal, piloting and engineering among other job opportunities. Examples

of such benefits including the Delft University of Technology's advancements into research related to emergency medical deliveries and its investment into Delft Aerial Robotics that recently announced plans for the first fully autonomous drone network in the city of Delft
- National authorities throughout Europe to gain confidence on new technologies as they mature and anticipate subsequent deployment challenges
- European level institutions and authorities, including the Directorate General for Mobility & Transport (DG MOVE), Directorate General for Internal Market, Industry, Entrepreneurship & SMEs (DG GROW), European Aviation Safety Agency (EASA), Eurocontrol, European Defence Agency (EDA) and the SESAR JU itself

Building a designated 'home' for the drone traffic management R&D at European level has extended benefits related to the creation of a single market. First, such coordination signals that broad market opportunities will exist and thus attracts market participation by existing and emerging private stakeholders. Second, signalling broad opportunities helps increase confidence by these same organisations to proceed with R&D activities that may still be on hold. Furthermore, removing barriers between states increases the probability any European benefits will provide return to citizens by offering scale to remain globally competitive. Finally, cross-border flights will also likely increase in the future, especially in relation to 'certified' drone missions that include border security, maritime surveillance and future unmanned aviation, showing the necessity of European level coordination.

Multi-national operations and cross-border flights align drones to broader aviation where a single European market has remained a foundation for growth over the years. In the case of drones, avoiding fragmented and duplicative investments across Member States is especially important given the current gap in total investment between Europe and markets like the US that have already started on topics such as very low level traffic management. Efficiency and effectiveness in advancing technology will also be boosted if variation in regulation is limited and related standardisation processes are conducted quickly.

The role of an established PPP like SESAR for integrating drones in controlled and uncontrolled airspace (excluding VLL) demonstrates that EU level harmonisation and an accepted concept of operations can accelerate innovation. This remains an outstanding task for new mission types primarily operating at very low levels hindering the industry from cooperating towards efficient solutions. Datacom and spectrum and detect and avoid for such drones are examples of areas where academic, public and private institutions have put in place a number of low investment, disconnected programs working often times in separate directions. As different solutions such Lidar-based solutions, ultrasound solutions, “ADS-B like", ACAS-Xu, etc. for D&A are explored it will be important for research results to be shared and for performance standards of the environment they operate within to be standardised. Ensuring efficient comparison of potential solutions and effective decision making in regards to which solutions should be prioritised is a support function best enabled at the EU level. This level of interaction would further allow European stakeholders to compare priorities with those occurring in the US and globally to maximise the success of EU investments.

Key takeaway	Avoiding fragmented and duplicative investments across Member States is especially important given the current gap in total investment between Europe and markets like the US that have already started on topics such as very low level traffic management. The role of an established PPP for integrating drones can accelerate innovation. SESAR is well-positioned to play a central role to ensure the EU is globally competitive

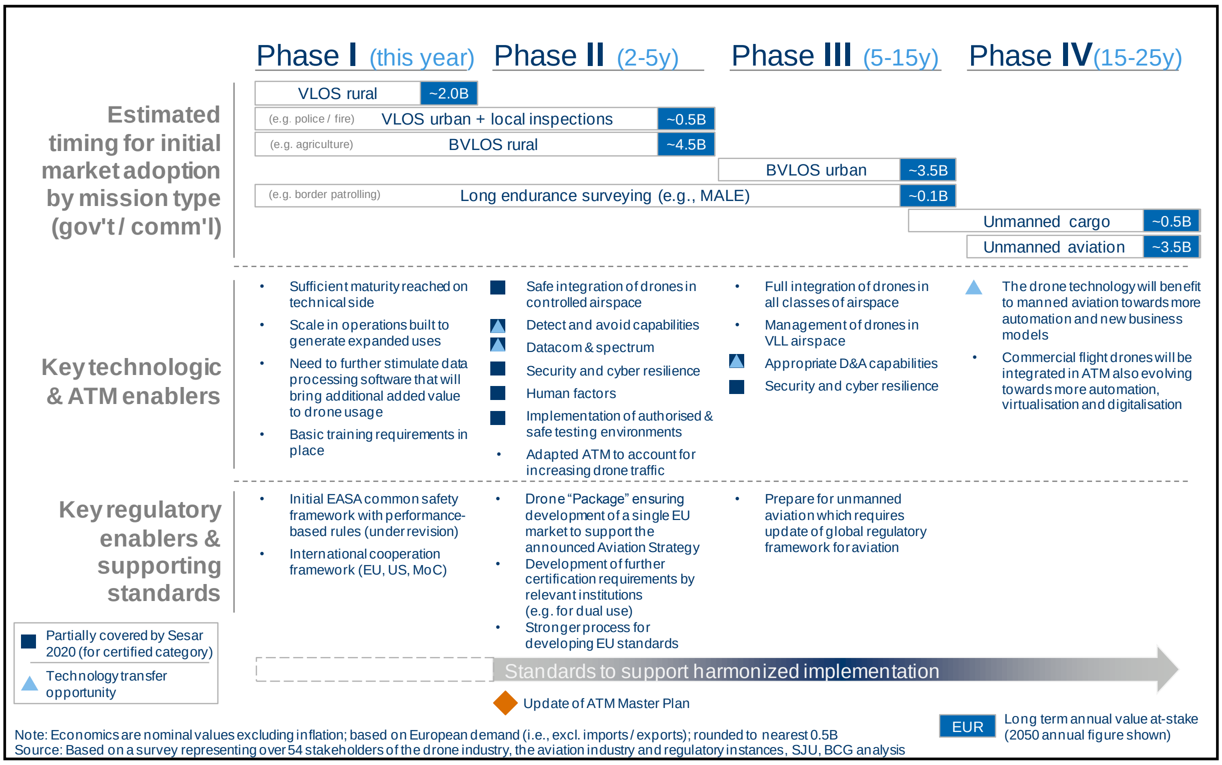
3.3 Next 5-10 Years Most Crucial Part of Potential Long Term Phased Roadmap

Overview of phased roadmap for drone market out to 2050

To tackle the technologic and regulatory challenges of the years ahead, the efforts requiring coordination and harmonisation at the European level have been prioritised and built into four phases. The time horizons for each are related to both the expectations of the market for much of the technology advancements to be completed within the next 5-10 years and also to prioritise efforts on the basis of when demand within the commercial and government domain is expected. This timing therefore is meant to prepare the market in advance of demand and optimise value creation and benefits across Member States.

A summary of these four phases, detailed thereafter, is shown in the following figure and includes a timeline for when market adoption is expected for the different drone mission types together with their potential long term value if successfully enabled.

Figure 14: Summary of European market drone roadmap



The first phase, which is already on-going, as announced in the Commission policy document "A new era for aviation – Opening the aviation market to the civil use of remotely piloted aircraft systems in a safe and sustainable manner",[40] aims to allow safe and mature operations to flourish by ensuring performance-based regulation, establishing common training requirements and stimulating service and data processing companies.

From a regulatory standpoint, it is expected that the EU common safety framework will be adopted and, will enable the development of a harmonised framework with performance-based rules. Meantime, EASA is expected to develop technical regulation to support the development of the 'open' category which include recreational and professional drone operations, while addressing some key concerns such as identification, protection of privacy or EU consumer rules conformance and ensuring safety with regards to protected sites for which work on the use of geofencing is currently on-going.

As the operation centric approach is developed and performance-based rules are set, identifying sufficiently mature technologies and mission types as generally permissible (e.g., categorising 'open' operations) is an opportunity to unlock value related to visual line of sight applications in both rural and urban settings as well as for some rural beyond visual line of sight missions where demand already exists. Separately, ensuring government missions related to long endurance surveying receive clearance in the near-term will help further gain experience in drone operations and build a position in services.

40 COM(2014)207

Finally, the near-term represents an opportunity to put in place an international cooperation framework that supports development of the market in a safe, efficient manner.

A second phase, anticipated to be completed between 2 and 5 years from now, is especially important given a high number of both technology and regulatory priorities that must be completed in order for Europe to be a global leader. From a technology standpoint, the safe integration of drones into controlled airspace is targeted for completion as part of SESAR 2020. Related to this integration is the prioritisation of detect and avoid, datacom and spectrum, security and cyber resilience, human factors, safe and authorised testing environments for applications of highest EU relevancy and adaptations to ATM for increasing levels of drone traffic.

Although many of these aspects are being initially covered by current SESAR 2020 and EDA investments, the previously mentioned increases in investment are essential in the very near-term in order to successfully complete all of these advances within the window of 2-5 years. These investments, especially into detect and avoid and datacom for 'certified' drones, offer transferrable benefits into both manned and unmanned aviation. These advancements will support the further development of long endurance surveying and beyond visual line of sight growth and lay the groundwork for these BVLOS capabilities to be safely leveraged in urban environments.

Two regulatory priorities exist at this stage of the market development. The first is to complete implementation of an "EU drone package" connected to the Aviation Strategy supporting a single market from drone production and services. This package is meant to include harmonisation legislation for European patents, standards and CE marking. Potential content features encompass the optimisation of internal accessibility and trade balances, promotion of entrepreneurship, guidance around liability and insurance issues, spectrum management, support of cross border operation and privacy and security issues. It also potentially will cover the establishment of European level coordination around the development and implementation of a VLL management system (i.e., UTM) and determine means of investment and pricing for common ground infrastructure and services provided. This coordination should be able to federate public and private interest to make innovation happen in the framework of the Aviation Strategy. The second regulatory priority is to stabilize certification requirements for key technologies (including detect and avoid) some of which are of dual use (civil and military). These regulatory priorities represent further maturity of the efforts that have been on-going since the 2013 Commission regulation.

The third phase, anticipated to take place and be completed between 5 and 15 years from now, will get regulation and technology to a point where all types of operations at low altitude (including BVLOS operation in urban environments) will be able to take place in safe conditions. Key to this development is the implementation of a drone management system in all classes of airspace and particularly at very low levels supported by, inter alia, improved detect and avoid capabilities and robust cybersecurity.

The third phase is also anticipated to prepare regulation for unmanned aviation which will require an update of the global regulatory framework. In doing so, it appears important to establishing a new certification philosophy and regulatory requirements to account for the increased degree of automation and robotics.

<u>During the fourth and last phase</u> likely occurring in 15 to 25 years, technology, regulation and social acceptance is expected to be ready to allow for unmanned cargo and unmanned aviation to happen (inclusive of optionally piloted systems). The level of automation, digitalisation and virtualisation of ATM will increase significantly by 2050 and many of the opportunities presented by these developments will be relevant to the evolution of unmanned flight. The benefits of automation will also be transferrable to manned aircraft that remains prominent all the way through and beyond 2050. Regulation will need to continually maintain a flexible operation-centric model, including during this time horizon.

A summary of potential regulatory content features during each phase is shown below. An inability to address these features is likely to lead to a market that provides insufficient scale opportunities for the European drone market to be globally competitive.

Figure 15: Outline of regulation enablers and potential content features

Phase **I** (in-progress)	Phase **II** (completed in 2-5y)	Phase **III-IV** (>5y)
Key enablers		
• Initial common safety framework with performance-based rules	• Drone "Package" ensuring development of a single EU market as part of the announced Aviation Strategy • Certification requirements are published also considering dual use	• Prepare for unmanned aviation which requires update of global regulatory framework for aviation
Potential content features		

• **Harmonising regulatory framework (EASA categories)**
• Protecting prohibited airspace by **geofencing**
• **Identification** of drones
• Ensuring **environmental requirements** are put in place
• Create **awareness** of drone regulation
 	
Need to identify certain VLOS and rural BVLOS applications as **generally permissible** (e.g., categorising as 'Open')
	• Implement "**EU Drone Package**" connected to Aviation Strategy supporting a **single EU market for drones** production & services (including harmonisation legislation for European patents, standards and CE marking):
	  • Optimising internal **market accessibility** & trade balances for drone products and services
	  • **Promoting entrepreneurship** and supporting small / medium enterprises (SMEs) by helping make it easier to attract investment
	  • Addressing liability (at national and EU level) and securing **affordable insurance** rates for new drone operations
	  • Setting up integration of drones in **all classes of airspace,** including addressing **spectrum management**
	  • Addressing **cost implications** of drones in controlled airspace
	  • Establishing **EU level coordination** around the development and implementation of aviation VLL management system and determine means of investment and pricing for common ground infrastructure and services provided. This structure should be able to federate public and private interest to make innovation happen in the framework of the Aviation Strategy
	  • Supporting **cross border operations** for the 'specific' category
	  • Addressing **privacy and security** to attain social acceptance
	• Stabilising certification requirements for key MIL-CIV dual use technologies (e.g., D&A)
		• Maintaining a **flexible operation-centric model**
		• Establishing **new certification philosophy** and regulatory requirements to account for the increased degree of automation / robotics (similar to automotive industry where 'self-driving automation' is beginning to be recognised at the same level as a human)

Across all phases, including on-going efforts today, it remains critical for industry standards to be developed to support harmonised implementation – an area previously discussed requiring EU level support. To support the development of standards across all phases of market growth, a stronger process to support EU standards should be targeted for completion within the next 5 years aligning it as well to the critical second phase. At this same time, potential updates to the ATM Master Plan should be completed in further ensuring EU level support of the marketplace.

Overall, from a technological standpoint, the anticipated evolutions as laid out in the roadmap align with the general views amongst stakeholders that most developments need to occur over the next 5 to 10 years. The next five years however will be crucial to unlock a majority of the market potential while assuring that Europe remains globally competitive. If Europe has difficulty allowing for technically mature missions at an efficient pace, capabilities will be more likely to develop abroad and export their expertise to Europe at a later stage thereby limiting economic potential locally. Success during these next 5 years can only occur with immediate actions and support at an EU level to the required drive investment and regulatory support.

Key takeaway	EU support critical immediately to complete critical set of technology and regulatory priorities within the window of opportunity that is likely limited to the next 5-10 years

Roadmap alignment with the EU Aviation Strategy

The presented roadmap fits into the EU Aviation Strategy by contributing to many of the priorities laid out by aviation stakeholders:

The development of a single EU market for drone products and services, including harmonisation and legislation for European patents, facilitated cross-border operations, standards, providing guidelines for insurance/liability issues and CE marking will allow Europe to <u>tap into growth by improving services and access to growing markets</u>. This growth will include the development of value added capabilities (e.g. 'big data' software) as well as the creation of a dual use of military drones for civilian operations.

Successful completion of the roadmap's activities would also <u>maintain high EU safety and security standards</u>. Having EU level coordination ensures that crucial R&D around the integration of drones in controlled and uncontrolled airspace will be conducted in addition to an assessment of the need for a drone management system for the very low level airspace. The improvement of security & cyber resilience as well as improved datacom & spectrum and a deeper understanding of human factors are key R&D areas that will reinforce safety and hence public acceptance of drones. On top of that, privacy and security as well as regulation awareness to attain social acceptance will be addressed.

Developments of the drone industry will help <u>maintaining a strong social agenda and creating high quality jobs in aviation</u>. Indeed, supporting the coordination of performance training and qualification at EU level will enable the supply of approximately 50 000 pilots needed to reach market potential while preserving a strong focus on safety. Promoting entrepreneurship and supporting small and medium enterprises (SMEs) via an economic framework will help in making it easier to attract investment and in creating new businesses. Further, the establishment of connections between universities and the private sector to support R&D efforts and attract talent will also be supported by a single EU market.

By ensuring the evolution of an innovative drone ecosystem, the EU will ensure the embracement of a new era of innovation and digital technologies via the development of state of the art data processing companies that support growth across many core EU sectors (e.g. precision agriculture, highly automated off-shore platforms). In the longer term, commercial flight drones will likely be integrated in ATM (triggering new business models) and also evolve towards more automation, virtualisation and digitalisation thereby benefiting manned flights.

Aligning a single drone market to the EU Aviation Strategy and providing EU level support also promotes long term international collaboration. This level of collaboration will be required for unmanned aviation and also provides many near-term benefits in ensuring the market develops safely with appropriate traffic management, security and interoperable technologies.

RECAP: Key takeaways on "what needs to be done"

Stimulating economic benefits and job opportunities for Europe will require many urgent actions to address the remaining gaps in technology and regulation. The following is a summary of main findings related to what needs to be done to effectively enable the drone market:

- More robust technology and an accepted concept of operations to incorporate VLL activity is required given drones significantly **impact all areas of the airspace.**
- An entire ecosystem around both technology and regulation is required to unlock growth safely with **ATM related technologies a critical component.**
- This **ecosystem has to be created at the EU-level** to ensure a proper 'home' for drones that brings all key stakeholders together (public and private) and supports the potential growth driven by the use of drones. The SESAR JU, with the criticality of traffic management for market development, will need to play its role as one of those key stakeholders.
- To take a global leadership position, fast implementation of a comprehensive EU "drone package" is required to **establish a single drone market.**
- **EU support of innovation capabilities is essential now** for much of the activity to be completed within the window of opportunity that is limited to the next 5-10 years, else global competitiveness will be difficult to obtain.
- EU support levels for R&D need to be re-assessed to enable the safe integration of drones in all classes of airspaceNear-term advancement has **transferrable benefits** into both manned and unmanned aviation of the future.

ANNEX – DETAILS INTO DEMAND OUTLOOK AND ECONOMIC POTENTIAL

Included is a description of the modelling performed in this study. Individual sections have been detailed for how mission types will impact different sectors – Agriculture, Energy, Public Safety & Security, E-Commerce & Delivery, Mobility and Transport, and a set of other growth sectors that includes Construction & Mining, Insurance, Media & News, Real Estate, Telecommunications and University & Research. Additionally, the methods used to assess economic value across Europe are also provided.

Mission and Demand Profile – Agriculture Sector

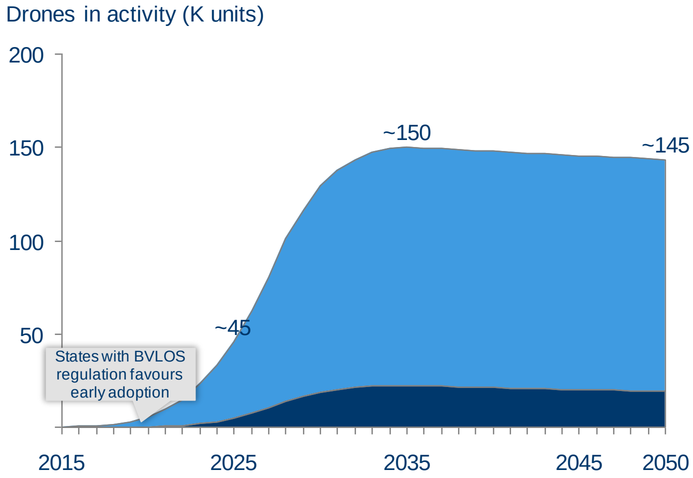
Drones are an attractive option to help European farms meet productivity demands in socially-responsible way. The EU's Common Agricultural Policy noted that world food production needs to double by 2050 and at the same time is working to institute 'greener' farming practices. Given there is not likely to be additional land available to meet these needs, higher yield influenced by precision agriculture will be essential. Drones, as part of overall autonomous robotics, play an essential role by providing new forms of rich, frequent data.

The use of drones for precision agriculture creates two primary mission types: 1) long range surveying (performed mostly by fixed wing drones) to execute remote sensing at an altitude of about 150 metres and 2) long range light payload drones to do precise spraying of chemicals at altitudes below 50 metres, as already performed over more than 20 years in markets such as Japan.

In summary, an estimated 150 000 drones by 2035 and 145 000 by 2050 are to be used across Europe's farms. In general, all of these units will fall into the 'specific' category under the EASA framework given are light in weight and fall into the set of drones flying near or below 150 metres, yet fly beyond visual line of sight often times. A view of this demand outlook over time is included in the Exhibit below.

Figure 16: Summary of demand outlook in agriculture

Demand evolution (fleet size) through 2050



Drones in activity (K units)

	2025	2035	2050
BVLOS Remote sensing	~40	~130	~125
Light load 'Spraying'	~5	~20	~20
Total	**~45**	**~150**	**~145**

Assumptions: 1. Inspection intensity: Weekly; 2. Spraying intensity: Weekly; 3. Technological readiness 2015; 4. regulatory readiness: FR: 2015; Ger, UK, Pol: 2019; 5. Adoption curve: 15 years, significant benefits but high farm fragmentation; 6; Sensing drone 62% of land; 7. Spraying drone over 62% of vineyards, vegetables & fruit land; 8. Shift from operator to ownership model starts in 2020 & lasts 15 years;
Note: Figures rounded to nearest 5K for applications above 5K units in total
Source: Eurostat; German Federal Statistical bureau; UK government statistics; INSEE; Central Statistical office of Poland; Expert interviews (Agricultural Equipment manufacturer, academics, precision farmer, drone manufacturers, drone service providers); BCG analysis

Long range surveying, described in this study as "remote sensing" is applicable to nearly all types of farms – including livestock and even fisheries – by using sensors to detect characteristics such as crop health or to count and profile livestock in different areas. This broad applicability drives the most significant portion of potential drone demand, although the relevance of these capabilities will be impacted by how large a farm is and, in relation, the general willingness to acquire services.

Industry estimates for today suggest farms are willing to spend at least 10 euro per hectare (Ha) to acquire information about their land and, at times, requiring this service a few times annually. Over time this willingness to pay is likely to see any price pressures, at minimum, offset by a greater frequency of flights as more data is collected and drone operators can build complex algorithms to further inform a farm's decisions. Given the combination of current willingness to pay and the expectation for needing higher levels of analytic capabilities and data processing, this industry is expected to develop as a service contracted model, except for large farms (i.e., those well over 100 Ha) where owning a commercial grade drone that today exceeds EUR 20 000 could make sense for better control of when drone flights are needed.

Overall, the outlook is for a general majority, approximately 65%, of the land to be drone operated after accounting for the fact that approximately 95% of farms that collectively represent around 40% of land are under relatively small (i.e., under 50 Ha and therefore have an estimated willingness to pay of under EUR 1 000 annually). Given there are nearly 175 million Ha in Europe[41], this would result in over 110 million Ha where drones are forecasted to operate.

[41] Eurostat: agricultural census 2010

Approximately 75 000 farms are anticipated to own their own or lease drone outright – representing 20% of the farms above 100 Ha and 5% of those between 50Ha and 100Ha. These farms are still likely to leverage the data processing capabilities of service operators that are expected to manage the remainder of the drone fleet. A summary of these views are summarized in the exhibit below.

Figure 17: Details into coverage of European farmland

~12M farms with ~60% of land in those >50 Ha	Farms (M)	Land (M Ha)[1]	WTP per farm[2]	Relevance of contracted service	Relevance of full ownership model
Micro (<10 Ha)	9.8 *(80% of total)*	27 *(15% of total)*	~EUR 150 annually	Very Low *~10% assumed*	Very Low *Not assumed*
Small (10-50 Ha)	1.7 *(14% of total)*	39 *(23% of total)*	~EUR 1 000 annually	Low *~25% assumed*	Very Low *Not assumed*
Medium (50-100 Ha)	0.4 *(3% of total)*	30 *(17% of total)*	~EUR 2 000 annually	Medium High *~75% assumed*	Very Low *<5% assumed*
Large (>100 Ha)	0.3 *(3% of total)*	78 *(45% of total)*	~EUR 3 000+ annually	High *>95% assumed*	Low *~20% assumed*
Total land	12.2	175		60-70% of land covered	Mostly by service model (with 50-100K farm owned)

1. Based on number of farms and midpoint of individual farm size categories – micro includes <2, 2-5 and 5-10 Ha categories and small 10-20, 20-30 and 30-50 Ha categories; 2. Willingness to pay based on industry estimates of farms paying current operators 10-15€ per Ha per flight and interested in a 2-3 flights annually (expect price decreases over time to be offset by higher intensity needs)
Source: Company and press search, expert interviews with equipment producers and users in Agriculture, Eurostat, BCG analysis

To service the remainder of the land, approximately 50 000 drones are expected to be needed bringing the total of remote sensing at 125 000. This remainder would allow any of the land to be serviced within a week (especially to account for peak demands on harvesting, fertilizing, weather impact assessments, etc.) by service operators operating drones for a few hours a day and after factoring in utilization and spare parts.

Other uses include more precise spraying and seeding activities using light payload drones. However, spraying activities of today require moving significant weight – measured in the tons – and as a result our expectation is for light payload drones, mostly multicopters, to be used for just high value crops such as wine, fruit and vegetables that are naturally part of smaller farms on average. On the whole there are 12 million Ha across Europe related to these crops and after providing for a similar service level need (weekly), there is the potential for 25 000 drones in the future. Reaching this market potential requires beyond visual line of sight regulation (both in order to execute the flight and also for a service contractor to have favourable enough economics to earn a profit). France is a market that has already started as a result of allowances past visual line of sight. Given the relatively low risk of flying in rural environments and limited social concern, the market could start across most of Europe in the next few years. Additional regulation will be needed for spraying missions as today's European environment prevents aerial application of spraying.

Overall, the evolving benefits of leveraging data for precision agriculture from drones and the degree of fragmentation in Europe lead to expectations of a "medium" speed maturity cycle of 15 years that will be slower than very rapid technologies as fast as 6 or 8 years but not as slow as cycles with heaver competition and more limited benefits that last up to 25 years.

These estimates are subject to a few key sensitivities beyond regulation that are important to understand in considering scenarios. Firstly, the coverage intensity or service level required impacts the inventory of service providers and also the relevance of owning or leasing the drone by the farm itself. The value generated by the data may also drive different levels of land coverage for different size farms in both remote sensing and spraying. If, for example, the service level was increased from weekly to bi-weekly and the value drives the land coverage up to 75% from 65% with more larger farms possessing their own drone the outlook would increase to in excess of 300 000 units for Europe alone. If the value of data does not greatly expand, as expected, and a service orientated model is used across more farms then drones could be closer to 50 000 in total.

Mission and Demand Profile – Energy Sector

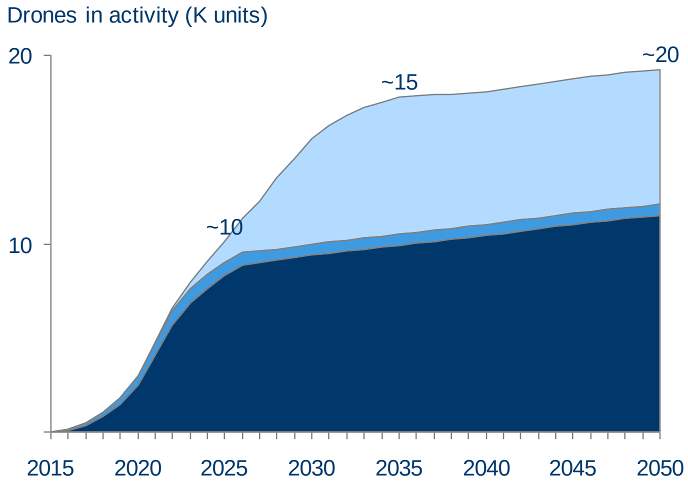
In the energy sector, drones are expected to improve maintenance and be used for inspections, which are segmented into two primary mission types: 1) local site inspections, performed by multicopters operating today in visual line of sight (VLOS) and below 150 metres altitude and 2) long range utility inspections for which the fleet is expected to be composed of BVLOS fixed wing drones flying near 150 metres of altitude with potentially, some certified drones operating at higher altitude (likely between 300 metres and 3000 metres).

Beyond inspections, up to 20 000 certified, tethered drones flying up near 500 metres altitude could emerge in European skies by 2035 in order to convert high altitude winds into renewable, "green" electricity.

In summary, the outlook (summarized in the below exhibit) calls for 30 000 drones by 2035 and 35 000 drones by 2050. Most of inspection drones will fall into the 'specific' category under the EASA framework, whereas the electricity production drones may be considered as 'certified' given they will exceed 150 metres in altitude.

Figure 18: Summary of demand outlook in energy

Demand evolution (fleet size) through 2050



Drones in activity (K units)

	2025	2035	2050
Tethered wind E production	~2	~5	~5
Long range Inspection	~1	~1	~1
Stationary inspection	~8	~10	~12
Total	**~10**	**~15**	**~20**

Assumptions: 1. 1 drone per facility; 2. Linear corridors: 2 inspections per year; 3. Regulatory readiness: FR: 2015; Ger, UK, Pol: 2019; 5. Adoption curve: facilities: 10 years; 6. Drones operated by inspection contractors; 7. 30% of additional wind energy production capacity by drones; 9. Drone useful life: 3 years for inspection; 10 years for wind energy production ; 11. Drone unit price follows 85% cost curve
Source: Eurostat; EU Energy production forecasts; OSPAR Offshore Installations Inventory 2015; Verivox; Eurelectric; National Grid; RTE France; PSE Poland; German Federal Statistical bureau; UK government statistics; INSEE; Central Statistical office of Poland; Expert interviews (Oil & Gas companies, inspection contractors, drone start-ups); BCG analysis

An early adopter for local site inspections is the oil & gas industry which has already started using drones on offshore facilities. Drones offer the possibility to inspect hard to access locations on platforms as well as at other production plants (e.g., flare stacks, cooling towers) without putting personnel at risk. Today, teams of specialised crew are climbing temporary structures to perform asset inspections which at times require a (partial) shutdown of the facility with extremely high opportunity costs. The detailed imagery collected by a drone can be used to better assess and forecast the asset's maintenance needs. This will reduce the risk of breakdowns and minimize production downtime, therefore improving the industry's competiveness. Additionally improved maintenance limits related environmental impact and reduces hazards for personnel. Industry players expect that drone inspections will co-exist with traditional inspection methods, where humans perform more complicated tasks, e.g. non-destructive testing. Yet, the safety, environmental and financial benefits accompanying drones usage justify a wide adoption within the industry, especially, seen the significant improvements in the drone technology, e.g. dynamic crack monitoring. The extremely agile inspection drones, equipped by high end cameras and sensors, will be able to access unreachable places (flare stacks, inside tanks, etc).

Although today's drone inspection campaigns are mostly carried out by specialized subcontractors, over time drones inspections could be carried out remotely resulting in the availability of 1 drone per site. This would permit high responsiveness to unforeseen events (e.g., storms, accidents). Upon adoption of drones by other energy players, we believe that by 2035 around 10 000 sites (power plants, dams, wind parks, solar farms, offshore platforms, refineries, etc.) will have dedicated inspection drones. See the exhibit below for details on this estimate.

Figure 19: Details into estimated sites for industrial inspections

Energy source	Production	Estimated sites	Drone coverage & needs
Hydraulic	**370 TWh** *(forecasted to be 410K by 2035)*	**~750** *(~800 in 2035)*	**1 per site** *1 full week of service required; new uses likely to drive need for 1 per site in future*
Wind	**265 TWh** *(forecasted to be 855M by 2035)*	**~1 300** *(~4 300 in 2035)*	**1 per site** *Turbines inspected bi-annually; drones would consistently inspect set of turbines*
Solar	**95 TWh** *(forecasted to be 250M by 2035)*	**~300** *(~700 in 2035)*	**1 per site** *Range of drones makes routine inspection possible without need for multiple drones*
Other power plants	**2690 TWh** *(forecasted to be 2 290K by 2035)*	**~3 200** *(~2 500 in 2035)*	**1 per site** *Few annual inspections required; new uses likely to drive need for 1 per site in future*
Oil, gas & other (Offshore, vessels refineries, etc)	**N.A.**	**~1 500** *(~1 500 in 2035)*	**1 per site** *Few annual inspections required; new uses likely to drive need for 1 per site in future*
		~7K (~10K in 2035) **facilities for short range service**	**Contracted model whereby ~10K drones supplied to individual sites over time given remote locations**

Source: Eurostat; EU Energy production forecasts; OSPAR Offshore Installations Inventory 2015; Verivox; Eurelectric; National Grid; RTE France; PSE Poland; German Federal Statistical bureau; UK government statistics; INSEE; Central Statistical office of Poland; Expert interviews (Oil & Gas companies, inspection contractors, drone start-ups); BCG analysis

As drones have been used in the oil and gas sector for several years, other energy companies, also dedicating significant budgets to inspection and maintenance, will soon be convinced by the financial and safety benefits drones are bringing. Since the drones will be operated within specific facilities, social concerns will remain limited. Hence, the outlook calls for the use of drones reach full penetration across the energy sector within a decade.

Additionally, utility lines (transmission and distribution grids, pipelines) are currently inspected once every 3 to 18 months. Inspections today are carried out either by manned flights, or by on-the-ground teams driving along the lines. The use of drones could drastically reduce the inspection costs while increasing the monitoring intensity and quality once beyond visual line of sight capabilities are more mature. Current technology enables the detection of minor gas leaks or can map out temperature differences along the infrastructure. These drones could be composed of small fixed wing drones operating near 150 metres altitude with some remaining personnel support or, if cost-effective enough, be done at higher altitudes (well above 300 metres) where drones would have significantly longer range per flight.

Just under 1 000 drones would be needed if using a fully low altitude operating model supported by a limited personnel force (limited range would require team to retrieve and re-launch the drone) to support the near 8 million km of above ground lines[42]. This set of drones would allow for the entire network to be monitored more often (3 times a year versus up to once every 18 months) assuming

[42] Based on data made available by EU transport in figures, statistical pocketbook 2015; VERIVOX; Bundesministerium für Wirtschaft und Energie; Eurelectric, Power distribution in Europe, Facts & Figures; National Grid; RTE (Réseau de transport d'électricité - France); PSE S.A. (Polish Government Plenipotentiary for Strategic Energy Infrastructure) and BCG proprietary data

the drone covers 250 km per day during 200 days of good weather conditions. Based on collected data, network operators could send task forces to identified hotspots to perform more detailed inspections (supported by multicopter drones) or to undertake required reparations.

Similarly to the expected pace of adoption for local site inspections, a rapid adoption curve of within 10 years is expected once the technology is robust enough to yield the cost savings, especially given limited social resistance for flying over "no mans' lands".

A third type of drone demand is related to producing wind energy. In its shift towards a greener economy, the EU has issued targets to increase the share of renewables in the energy mix. Wind energy is a critical component of the new energy mix, where predictions are that the yearly production of wind generated electricity will raise from ~260 terawatt-hours ("TWh") in 2015 to ~850TWh in 2015 and >1 000TWh in 2050[43]. To reach this capacity, knowing that Europeans pay more for their electricity than in other regions, there will be push to develop cost effective production methods. Tethered drones, producing electricity by capturing steadier and stronger high altitude wind force, could contribute significantly to meet the EU's targets as prototypes suggest their installation is less expensive than a turbine that traditionally has cost over EUR 5 million per unit and their overall operating costs are also more efficient. If this more efficient form of producing Europe's renewable is able to capture 10% of the additional capacity needed we could see the emergence of approximately 5 000 tethered drones flying at 450 metres altitude by 2035.

These estimates are subject to a few key sensitivities that are important to understand in considering scenarios. Firstly, for localized infrastructure inspections, there could be significantly less than 10 000 units if drones are not dedicated to a specific site but operated by service providers, who would serve several sites with the same equipment. Secondly, the emergence of long range inspection drones will be prevented as long as BVLOS regulation is not in place. Lastly, the penetration rate of tethered drones still is reliant on successful initial installations.

Mission and Demand Profile – Public Safety & Security Sector

Civil missions for a variety of task forces are an opportunity for drones to meet existing unmet needs. The dual use of defence systems for national state and regional security is a leading discussion topic for drones. This security includes making it easier, more effective to conduct border security and maritime surveillance and extends into providing the capability to prevent and add disaster relief (e.g., forest fires, floods, earthquakes) with aerial views and monitoring. Drones also have the potential at low altitudes to assist first response teams, primarily fire and police, in identifying civilians, gathering evidence, tracking fugitives and assessing other safety hazards more immediately, as today's helicopters for such purposes as both limited in quantity and expensive in operation. As an added benefit for local communities, these drones could also offer potential to conduct bridge inspections among other local needs as resources are available. These needs create three general mission types: 1) stationary surveying by multicopter drones that are operated by on-

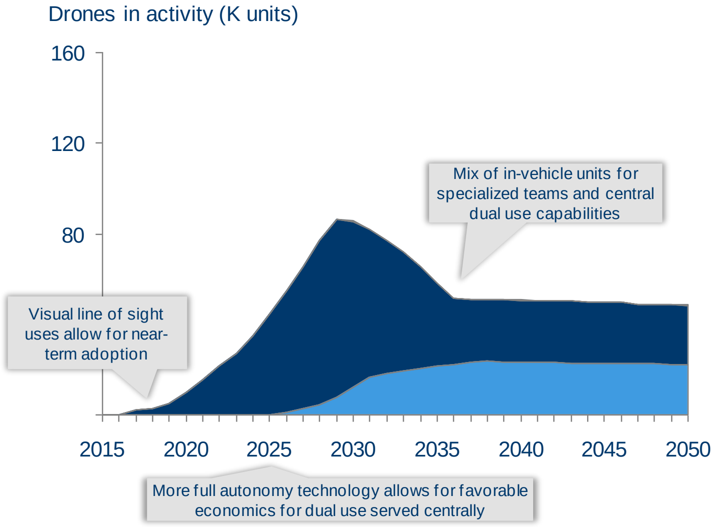
[43] EU Energy, transport and GH Emissions Trends to 2050, reference Scenario 2013

site forces that carry a drone in their vehicle 2) long range surveying by future versions of the technology that operate more beyond visual line of sight and are operated more centrally at altitudes near or below 150 metres and finally 3) higher altitude (i.e., above 150 metres) surveying drones to screen large areas as part of border security, maritime surveillance and environmental protection.

In summary, the outlook is for nearly 60 000 drones by 2035 and 50 000 drones by 2050 with the decrease coming from the ability to leverage more complex systems centrally in replacing larger sets of drones carried "in-vehicle". Most of these units are estimated to be classified under the 'specific' category of the EASA framework given these first response drones are light in weight and expected to operate near or below 150 metres, yet fly beyond visual line of sight. The higher altitude surveying drones are likely to fall under the ‘certified’ category, especially given most of the technology is a transfer opportunity out of aerospace & defence. The evolution of this demand is summarized in the following exhibit.

Figure 20: Summary of demand outlook in public safety & security

Demand evolution (fleet size) through 2050



Drones in activity (K units)

	2025	2035	2050
High altitude surveying	<1	<1	<1
Stationary in-vehicle units	~44	~37	~27
Long range central service	~0	~22	~22
Total	**~45**	**~60**	**~50**

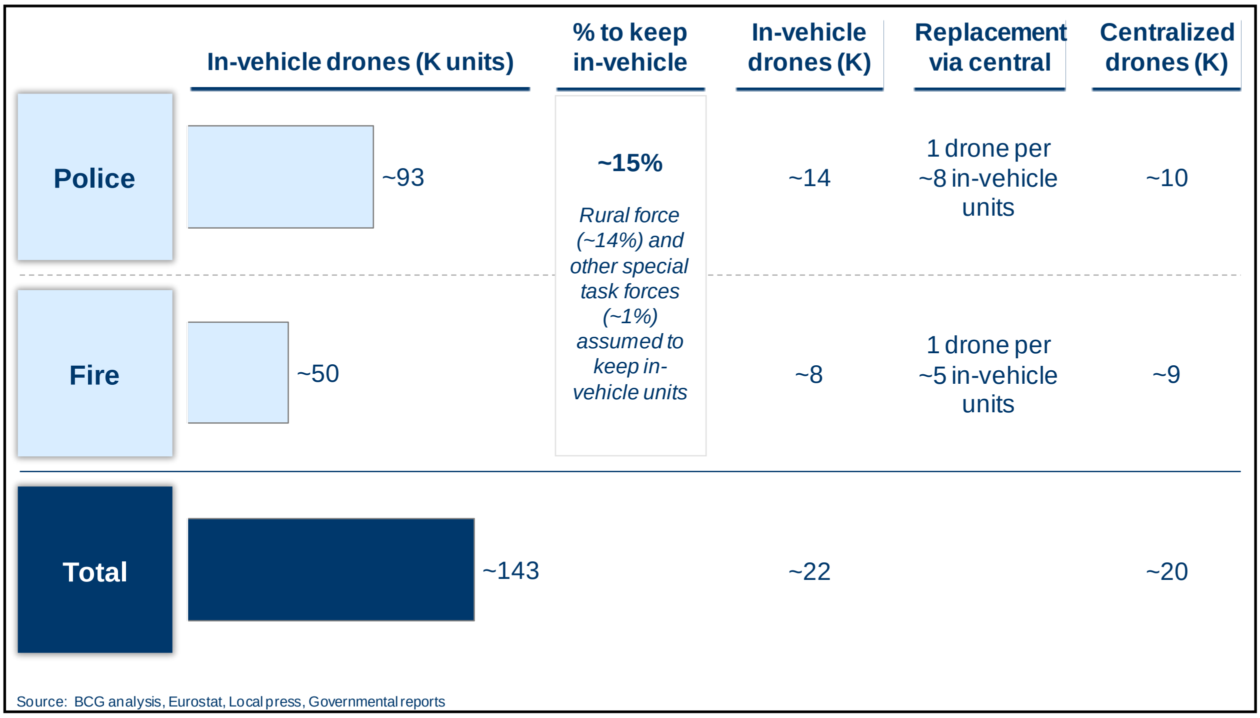
Source: BCG analysis, Expert interviews, Eurostat, Local newspapers, CIA fact book, CTIF, Local police and firefighting statistics

First responders will likely use drones as pooled resourced to take away in-vehicle on missions in a similar way as the actual vehicles are being pooled today for officers of a particular station. In order to supply an estimated force of over 400 000 police and 100 000 fire vehicles in the EU[44], nearly 150 000 pooled drones will be potentially needed (equating to 1 drone for every 4 police vehicles and 1 for every 2 fire vehicles). However, as technology and regulation improve, the apparition of station-based drones that operate more centrally and able to fly toward officers on-demand may replace the need for drones carried in-vehicle. The use of these drones operating at higher utilisations

[44] Based on numbers of police vehicles in UK, Germany, Poland and France, scaled up by number of police officers (as provided by Eurostat)

means that as in-vehicle units become obsolete that the total fleet supporting first response teams will decrease (estimate a centralized drone may be able to replace upwards of 8 police in-vehicle units or 5 fire in-vehicle units). In-vehicle units are likely to remain the primary type of drone in rural areas (where longer range needs will impact service levels and feasibility) and for specialized intervention squads that together represent near 15% of vehicles[45]. Together, a total of nearly 20 000 units would be needed of both centralized station drones and in-vehicle units in 2050. These details are summarized in the following exhibit.

Figure 21: Details into number of pooled units for first responders



Police and fire will not be the only forces to use these drones in the public sector (e.g., prison guards). These additive forces represent around 15% of government budget spending across most European countries, driving up the total estimates for these low altitude drones to nearly 50 000 in 2050[46].

The opportunity to secure borders, perform maritime surveillance, and increase environmental protection will drive additional units, estimated to be under 1 000 in total (specific estimate is close to 100 systems). This estimate provides the capabilities to consistently cover the close to 115 000 km of EU borders[47] – including flying higher risk controlled borders daily, monitoring the coastlines every 2 days and having added capacity to also survey the Schengen borders every 5 days or to respond to

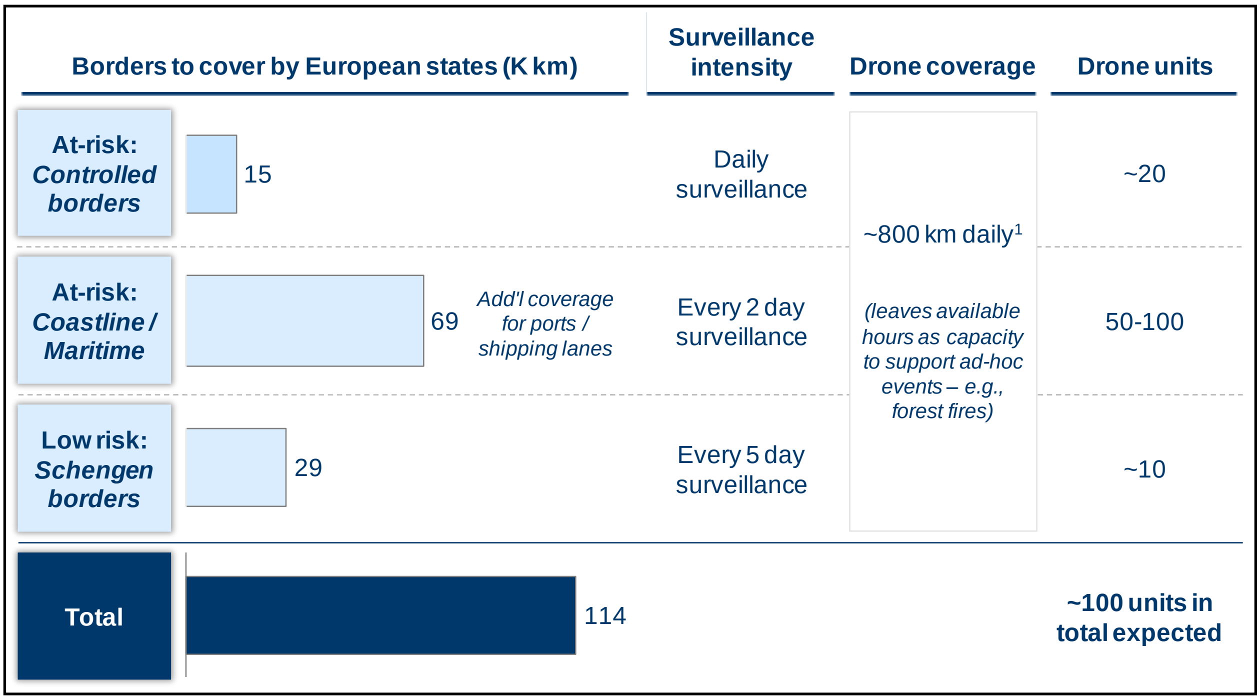
[45] Based on Eurostat and INSEE data on the proportion of rural areas in France and on data on special forces units provided by FIPN

[46] Based on budget spending in public safety as a whole excl. justice vs. budget allowed for police and firefighting (data provided by Eurostat)

[47] Based on the CIA world fact book

environmental situations (including disaster relief and deforestation assessments). This estimate is detailed in the exhibit below.

Figure 22: Details into demand of long endurance drones used for border security and maritime surveillance



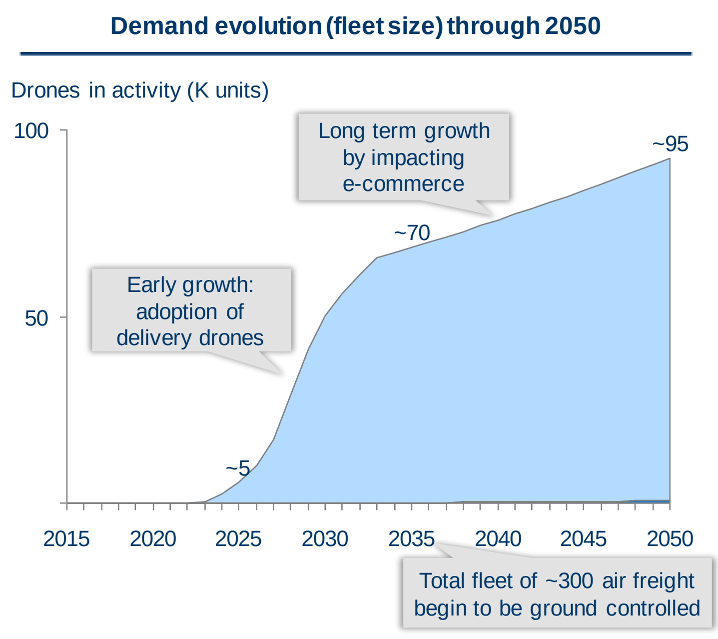
The in-vehicle first responder market is already starting to grow with some stations experimenting with the use of pooled drones and demanding certification training. In order for the market to further take off, public acceptance and regulation regarding VLOS flights in populated areas will have to evolve. Another limiting factor in the coming year will be around the procurement decisions at all levels (regional, national and local) that will exist between buying drones versus other pieces of equipment such as vehicles that are increasing in average age. For these reasons, adoption is expected to occur over a longer cycle (approximately 20 year adoption S-curve). Additionally, in order for centrally operated drones to become viable alternatives to drones carried in-vehicle, further progress is necessary in automatic flight capabilities (including but not limited to sense and avoid, improved energy sources for longer durations) and related regulation in operating these BVLOS. If these developments occur, their ability to improve efficiency by replacing less utilized assets carried in-vehicle will likely increase the rate of adoption. Lastly, the more centralized procurement decisions for higher altitude surveying and the current security climate have the potential to make the transfer of defence technologies for civil missions occur rapidly (i.e., within 10 years).

Uncertainly regarding these regulatory and technology advances creates a set of scenarios around the demand outlook in public safety & security. High constraints around operating BVLOS automatic flights over crowded areas and distributed decision making could make in-vehicle drones the primary type of unit and potentially increase the total outlook to in excess of 200 000 units plus 20 000 station drones only used for specialized services such as bridge inspections that avoid densely populated areas. Alternatively, if regulation for VLOS drones by task forces in populated settings is constrained past 2020 and centralized BVLOS drones render drones carried in-vehicle mostly obsolete then the number of units could be closer to 25 000 in total. Scenarios for higher altitude surveying around intensity of coverage and distributed department purchases may drive the total units closer 1 000 versus the current projections near 100.

Mission and Demand Profile – E-Commerce & Delivery Sector

Drones able to avoid today's growing traffic are expected to offer opportunities for faster, more customised delivery and increase access of communities to the retail outlets near them. These opportunities are expected to be considered value-adding services (e.g., emergency medical supplies, rush order official documents) that both consumers and businesses are willing to pay a premium for. In summary, the outlook is for 70 000 drones to deliver some 200 million light weight parcels across Europe in 2035. Additionally, larger freight aircraft that currently represent a fleet size of less than 1000 may also become unmanned by 2050. This evolution is depicted in the exhibit below.

Figure 23: Summary of demand outlook in e-commerce & delivery



Drones in activity (K units)

	2025	2035	2050
Parcel delivery	~5	~70	~90
Air freight	--	<1	<1
Total	**~5**	**~70**	**~95**

Assumptions: A. Delivery: 1. 10% of packages are same day deliveries; 2. 60% of packages <2.5kg; 3. utilisation rate: 75%; 4. overcapacity: 125%; 5. Regulatory readiness: 2023; 6. Penetration: Rural: 8%, Suburban: 27%; Urban: 18%; 7. Adoption curve: 10 years; B. Cargo: 1. Regulatory & technological readiness: 2031; 2. Adoption curve: 20 years
Source: BIEK; Barclays; ARCEP; EU Commission; Amazon; Ecommerce-Europe; Eurostat; German Federal Statistical bureau; UK government statistics; INSEE; Central Statistical office of Poland; Expert interviews; Boeing; Airbus; (E-retailers, post & parcel industry specialists; Airplane manufacturers; Drone manufacturers); BCG analysis

Today, over approximately 7 billion packages are delivered annually in Europe[48]. While e-commerce retail represents a significant portion of this demand, online channels still only account for a fraction of total retail. Drones may further boost e-commerce by making it more convenient to access a

[48] BIEK (Bundesverband Paket & Express) : KEP - Studie 2015-Analyse des Marktes in Deutschland

greater variety of local retailers and providing end customers more flexible, efficient options for purchasing goods such as pharmaceuticals, food & groceries, clothing, electronics and do-it-yourself (DIY) items.

A closer view at the economics of delivery in determining the feasibility of using drones for such deliveries indicates that drones are likely relevant in providing premium, same day services which are value adding. A drone operating at full capacity could be able to complete 5 000-9 000 deliveries and at a price point equivalent to today's average premium delivery of EUR 10 would be profitable if able to operate under EUR 50 000-90 000 annually[49]. This break-even point appears realistic as long as a single pilot is allowed to operate many drones simultaneously. Drones are not expected to be viable for standard parcel deliveries, as current last mile economics only provide EUR 10 000 annual cost base for a single drone. Additionally, other express services across longer distances (e.g., between European states or distant cities) also have less favourable economics given the high processing costs related to multiple exchange points. Finally, it may be feasible for retailers with substantial scale to replace the "delivery middleman" by a drone fleet, although this likely applies to a limited number of retailers. These retailers may also be able to leverage drones for products with significant enough margins (e.g., pharmaceuticals) where offering this convenient, efficient delivery capability increases unit sales enough to offset any per unit margin losses. The estimated feasibility of these types of deliveries is below with premium, same day deliveries serving as the basis for the outlook with the potential for standard retailers captured as part of the study's upside scenarios.

Figure 24: Feasibility assessment for delivery via drones

	Premium: Same day, close proximity	**Premium: Next day & regional transport**	**Standard: delivery by traditional player**	**Standard: delivery by originator / retailer**
Cost base per parcel	**~EUR 10[1]** *Average price paid for premium delivery that a drone player could capture*	**~ EUR 4** *High processing costs with multiple exchange points reduces value a drone could capture*	**~EUR 1.50[2]** *Variable 'last mile' costs that a traditional player could replace with drones*	**~EUR 4[2]** *Average cost of delivery EUR 3.50 before margin a retailer would pay for*
Drone capacity (annual)	**5 000 to 9 000 parcels annually** *Daily operations for 12 hours a day and an ability for a drone to deliver in 30 mins. roundtrip* *Lower end of 5 000 factors in utilization of ~60%*			
Maximum drone operations cost & feasibility	**EUR 50-90K** **Medium feasibility** *Requires more robust technology and a ratio of many drones to 1 operator* Base demand	**EUR 20-35K** **Low feasibility** *Requires significant scale to avoid eroding margins in express deliveries* Additional upside	**EUR 7.5-13.5K** **Very low feasibility** *Commercial grade drones and operations need to be commoditized heavily*	**EUR 20-35K** **Low feasibility** *Only retailers at very high scale likely to benefit enough to develop own operations* Additional upside

1. Based on German market indicating ~EUR 13 per premium package and consumer assessment of Amazon delivery costs at ~EUR 8 per package; 2. Based on Western European industry best practices per BCG experience
Source: Company and press search, expert interviews in post & parcel, BCG analysis

[49] European Commision: Digital Single Market & BIEK (Bundesverband Paket & Express Logistik): KEP-Studie 2015 - Analyse des Marktes in Deutschland

Today, around 10% of the nearly 7 billion annual EU packages appear to be same day premium deliveries applicable drone capabilities[50]. Most of these packages, approximately 60% are less than 2.5 kg, are also light enough for expected drone delivery[51]. The penetration of drones into this addressable market is impacted by whether the delivery takes place in more rural or urban settings. Multiple factors drive differences between these environments, including:

- Destination accessibility: Ease of a drone landing and delivering a package. Expected to be greatest in rural settings and more limited, but increasing over time, in urban areas.
- Proximity to sender: Range within acceptable means for a drone (i.e., long hour or greater deliveries not likely to have favourable economics). Rural areas are most impacted.
- Impact of alternatives: Share earned by drones compared to alternatives such as bikes in urban areas. The continued use of vehicles for standard deliveries makes them a consistent alternative, especially in rural areas where lead times are likely to be longer and traffic conditions are less of an issue. The highest impact is expected in suburban areas where bikes are difficult to leverage and proximity between retail outlets is lower than in cities but better than in rural areas.

Overall, about 15-20% of premium lightweight packages are considered for potential drone services based on the split of European's population between these rural, suburban and urban environments[52]. As a result, approximately 15 000 drones would potentially be demanded to serve today's volume of deliveries (see exhibit below).

Figure 25: Details in demand needs for current European parcel volumes

	Yearly packages	Premium[1]	% Small[2]	Penetration[3]	Eligible packages	# Drones
UK	~1 000 M	Assumed 10%	60%	~20%	12 M	~2 K
Poland	~100 M		Assumed 60%	~15-20%	1 M	<1 K
France	~900 M			~15-20%	10 M	~2 K
Germany	~3 000 M	~10%		~20%	35 M	~6 K
Other countries	~2 200 M	Assumed ~10%		~20%	27 M	~5 K
	~7 200 M				**~85 M**	**~ 15K**

1. 10% of packages are same day deliveries; 2. 60% of UK parcels fit a shoebox size, assumed to weigh 2.5kg; 3. Function of urbanisation rate
Source: Barclays, Amazon; BIEK (German Parcel delivery association); Eurostat; ARCEP; German Federal Statistical bureau; UK government statistics; INSEE; Central Statistical office of Poland; Expert interviews (Oil & Gas companies, inspection contractors, drone start-ups); BCG analysis

[50] BIEK (Bundesverband Paket & Express) : KEP - Studie 2015-Analyse des Marktes in Deutschland

[51] Barclays: The last Mile, Exploring the online purchasing and delivery journey, 2014

[52] Based on Eurostat's Urban-rural typology update 2010; German 2012 statistical yearbook:, families, living arrangements; INSEE, le nouveau zonage en aires urbaines de 2010, UK office for national statistics, 2011 Census analysis

The need for drones is expected to increase from 15 000 to 70 000 by 2035 as result of both the impact of drones on e-commerce and also capacity needs to handle peak demand and periods of high utilisation. The impact of drones on goods such as pharmaceuticals, food, electronics, do-it-yourself items and clothing will almost certainly increase the volume of parcels to be sent. Growth in value added services is currently expected to lag the overall industry (4% growth versus standard delivery of nearly 6%)[53], however drones have the potential to ensure these services grow at least on the same order of magnitude and growing estimated deliveries in Europe from 85 million to near 200 million by 2035. Utilisation of drones will also vary throughout the year (e.g., high demand during holidays like Christmas) and excess capacity will be necessary to avoid too high of utilisation rates. The impact of these will continue out to 2050, with demand further increasing from 70 000 units to close to 100 000 units.

In addition to low altitude drones, Europe has over 300 freight aircrafts, a number expected to grow to near 500 units by 2050, where ground-controlled operations are likely to be more efficient than today's pilots[54]. Following the emergence of automated vehicles in the 2020's, it is anticipated that the first remotely piloted air freighters could potentially appear. This movement, estimated for around 2035, would result in a total conversion of these approximately 500 aircrafts by 2050 even with maturity cycle of 15 years.

A key enabler for all of this growth to happen is the regulations for BVLOS operations and separately for these operations in densely populated areas. The pace of technology is likely to bring viable solutions that can be tested and validated by authorities in the coming years. Potential demand in the outlook forecasts this technology to be ready, social accepted and permitted under regulation to allow for commercial drone deliveries in Europe between 2020 and 2025. Additionally, the economics impacting feasibility of drones are rooted in the assumption that other forms of technologies and processes do not significantly alter pricing and costs.

The timing of regulation and readiness of the technology, which will need to achieve high safety standards given proximity to populated areas, are part of a number of key sensitivities around this emerging mission type and value proposition. Scenarios around growth within this domain are considered for regulation and technology being ready as early as 2020 or as late as 2030. Further, the impact of large retailers on the total volumes for drone deliveries is included in a more aggressive case. Finally, penetration of the addressable premium deliveries is also a critical assumption for consideration that could further boost the number of parcels for delivery. Overall, the delivery domain shows the potential to become the leading domain in terms of number of drones, with more aggressive cases surpassing the expectations in agriculture for 150 000 drones. Conversely, more conservative estimates drive an estimate of around 55 000 in 2050. Air freight scenarios are not likely to dramatically increase the total above 500 although the potential use of such unmanned aircraft still may not come to fruition at all depending on societal acceptance and the readiness of the technology to be as safe as today's piloted aircrafts.

[53] BIEK (Bundesverband Paket & Express) : KEP - Studie 2015-Analyse des Marktes in Deutschland; Barclays: The last Mile, Exploring the online purchasing and delivery journey, 2014; ARCEP: observatoire des activités postales, 2014

[54] Airbus Global Market Forecast 2015-2034; Boeing, World Air Cargo Forecast 2014-2015

Mission and Demand Profile – Mobility Sector

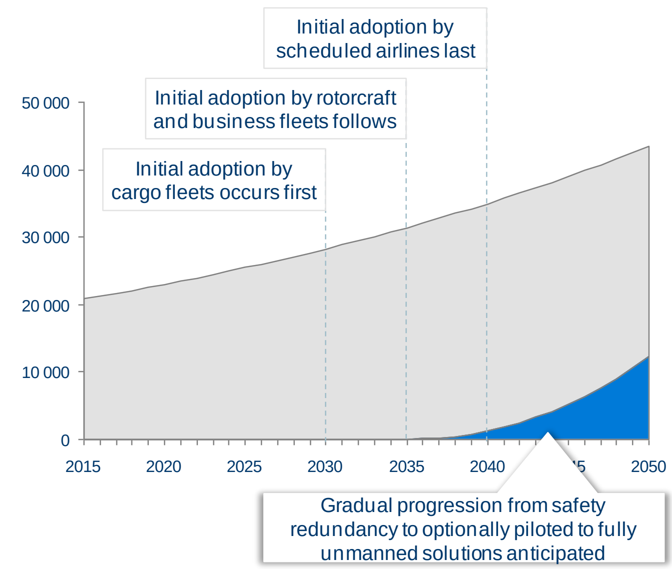
One of the critical questions for future of Europe's skies related to drones is how ground control capabilities could impact the future aviation fleet, including scheduled airlines. Current and developing aviation technology has already brought us fairly automated commercial passenger aircraft. However, despite how most parts of today's passenger flights are auto-piloted, removing the pilot from the aircraft will require significant evolution in regulation and, more importantly, passenger acceptance.

Public acceptance for automatic flying is likely to be impacted by advancements in other sectors and technologies, notably by self-driving vehicles in combination with unmanned cargo and military aircraft. Multiple commercial announcements have already been made for both partial and fully autonomous ground vehicle capabilities over the coming years with 2025 being targeted for full autonomous vehicles. Advancements in such related technologies and the transfer opportunities of aviation technology from defence drones leads to an outlook for these capabilities to begin before 2050.

In summary, 10 000 aircraft and rotorcraft capable of being ground controlled are expected by 2050, representing around 20% of the total forecasted fleet at that time. All of these will fall into the 'certified' category under the EASA framework given their size, altitude and complexity. A summary of this projection is shown in the exhibit below.

Figure 26: Summary of demand outlook for unmanned aviation in Mobility & Transport (excluding Cargo)

Initial adoption after 2030 with cargo solutions first followed by business fleet and finally scheduled airlines



Estimates for unmanned aviation include optionally piloted fleet

	Fleet size (K) 2035	Fleet size (K) 2050	% of total 2035	% of total 2050
Manned fleet[1]	~31K	~31K	~100%	~72%
Unmanned drone fleet[2]	~0.1K	~12K	<1%	~28%

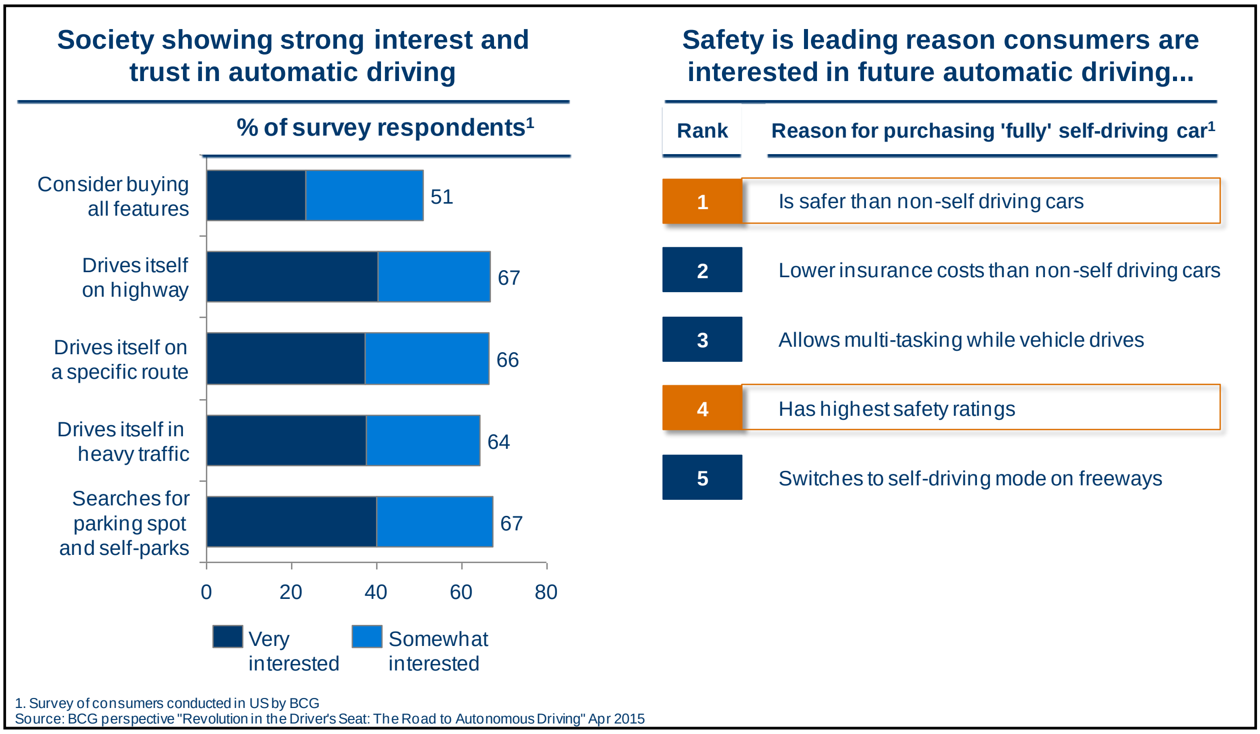
Unmanned fleet includes aircraft that are operate as optionally piloted

1. Excludes general aviation; 2050 figures based on extrapolation of 2015-2035 growth rates of scheduled airlines, business aircraft and rotorcrafts; 2. Excludes cargo aircraft estimates of <1K
Source: SESAR ATM Master Plan research, BCG analysis

This estimate is built on the forecasted number of aircraft in European skies according to SESAR's own ATM master plan projections. The expectation is for the fleet to increase from just over 20 000 units to over 30 000 by 2035 across, scheduled airlines (growth close to 2.5% annually), business airline fleets (1% growth annually in fleet size) and rotorcraft (just under 2% annual growth rate)[55]. Carrying these growth rates forward leads to a total fleet of around 45 000 by 2050 of which 30 000 are scheduled airlines, 10 000 are business aircraft and around 4 000 are rotorcraft.

Drone capabilities are anticipated to occur once self-driving capabilities have increased public acceptance. A view into the potential adoption of self-driving vehicles from a series of efforts performed by The Boston Consulting Group highlights strong momentum to generate such acceptance. Specifically, a demand study by The Boston Consulting Group indicated that over 50% of consumers have interest in acquiring a partial or fully autonomous vehicle[56]. Furthermore, safety of these vehicles was reported as the leading rationale for purchasing by those interested. The fact that safety is being linked with automatic capabilities drives the basis for inclusion in the study's outlook. Details regarding this study are included below.

Figure 27: Details into societal interest in autonomous vehicles based on recent U.S. study



Allowing for duration of 10 to 15 years between the introduction of fully autonomous vehicles in 2025 and the initial ground-controlled aviation offerings, demand of approximately 10 000 units is expected by 2050. Lengthy adoption cycles in excess of 15 years and a ceiling to the addressable portion of the market (e.g., up to two thirds of consumers indicated interest in self-driving vehicles driving an assumption that at least a third of commercial passenger planes would remain piloted

[55] SESAR ATM Masterplan: D68 – New CBA models and Methods 2015

[56] The Boston Consulting Group, "Revolution in the Driver's Seat", April 2015

even at full maturity) are factored into this estimate to account for where pilots will remain essential. Furthermore, even when allowing for these 10 000 units, the need for pilots will remain at levels above today's given the overall growth of aviation.

Additionally, drones could benefit the mobility sector through railway inspection (similar to pipeline inspection in energy). A few hundred units is estimated to be sufficient to monitor approximately 200 000 kilometres on a tri-annual basis given the long range of fixed wing drones over an extended period of time[57].

This forecast remains highly sensitive to the social perception of unmanned flights and it remains possible for airlines to not adopt the capability within the study's time horizon. Other business and private aircraft are likely to be less impacted by shifts in popular opinion, and thus conservative estimates result in the demand for 1 000 to 2 000 units. Alternatively, given the high level of competition between airlines, if social acceptance allows for earlier introduction and more rapid adoption then ground control would be possibly required for a majority of the fleet.

Mission and Demand Profile – Additional Growth Sectors

Construction & Mining

For mining & construction, drones are already being demanded for civil surveying (e.g., during excavation, backfilling and roadwork) and site management. The market potential and business case is exemplified by large data processing contracts that exceed EUR 10 000 annually for a single drone used across multiple sites given drones enable routine surveys over large areas in a more timely and cost effective manner. In the near term, mining is likely to drive significant growth with 7 000 drones expected across around 20 000 quarries and mines that are mostly small (i.e., 15 000 sites have approximately 3 employees)[58]. The number of drones in a variety of construction sites is likely to be much larger, estimated at 35 000, especially once drones can operate closer to populated areas.

The expected operating model within construction is for individual surveyor teams to be allocated a drone. 35 000 drones are expected to be needed to serve a large proportion of over 2 million estimated construction sites in Europe given each team has the ability to serve multiple sites (estimated at 8 per team) that each need support for a portion of the total duration (requirement of 3 months, acknowledging different usage intensities across sites, as part of sites that may last beyond a single year)[59].

[57] Eurostat, Length of Railway network, 2013

[58] Based on Eurostat data on mining and quarrying

[59] Based on 280 000 residential sites in UK and Germany and scaled based on residential representing 35% of construction in the UK and both countries representing 35% of all EU construction

Telecommunications

The telecom industry is beginning to benefit from the use of drones in performing routine tower inspections. Similarly to power line inspections, the benefits are both reducing personnel risk, limiting time spent driving between sites (fewer crew members would be required) and climbing towers, and lowering overall inspection costs. Approximately 3 000 drones are estimated to be needed to inspect Europe's near 450 000 towers twice a year – assuming a drone operates 200 weather permitting days, completes multiples towers a day (around 3) and after accounting for utilisation and industry fragmentation (factor of 60% leveraged)[60].

The industry may also account for high altitude drones capable of providing communication services. However, these services are better suited for developing markets outside Europe and are more likely to act as export opportunities than as means of telecom services within the EU if able to perform better than new developments in lower cost satellites. Additionally, if these services are conducted within EU, the total number of units is expected to be very small (i.e., less than 10 including redundancy).

Insurance

In the sector of insurance drones have the opportunity to increase the safety in performing claim assessments in tandem with making the process more efficient overall. Exterior damage or roof assessments often require an inspector to be in hazardous environments whereas drones can capture these images more timely and without putting an inspector in those positions. In addition, insurance companies could map the state of properties upon contract signature which could be used as reference to assess damages in case of adverse event. 3 000 to 4 000 drones are included in the outlook to assess 1.75 million annual fire and weather related claims[61]. This estimation relies on 4 daily inspections during 250 working days, at a 60% utilisation rate.

Media & Entertainment

The media and film industry are already a driving force behind the use of drones, with existing uses in sport event broadcasting, movie making and news coverage. As drones provide a cost effective alternative to helicopters for aerial views and offer new opportunities to capture unique vantage points or data in assessing weather conditions, wide adoption across the media landscape is expected. Today there are nearly 11 000 channels broadcasting across Europe[62]. Those related to sports and entertainment are expected to be the greatest users (assumed at 10 drones per station) with other generalist and regional news and programming also being relatively high users (assumed at 5 drones per station). Other channels (e.g., home shopping, cooking and foreign films) are not expected to contribute significantly to the total drones (around 1 drone per station factored into outlook). In total, approximately 30 000 drones may potentially be demanded with the vast majority

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[60] Based on press review

[61] UK estimate of fire and weather related claims from Association of British Insurers; UK proportion approximately 20% of Europe based on OECD data on insurance

[62] Based on Mavise database

being stationary imaging multicopters with exceptions for BVLOS drones that replace some helicopter based imaging.

Real Estate

Local surveying drones are also likely to be used in the area of real estate where the technology can be used to capture aerial views of for sale properties for promotional purposes. The use for promotional purposes and visualisation will be influenced by high competition between real estate agencies, as evidenced by luxury real estate companies providing clients with virtual reality tours of properties. The tasks around capturing these images are similar to how leisure drones are used and, therefore, the majority of these drones are likely to be relatively basic, affordable units. As technology becomes more robust, these same drone assets are likely to complete indoor modelling for agencies as an additional value add. Overall, these aerial images are of most value with larger, more luxurious properties. Using the case study of the French market, approximately 15% of agencies sell assets with at least 6 rooms in defining the point of emphasis for this market[63]. Across Europe there are some 100 000 real estate agencies leading to a total demand outlook of 15 000 units[64].

University & Academic Research

Drones can also be used in support of research and education, where universities, and other research centres could use drones for a variety of tasks varying from wildlife behaviour to pollution monitoring or geological studies. A mix of drones for localized surveying where researchers are present and more complex BVLOS systems that provide access to new environments, including hazardous settings (e.g., near a volcano for a geological study).

A few thousand of such drones are estimated, especially in larger universities. Overall, there are nearly a million individual staffers in the academic setting with the larger universities individually having on average around 5 000 staff[65]. At each of these relevant institutions, measured in the hundreds as a result of the staffing metrics, multiple departments are candidates to purchase drones over time. 5-10 drones are forecasted given the number of applicable areas of research such as Engineering, Manufacturing, Construction & Architecture, Sciences (e.g., Geology, Anthropology), Mathematics, Computer Sciences, Agriculture and Veterinary.

Economic Impact Assessment – Additional Details

The efficiency, cost and safety benefits brought by drones to businesses and government authorities will inevitably drive market growth, resulting in new employment opportunities and a positive impact on the EU's economy. All over the globe, start-ups and established companies are developing and providing capabilities ranging from drone development and production to drone operations and/or the development of data analytics and user platforms that act as entire area of services.

[63] Based on INSEE, Habitat 2012

[64] Based on press review

[65] Based on the staff for 5 top EU universities ranging from 2 000 to 10 000

Now, Europe, thanks to its innovative industrial tissue, has an opportunity to emerge as a core region in the drone market. The global implications of this developing market for both products and services should be used to inform priorities in research and regulation, and as a result, this study shares a view on where value exists throughout the complete value chain and where the global nature of the market is likely to have the greatest impact.

To assess the output related to the drone activity and the value associated with each of the value chain steps, an economic impact analysis is presented. This analysis has as objective to determine all drone revenues and employment opportunities that are “at stake for Europe”, since not all European spending related to the commercial use of drones will flow to the local economy. Yet, if Europe successfully manages to establish its position in the global marketplace, not only is it possible for the majority of the “value at stake” to remain in Europe, but incremental export potential may further grow the benefits of a drone market for European citizens.

The output impact analysis measures the total increase in business sales in the European Union. The study emphasises the long term potential of drones, i.e., the values in 2035 and 2050, for which all monetary figures are given in 2016 nominal euros. Beyond direct impacts throughout the value chain, many indirect benefits are also likely to be generated. To present a view of these indirect benefits the study leveraged ratios of similar industries from the OECD to provide a directional view. The OECD knowledge base was also the source of translating economic impact figures into potential job creation through an analysis of jobs per turnover at different stages of the value chain.

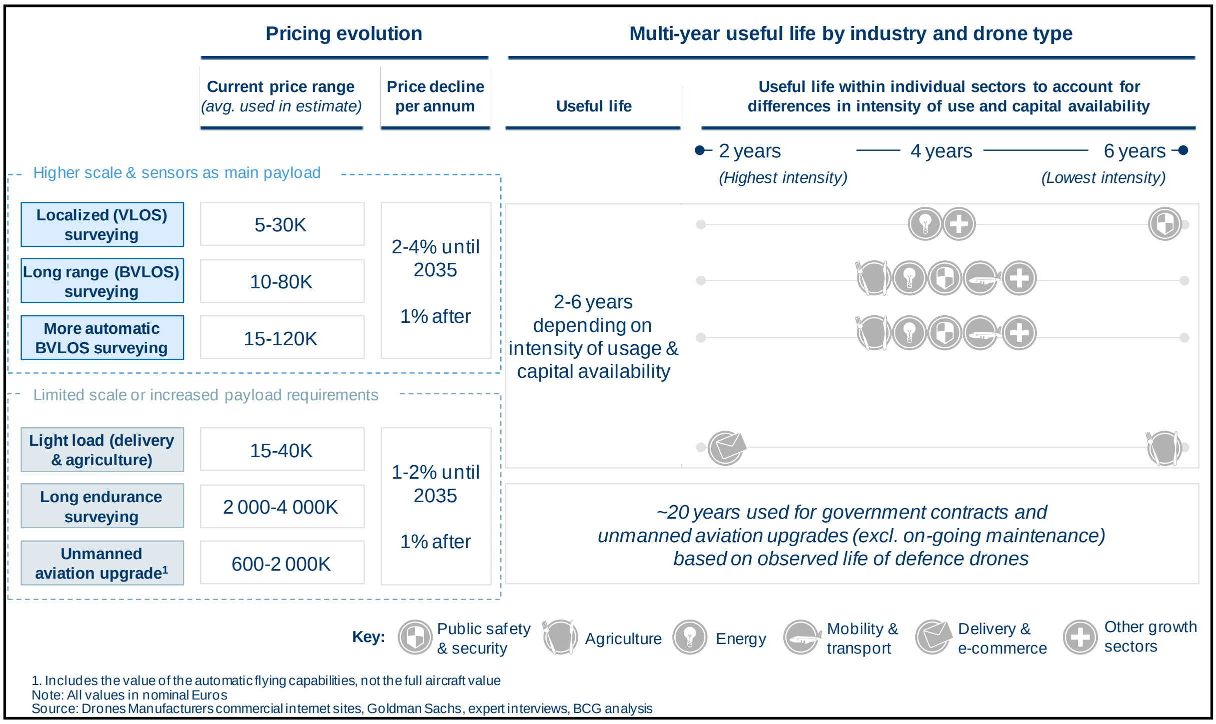
Overview of economic impact for products

Drone sales in the area of commercial and government systems is expected to grow steadily and reach EUR 2 billion by 2030. The emergence of unmanned aviation after 2030 will further drive growth towards and beyond 2050 with annual drone sales estimated to exceed EUR 2.5 billion in 2050. Additionally, a long term valuation of near EUR 0.5 billion is anticipated for leisure products on the basis of nearly a million units being sold annually at prices of a few hundred Euros. Further defence systems, procured at costs per unit that average in the millions, are expected to drive nearly EUR 1 billion in product-related value. This EUR 1 billion estimate is suggested by the ratio of the European fleet size (~750 units per the EDA) to the US fleet (~6 500 units) applied to the US annual spend of approximately EUR 1.5 billion annually and a long term annually compounded growth rate of nearly 5%. Overall, products represent a total marketplace of approximately EUR 4 billion in 2050 across all types of demand.

The largest portion of this demand in the long term, drones for commercial use and civilian government missions, is impacted by the growth in the fleet, multi-year useful lives dictating the number of units to be replaced in any one year and the prices per unit that are expected to decline (in nominal terms) over the long term as the technology matures. The growth in the fleet, as detailed in the discussed of industry-specific demands, is combined with replacement rates that differ depending on the type of drone and also by the intensity of use (a function of how the drone is leveraged and therefore the industry and ownership model inherent for each). 'Certified' drones, similarly to military drones are expected to have a useful life spanning several decades, whereas 'specific' drones will rather last for multiple years before being replaced. The useful life factored into the study's estimates for 'specific' drones generally ranges from 2 to 6 years, where a delivery drone flying for multiple hours per day is expected to have a useful life closer to 2 years and drones used for purposes such as spraying in agriculture are assumed to have longer life spans of 6 years.

The prices of commercial drones vary significantly across mission types, ranging from the low thousands to several millions euros. As technology advances and products commoditize, prices are assumed to decrease approximately by 2-4% year on year until 2035 and by 1% onwards. More complex solutions with less scale and those drones with increased payload requirements are expected to have more limited price pressure, shown as 1-2% as part of the price and useful life assumptions outlined in the figure below. It is also important to note that for unmanned aviation, the cost of the drone solution only represents incremental equipment and capabilities to manned aircraft, and therefore represents only a small fraction of the full cost of acquiring such technologies.

Figure 28: Annual production factors in declining prices and replacement rates that last multiple years



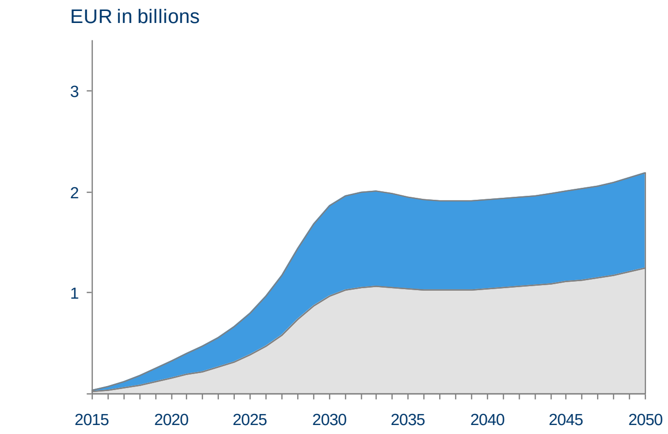
European players are expected to play a key role in developing and commercialising drone technologies compatible with future airspace management requirements, e.g. detect and avoid technology. However, since gaining a sustainable leadership position in manufacturing of less complex, smaller 'specific' drones will include a reliance on cost efficiency, it seems likely that the production value will be impacted by global trade with regions holding comparable advantages in manufacturing (including lower labour costs). In order to identify the value at stake related of the conception and commercialisation of drones on the one side and of the production on the other sides, ratios based on the cost structure of players active in aviation electronics systems, military UAVs and commercial drones are used. Details are provided in the figure below and indicate that, overall, a 50/50 split is expected with assembly and manufacturing becoming a more significant portion of the valuation towards 2050 when unmanned aviation acts as a key area for growth.

Figure 29: Proportion of manufacturing value increases over time as more complex machines are used

Design vs. manufacture breakdown assumptions

	Public company proxy[1]	Breakdown design/manuf. Des.	Man.
Localized (VLOS) surveying & monitoring Long range (BVLOS) surveying & monitoring Light load for agriculture 'spraying'	Consumer / Civil drone manufact.	~55%	~45%
Light load for delivery More automatic BVLOS surveying	Mix of consumer / civil and military	~40%	~60%
Long endurance surveying & monitoring	Military equipment	~25%	~75%
Unmanned aviation	Aviation electronics and navigation	~30%	~70%

Taking into account depreciation, both design and manufacture end over EUR 1 billion by around 2030



	2020	2025	2030	2035	2040	2045	2050
Design	0.2	0.4	0.9	0.9	0.9	0.9	0.9
Manufacture	0.2	0.4	1.0	1.0	1.0	1.1	1.3

1. Consumer/Civil based on Parrot, Military based on Lockheed Martin, Aerovironment and General Dynamics, Aviation electronics based on Rockwell Collins and Honeywell Automation and Control Solutions; 2. Calculated as average of cost of goods sold on sales in 2014 annual reports;
All values in nominal Euros;
Source: BCG analysis, Company annual reports

Overview of economic impact of piloting & operations services

In 2035, approximately 250 000 pilots are expected to support the operation the 400 000 drones' fleet. Less pilots than drones are needed due to the fact that some drone missions, e.g. delivery, are not economically viable if a single pilot does not operate several drones simultaneously. Drone to pilot ratios not only vary between missions but also evolve over time. For example, offshore facility inspections are currently carried out by a drone pilot and a camera operator, where from 2020 onwards, it may evolve towards 1 operator per inspection drone. Similarly, there is an assumption that the current requirement of a pilot flying a single drone will disappear in the mid 2020's for 'specific' drones and in the 2040's for 'certified' drones. This ratio of trained pilots per drone is summarised in the following figure, showing differences across drone types.

Figure 30: Assumption on drones per pilot ratios

Regulatory & automation evolutions[1]

- **2020**: Piloting and analyst tasks combined for surveying
- **2025**: Single pilot manages multiple Specific drones
- **2045**: Single pilot manages multiple Certified drones

Mission type[2]	2020	2035	2050
Localized (VLOS) surveying & monitoring	0.5	1	1
Long range (BVLOS) surveying & monitoring	1	3	3
Long range light load for agriculture 'spraying'	1	3	3
Long range light load for delivery	-	15	15
More automatic long range surveying	1	5	5
Long endurance surveying & monitoring	0.5	1	1
Unmanned aviation	-	1	3

1. Date indicates when regulation and technology enables improved drone to pilot ratio, implementation within industry within 8 years; 2. Slight variations across specific mission possible; 3. Professional trained as drone pilots operate a single drone

From the total of 250 000 pilots, 80% are trained end-users who in the future will pilot drones in addition to their existing task set (i.e., do not represent incremental job creation). An example is land surveyors who start using drones for surveying purposes but still perform their other tasks, e.g. mapping out positions. The remaining 50 000 pilots are new jobs directly imputable to the commercial drone industry. These pilots will spend the major part of their work time flying drones / operating drone fleets but are still expected in many cases to perform additional duties related to the commercial activities of the operator (e.g., sales and marketing outreach). All drone pilots – both full-time pilots and trained end-users – will require appropriate training, resulting in additional 5 000 and 10 000 jobs in 2035 and 2050 respectively.

As technical expertise and responsibility of the pilots varies across mission types, different salary costs are allocated to different type of pilots. For example, a pilot responsible for the flight of an unmanned passenger aircraft bears more responsibility than the pilot supervising inspection flights above pipelines. Similarly, staff carrying out detailed flare stacks inspections on oil platform require a higher level of technical skills (i.e. knowing where to fly the drone to identify potential areas of concern) compared to contractors supervising automatic flights of agricultural drones. Assumptions on the respective salaries, training and other costs for each pilot category are provided in Figure 31. Multiplying the number of pilots by their respective salaries, training and other costs results in a total value for drone operation nearing EUR 3 billion in 2035 and EUR 3.5 billion in 2050.

Figure 31: Assumption of pilot costs and value of drone operations

Technical expertise and responsibility of pilots varies across missions

Annual salary cost

High	125K	High liability & risks; e.g. Passenger flights
Medium	50K	Requires additional technical skill; e.g. facility inspections
Low	30K	Simple and repetitive mission types; e.g. pipeline or agriculture surveying
None	0.5K	Flying drone non-core activity of professional; e.g. constr. & mining, Agric.- owned drones

Annual training cost

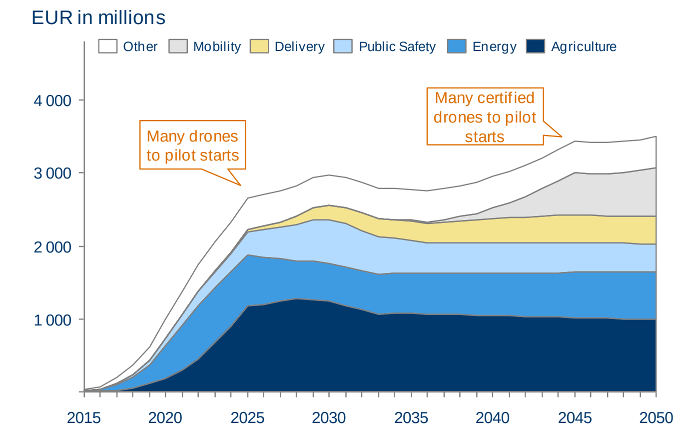
Certified	10K	Requires airmanship skills; e.g. taking over command in emergency
Specific & Technical skills	5K	Important investment in training, developing both piloting and technical skills;
Specific	2K	Trained in flying drone in standardised conditions; e.g. Agriculture surveying

Other personnel costs

High	30K	High travel intensity, incl. overnight costs; e.g. going to offshore platforms
Medium	5K	Moderate travelling; e.g. service provider going to client locations
Low	0.5K	Centralised drone control centre – no travel; e.g. Managing delivery drones fleet

Note: All values in nominal EUR
Source: BCG analysis

Very few, skilled pilots in energy (utility networks) and mobility account for 40% of piloting costs



	2020	2025	2030	2035	2040	2045	2050
Salary	550	1 750	2 000	2 000	2 200	2 650	2 700
Training	250	600	800	650	650	650	650
Other	200	300	150	150	150	150	150

As pilots in charge of passenger flights hold great responsibility and as inspectors performing detailed facility reviews require great technical knowledge, the energy and mobility sectors account for less than 10% of the pilot headcount but nearly 40% of the operation value.

Overview of economic impact of valued added services

Much of the value of the commercial drone industry is related to the insights drones offer end users. 'Big Data' and other specialized data processing capabilities provided by drone operators are a key source of the industry's value. In fact, this portion of the value chain represents what appears to be the greatest portion of economic impact – valued at EUR 4 billion by 2035 and representing 2 times the value of actual drone production.

Examples of how this service component generate the most significant value include mining & construction where contracts for a set of mines and quarries can exceed EUR 10 000 annually where no drone operator is needed and the drone, lasting multiple years, is only a few thousand euros. The real value is captured by the computing of images and data the drone makes available. To highlight this portion of the value chain, consider the area of agriculture once an operator is able to enlist multiple farms located within close proximity, as is expected to occur over the long run. Detailed below is breakdown of total willingness to pay estimated across the entire European landscape along with the associated costs from acquiring, operating and maintaining the drone products that act as tools in delivering precision agriculture and other related services. In total, the premium and value associated the service aspect represents approximately 50% of the consumer's willingness to pay once scale is obtained.

Figure 32: for agricultural remote sensing, over 50% of the value lies in the data analytics

Detailed calculations – 2050 values

Willingness to pay: **EUR 3.5-4 billion**

Service model	**~EUR 3 billion:** Farmers representing **105M Ha** of land, requesting **3 yearly** inspections for which they currently pay **EUR 10/Ha** to receive intelligence.
Ownership model	**~EUR 0.5-1.0 billion:** **85K farmers**[2] owning drones (and bearing all related costs, i.e. **~EUR 8K per drone annually**) are willing to pay a **EUR 500** yearly service fee to access and use "software / cloud services" processing collected images into actionable data

Other costs[1]: **EUR 1.5-2 billion**

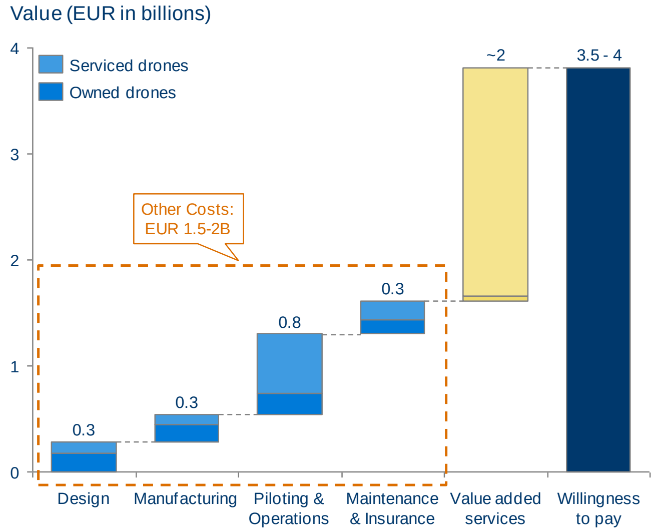
Design	**EUR 0.3 bilion**	Operations	**EUR 0.8 billion**
Manufacture	**EUR 0.3 billion**	Other[3]	**0.3 B€**

Value added services: **~EUR 2 billion**

Difference between the willingness to pay (i.e. benefit to customer) and all other costs related to drones is the amount available for developers and service providers to develop and offer
- Software: data analytics, cloud based services, …
- Hardware: Sensors, infrared camera's, Lidar's, …
- Integration with other agricultural machinery

providing farmers with actionable data, upon drone inspections

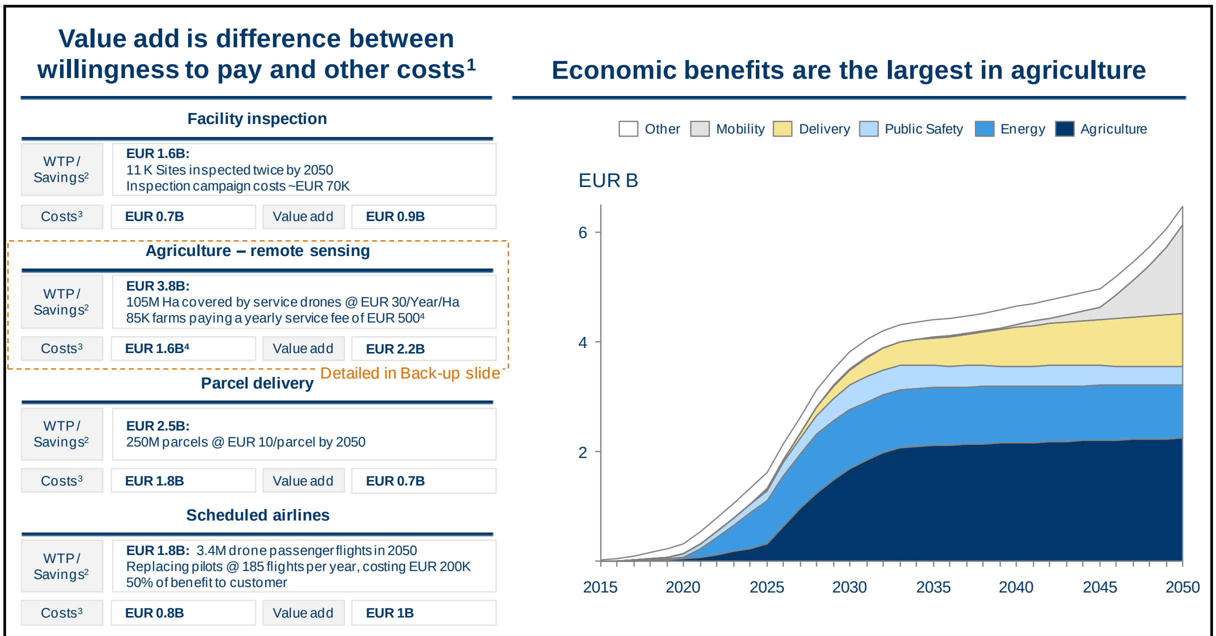
Value to farmers comes from sensors, data analytics & integration with machinery



1. "Unavoidable cost" related to drone use before any "value" can be extracted for the end customer; For details refer to value chain step calculations; 2. Drone ownership provide farmers additional flexibility in data gathering and economically interesting for farm sizes over 280Ha; 3. Maintenance and insurance
Note: All values in nominal Euros;
Source: BCG analysis; Expert interviews (Agricultural Equipment manufacturer, academics, precision farmer, drone manufacturers, drone service providers)

Applying a similar methodology to other industries to estimate the value of these services whereby the "unavoidable drone costs" (design, manufacture, operations, insurance and maintenance) are subtracted from the final value to customer, expressed in willingness to pay or cost savings leads to a result of approximately EUR 4.5 billion by 2035 and EUR 6.5 billion by 2050. The results for the largest contributing sources of value added services are provided in the following figure and include the wide range of facility inspections, done for example in energy, along with delivery services and potential unmanned aviation. The evolution of unmanned aviation is included as potential beyond 2035, but will depend on how the technology evolves. Artificial intelligence may in fact keep unmanned aviation as completely product-based whereby additional benefits would be captured earlier in the value chain. However, if operations and data processing become an on-going activity and considered a service, unmanned aviation will only increase the differential between production value and services as 2050 approaches.

Figure 33: Value added services and analytics are largest source of value



1. Illustrated by selected examples; 2. Savings that the use of drones could potentially generate; 3. Costs to be subtracted from the willingness to pay to obtain economic value of value added services; 4. Farmers owning drones bear all costs directly and are only charged a premium for the access to cloud services/on-line analytics
Note: All values in nominal EUR
Source: BCG analysis,

Overview of economic impact of maintenance & insurance

Similarly to other vehicles, drones will need to be maintained, repaired or enhanced with slight upgraded components and insured for liability against potential damages. The costs related to maintenance and insurance of drones are estimated to be around EUR 1.5 billion and EUR 2.3 billion respectively in 2035 and 2050, resulting in 10 000 to 15 000 jobs. Approximately two thirds of this value is related to maintenance. Indeed, there is a desire to use drone assets for multiple years, especially for more expensive assets. It is therefore expected – similarly to what exists for heavy industrial equipment – that opportunities for local maintenance companies will emerge. To estimate the value of the maintenance business for 'specific' drones, maintenance to amortisation cost ratios based on cars running costs have been used given they are in general are on the same order of magnitude in terms of overall price (typically both in excess of EUR 10 000) and used on a consistent basis for a variety of specific needs. In order to account for the different use intensities of different mission types, the different ratios have been applied as included in the trailing exhibit. For the more complex 'certified' drones, the ratio and valuation is based on maintenance to depreciation ratio of large airline companies.

Figure 34: Insurance and maintenance cost based on drone size & flight intensity

Other maintenance costs			Annual insurance cost		
Specific High intensity use	75% of amortisation cost	Drone operated by service provider or shared across multiple end-users E.g. Agriculture-service, centralised police, delivery, passenger aircrafts, inspections, …	Certified	20-50K[1]	Large drones with high initial cost or with significant impact in case of accident E.g. Scheduled airlines, rotorcraft, cargo drones, border patrol
Specific Low intensity use	25% of amortisation cost	Drone owned or allocated to single end users resulting in lower use intensity: E.g. Agriculture-owned, in vehicle police, constr. & mining, real estate, insurance	Specific – High usage	0.5-3K[2]	Drone operated by service provider or shared across multiple end-users E.g. Agriculture-service, centralised police, delivery, inspections, …
Certified	40% of amortisation cost	E.g. Scheduled airlines, rotorcrafts, cargo aircrafts	Specific – Low usage	5% of drone value[3]	Drone owned or allocated to single end users resulting in lower use intensity: E.g. Agriculture-owned, in vehicle police, constr. & mining, real estate, insurance

Liability insurance premiums for drones are based on the drone type, where premiums are expected to be substantially higher for certified drones than for specific drones. Premiums for insuring 'certified' drones are of the same order of magnitude as premiums for manned aircrafts – scaled for percentage accidents caused by pilot errors, i.e., excluding mechanical failure, etc. For 'specific' drones most insurance companies lack historical drones' data needed to price appropriate insurance policies, yet premiums are expected to be higher as the use intensity of a drone increases. Order of magnitude of is based on Goldman Sachs predictions in a recently released report.

In 2035, delivery and agriculture account for 67% of the insurance and maintenance costs as the drones are intensively used. The picture changes by 2050, when insurance and maintenance costs related to unmanned aviation accounts for 30% of the total value.

Overview of job creation

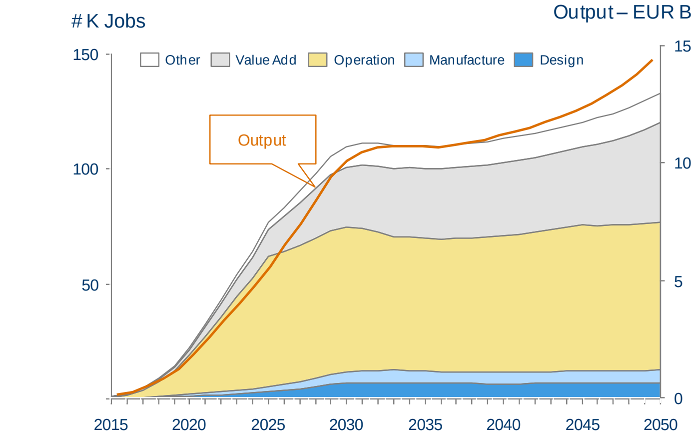
In determining the employment impact of the drone industry, it is important to acknowledge that a Euro spent in producing drones does not create as much employment as a Euro spent in training. The OECD STAN Database for structural analysis provides macro-economic data permitting the calculation of Output to job ratios for different employment activities. For the sake of this study, each step of the value chain has linked to one or several activities. For example, manufacturing of certified drones has been associated to "Manufacturing of Air & Spacecraft & related machinery". Further details are provided in the following figure.

Figure 35: Drone industry could create over 110K jobs

Output/job ratio based on OECD ratios[1] for similar industries

Value chain step	EUR per job	OECD industries used as proxies
Design	~130K	• Professional, scientific & technical activities • Scientific research & development
Manufacture Specific	~200K	• Manufacturing: Machinery & equipment • Manufacturing: Computer, electronic & optical products
Manufacture Certified	~450K	• Manufacturing: Air & Spacecraft & related machinery
Training	~70K	• Education • Administrative & support service activities
Value added Analytics	~140K	• Professional, scientific & technical activities • Scientific research and development • IT and other information services • Computer, electronic and optical products
Value added Payload[2]	~160K	• Professional, scientific & technical activities • Scientific research and development • Manufacturing: Machinery & equipment
Insurance	~310K	• Insurance, reinsurance and pension funding, except compulsory social security
Maintenance[3]	~130K	• Repair & installation of machinery & equip. • Repair of computers, pers. & househ. goods • Trade & repair of motor vehicles & cycles • IT and other information services

Beside 50K pilots, over 30K jobs in value added services



	2020	2025	2030	2035	2040	2045	2050
Value Add	<5	10	25	30	30	35	45
Training	5	10	10	10	10	10	10
Piloting	10	45	50	50	50	55	55

1. OECD STAN Database for Structural Analysis (ISIC Rev. 4): For listed industries, division of "Production (gross output)" by "Number of persons engaged (total employment)"; 2. E.g. Spraying, human transport; 3. Selection of OECD industries in function of drone mission

Overview of indirect macroeconomics

In addition to the direct economic impact the drone industry brings in the form of money spent on salaries, services and operations, the indirect effects resulting from increased business to business spending should be considered. In order to capture the effect on the drone sector on the entire upstream value chain, the study leveraged ratios of similar industries from the OECD, more specifically Type I multipliers based on interindustry Input/Output tables have been used.

Since the drone industry is not established, multipliers from different adjacent industries are considered as proxies resulting in factor ranging from 1.9 to 3.0. This range is based on the following list of comparable industries as sourced from the OECD:

- Computer and related activities (C72) – factor of 1.9
- Transport and storage (C60T63) – factor of 2.2
- Medical, precision and optical instruments (C33) – factor of 2.3
- Machinery and equipment n.e.c (C29) – factor of 2.5
- Electrical machinery and apparatus n.e.c (C31) – factor of 2.6
- Radio, television and communication equipment (C32) – factor of 2.7
- Motor vehicles, trailers and semi-trailers (C34) – factor of 3.0

As such, the total (direct and indirect) impact of the drone industry could range between EUR 27 billion and EUR 43 billion in 2050, resulting in 250 000 to 400 000 additional jobs. Induced effects, i.e. additional household consumption due to increased income, are not considered in this study.

Summary results of economic impact by industry sectors

As a summary of the expansive impact drones will have in many businesses, the following table provides the breakdown of product, service and other support capability values at-stake for European demand.

Figure 36: Industry view of forecasted economic impact

in EUR	2035 impact Products	2035 impact Services	2035 impact Others	2035 impact Total	2050 impact Products	2050 impact Services	2050 impact Others	2050 impact Total
Agriculture	800 M€	3 200 M	500 M€	**4 500 M**	600 M	3 200 M	400 M	**4 200 M**
Energy	<100 M	1 600 M	<100 M	**1 600 M**	<100 M	1 600 M	<100 M	**1 600 M**
P.S.S[1]	300 M	800 M	300 M	**1 400 M**	300 M	700 M	200 M	**1 200 M**
Delivery	600 M	800 M	600 M	**2 000 M**	700 M	1 400 M	800 M	**2 900 M**
Mobility	<100 M	<100 M	<100 M	**<100 M**	400 M	2 600 M	600 M	**3 600 M**
Others	200 M	700 M	100 M	**1 000 M**	200 M	800 M	100 M	**1 100 M**

1; Public safety and security
Note: Figures rounded to EUR 50M and 1K jobs, differences in totals due to rounding; Nominal 2016 EUR

Closer View of Regulation by Member State

Austria

Weight Limit	150 kg
Categories	Yes, 5 and 25 kg
License	For more risky categories gradual increase of pilot qualifications. Varies from operator responsibility, via operator declaration to ACG approval.
VLOS	Yes
BVLOS	Yes, provisions in the Aeronautical Act, detailed regulation pending.
Height Limit	150 m AGL[66]
Operational limitations	Depends on area of operation. AOO[67] has 4 categories: undeveloped area, unsettled area, settled area and densely populated/gathering of people area. Operation within 2500 m from airport only with permission of the owner.
Remarks	Rules not applicable < 79 Joule. BVLOS has to adhere to manned aviation rules. Categorisation in 4 categories for area of operation, based on population density

[66] Above Ground Level
[67] Area of Operation

Belgium

Weight Limit	150 kg
Categories	< 1 kg recreational < 5 kg class 2 activities > 5 kg class 1 activities (low risk 1b - high risk 1a)
License	Yes, Remote pilot licence including LAPL medical for all class 1 activities. For class 2 activities only practical examination with certificate from examiner when you passed successfully, without LAPL medical.
VLOS	Yes
BVLOS	BVLOS only possible with derogation to rules of the air. It is immediately a class 1a (high risk) activity, requiring a prior authorisation with extra restrictions, if necessary.
Height Limit	300 ft AGL. Above 300ft AGL only possible with derogation to rules of the air. It is immediately a class 1a (high risk) activity, requiring a prior authorisation with extra restrictions, if necessary.
Operational limitations	Not in controlled airspace, not is special airspace areas, > 1,5 NM distance from airports, > 0,5 NM from heliports > 50m from buildings, persons, animals
Remarks	Publication planned 10th April, 2016

Czech Republic

Weight Limit	150 kg in general, but experimental, research and individually built RPA have unlimited MTOM
Categories	Yes: 0.91 kg; 7 kg; and 20 kg
License	Every **RPA** for professional use (= commercial or corporate) must receive a special authorization. **Pilot** passes practical (pre-flight preparation and piloting skills) and theoretical test (rules knowledge). No medical licence required so far. The **operator** has to compile the operating manual and receive the ROC (aerial work certificate).
VLOS	Yes
BVLOS	Only in segregated airspace and over clear ground. (to enable research and development)
Height Limit	Generally 300 m AGL (class G) but if equipped with RTH fail-safe, max. ALT is 120 m AGL. In CTR maximum 100 m AGL, unless coordinated otherwise.
Operational limitations	In class G freely. In ATZ[68] only if coordinated. In CTR <5,5 km from aerodrome OR >100 m AGL only if coordinated. No flight within predefined buffer zones (highways, railways, water source, nature reserve) nor restricted/prohibited

[68] Air Traffic Zone

	areas. RPA >7 kg must keep > 100 m from persons and > 150 m from congested area. All RPA should keep safe distances (=2 times the actual height).
Remarks	Registration required. Registration mark and ID plate required according to ICAO Annex 7 (specific syntax e.g. OK-X013B = 24000 combinations). No dangerous payload, no dropping, no pulse jet or rocket engine. FPV possible only in crew of 2 (1 pilot keeps VLOS). Penalties levied from EUR 1 800 to EUR 180.000.

Denmark

Weight Limit	25 kg; Above 25 kg only by authorisation from the Danish CAA
Categories	1A: <1,5 kg 1B: <7 kg 2: 7-25 kg 3: BVLOS
License	For commercial use in populated areas permission is needed from CAA. Applicants have to deliver and have operations handbook approved and pass practical test
VLOS	Yes
BVLOS	Only by special permission in segregated air-space
Height Limit	100 m
Operational limitations	> 150 m distance from built-up areas and major public roads, > 5 km distance from civil airports, 8 km from military airports. Not over densely built up areas, areas with weekend cottages, camping sites and large open air assemblies of persons. > 7 kg or jet engine powered only allowed from model airfields. With special permission down to 15 m distance.
Remarks	Registration required. ID plate required. No dangerous payload, no dropping, no pulse jet or rocket engine. FPV possible only in crew of 2 (1 pilot keeps VLOS)

Finland

Weight Limit	25 kg
Categories	7 kg over densely populated areas
License	No
VLOS	Yes
BVLOS	Beyond visual line of sight operations are only permitted in areas that are specifically reserved for that purpose
Height Limit	150 m
Operational limitations	Flying a remotely piloted aircraft over an open-air assembly of persons or over a densely populated area is only permitted if the following requirements are met: a) The maximum take-off mass of the aircraft must not exceed 7 kilograms

	b) The aircraft must be flown at an altitude that allows the aircraft to be landed in an emergency in a manner that minimises risks to outsiders or their property, or the air-craft must be so equipped or have such characteristics that risks to outsiders and their property are minimal c) The operator of the remotely piloted aircraft shall have drawn up a written safety assessment for the specific operation, in which risks are identified, assessed and mitigated d) The operator of the remotely piloted aircraft shall have drawn up written operational instructions that include a description of both normal operations and emergency/malfunction procedures e) The documents referred to in paragraph c) and d) above shall be kept for a period of at least three months after the operation has ceased, and they must be presented to supervisory authorities upon request
Remarks	Direct link to regulation: http://www.trafi.fi/filebank/a/1444223591/7ded5988558660d38599203de96117fe/18706-OPS_M1-32_RPAS_eng.pdf

France

Weight Limit	150 kg
Categories	Yes: captive RPAS and RPAS <2 kg, < 25 kg and above 25 kg
License	Operational scenarios S1, S2, S3 : theoretical certificate (PPL or ULM) practical test under responsibility of the operator who provides declaration of level of competence Operational Scenario S4: Theoretical certificate (PPL or ULM) + manned aviation licence with minimum experience as PIC (Planned : a new regulation which will introduce a theoretical RPAS certificate instead of PPL or ULM certificate and a licence for S4 operations) Any use of an RPAS above 25 kg requires a remote pilot licence
VLOS	Yes (Operational scenarios S1 and S3)
BVLOS	Yes (Operational scenarios S2 and S4)
Height Limit	150m (Operational scenarios S1 S2 with RPAS < 2kg, S3 and S4) or 50m (Operational scenario S2 with RPAS > 2kg)
Operational limitations	Model aircraft : VLOS, day flights, not in public space in populated areas, away from airports, max height 150 m except < 50 m in CTR and Low altitude training areas Professional use: 4 operational scenarios: • S1 : VLOS over unpopulated areas, maximum horizontal distance 200m,

	maximum height 150m • S3: VLOS over populated areas, maximum distance 100m, maximum mass 8kg (with additional fail safe equipment provision if mass > 4 kg), maximum height 150m, safety perimeter • S2: VLOS/BVLOS over unpopulated areas, maximum distance 1km, maximum height 50m or 150m if RPAS < 2 kg • S4: BVLOS over unpopulated areas, maximum mass 2 kg, maximum height 150m". A risk assessment by the operator is required; it shall be approved by the NAA
Remarks	Regulation composed of 2 decrees dated 17/12/2015 All professional operators shall be registered and shall document their practices in an operation manual. Notification required : • Operations in populated area (to the prefectures, not for aviation safety considerations) • VLOS above 50 m under low level training areas and BVLOS (to DGAC and Defence) Certification of aircraft: “design attestation” delivered by NAA required for: • RPAS above 25 kg • RPAS used in BVLOS operational scenario • PRAS used in operational scenario S3 with a mass > 2kg

Germany

Weight Limit	25 kg
Categories	2 main categories: below/above 25 kg Differentiation between model aircraft and unmanned aircraft systems/vehicles (UAV) according to intended use.
License	Only theoretical and practical requirements above 5kg
VLOS	Yes
BVLOS	Only in segregated airspace
Height Limit	100 m
Operational limitations	Ascent of unmanned aircraft systems is subject to permission. Use of Model aircraft above total mass of 5 kg is subject to permission as well. The operation of unmanned aircraft systems is prohibited if conducted outside the operator's line of sight; or if the total mass of the aircraft system is more than 25 kg. In restricted areas and in the case of operations that are confined to the aerodrome traffic of an aerodrome, the competent aeronautical authority of the

	Federal State may grant exemptions provided that the requested use of airspace does not compro-mise public safety or order Not above (crowds of) people, accident and disaster areas, areas where police is active, prisons, military installations, industrial areas, power stations. Not in prohibited areas and areas with flight restrictions > 1.5 km from airports. In RMZ the ANS Provider has to be informed.
Remarks	Privacy and data protection specifically mentioned as an operator responsibility. Some requirements are ony part of administrative rule of procedure and not fully legally binding. The Federal States are in charge of the approval and oversight.

Ireland

Weight Limit	150 kg
Categories	Yes: 1.5, 7 and 20 kg
License	No, but theoretical and practical requirements
VLOS	Yes
BVLOS	Yes, if D&A
Height Limit	120 m for < 20 kg
Operational limitations	VFR, not over congested area, not in controlled airspace, > 8 km from airport, > 150 meter from assembly of people, > 150 meter from person, vessel, vehicle and structure, > 2 km from aircraft in flight. > 20 kg: specific approval required. Some additional limits for < 1.5 and 7 kg.
Remarks	Airspace segregation is essential in Irish approach. In line with ICAO.

Italy

Weight Limit	As per EASA Basic Regulation Annex I
Categories	Yes: 0.3 kg/ 2 kg / 25 kg
License	From 01.04.2016. Pilot Certificate for VLOS and < 25kg. [if < 0,3 kg, < 60km/h and rotors protection, no pilot certificate]. Otherwise Pilot License. Medical class LAPL for Pilot Certificate and medical class 3 for Pilot License
VLOS	Yes, EVLOS possible
BVLOS	Yes
Height Limit	VLOS: max 150 m
Operational limitations	Non–critical: > 150 m from congested area, 50 m from persons and property, in uncontrolled airspace, outside ATZ and > 5 km from airport. Sublasses exist
Remarks	ID plate on RPA and RPS. Simpler approval procedure for < 2 kg. No dangerous goods. Registration required > 25 kg. Requirements for privacy and data protection.

Lithuania

Weight Limit	25 kg, after it should be registered in CAA or approved organisation
Categories	1. Up to 300 g; 2. 300 g to 25 kg; 3. over 25 kg
License	Qualification requirements are set up in conditions given to conduct commercial flight
VLOS	Yes
BVLOS	In segregated areas
Height Limit	Over 400 ft in accordance with CAA permission and in compliance with defined conditions
Operational limitations	> 50 m from vehicles, people and buildings > 1,8 km from airfield 1 to 3 NM from obstacles
Remarks	Registration required over 25 kg

Malta

Weight Limit	150 kg
Categories	-
License	Medical declaration
VLOS	Yes
BVLOS	-
Height Limit	400 ft
Operational limitations	> 150 meter from congested area, infrastructure, assembly of persons, > 50 meter from person, > 150 m from vessel, vehicle, structure, > 7.5 km from aerodrome
Remarks	Does not have National Regulations but standardized operational procedures still given by the Director General on a case to case permit to fly. Concept regulation. Registration required

Netherlands

Weight Limit	150 kg
Categories	No
License	Yes
VLOS	Yes
BVLOS	No
Height Limit	120 m
Operational limitations	> 150 m from build-up area, crowds of people, main roads > 50 m from railway, industrial area limited access to CTR (outer ring, 150 ft)

Remarks	Registration required. ID plate required.

Poland

Weight Limit	150 kg
Categories	Yes, 25 kg
License	Certificate of qualification, including medical for commercial pilots
VLOS	Yes
BVLOS	In segregated airspace only
Height Limit	-
Operational limitations	Stay well clear and avoid collision. > 5 km from airport and not in CTR safe enough distance from people and property
Remarks	Registration required above 25 kg Multirotor is a separate category for the pilot

Portugal

Weight Limit	25kg, above only with a special authorization toy: less than 1kg
Categories	Yes: Toy: less than 1kg; Above 25kg only with a special authorization.
License	To be decided on a case by case above 25kg.
VLOS	Yes
BVLOS	Yes. Segregated Airspace inside controlled airspace after CAA authorization and ANSP approval; Free in G airspace up to 120 meters;
Height Limit	120 m, above that need segregated airspace. Toy: maximum 30 m outside controlled airspace;
Operational limitations	• Up to the height of the highest natural or artificial obstacle in a 75 meters radius outside what we have decided to be airport operational areas (15km length from the center of the runway, both directions and 5km width) inside controlled airspace • Night flight allowed inside segregated airspace • BVLOS and night flight allowed inside segregated airspace • Uncontrolled airspace maximum height 120 m • In some areas inside G airspace need to coordinate with uncontrolled aerodromes and heliports
Remarks	Regulation will be for public consultation next week. Several restrictions are applied:

	• Conditions to fly inside restricted areas: authorization from military authorities • Danger areas: no RPAS flights • Over governmental places, prisons, military facilities, police facilities, bridges, embassies, etc: no RPAS flights • 24 hours police and special forces on call for unauthorized RPAS flights special over the cities • Cannot fly over people concentrations

Slovenia

Weight Limit	150 kg
Categories	-
License	Yes
VLOS	-
BVLOS	-
Height Limit	-
Operational limitations	Daylight VFR, allowed in Class G airspace, > 300 m above crowds, > 50 m from powerlines, roads, railways etc.
Remarks	Regulation combined with regulation for ultra-lights. Registration required

Spain

Weight Limit	150 kg
Categories	Yes, 25 kg
License	<25kg: Theoretical knowledge from license or specific course at ATO + practical course on the RPAS + LAPL or Class 2 med. >25Kg: pilot licence + Practical course on the RPAS + Class 2 med.
VLOS	Yes
BVLOS	Yes, < 2 kg
Height Limit	120 m
Operational limitations	Diverse set of limitations. Categories: < 2, < 25 and > 25 kg. Operational conditions for > 25 are in CofA. All in uncontrolled airspace, not over urban areas nor people concentrations, not at night, only VMC. > 8 km from airport, >15km from IFR airports if BVLOS flight. NOTAM required for BVLOS operations
Remarks	ID plate required. Registration required above 25 kg.

Sweden

Weight Limit	150 kg
Categories	Yes Cat1A: 0 - 1,5 kg / max 150 J / VLOS Cat 1B: 1,5 - 7 kg / max 1000 J/ VLOS Cat2: 7 - 150 kg / VLOS Cat 3 BVLOS
License	Yes, > 7 kg By definition not a licence, but we require a written test in air space knowledge and a practical skill test.
VLOS	Yes
BVLOS	Yes, but only in segregated air space (closed for all other air traffic)
Height Limit	120m for VLOS
Operational limitations	No flight in controlled airspace, TIZ or TIA (unless specific approval) > 50 m from people, animals and property VFR night requires theoretical knowledge corresponding to a PPL VFR night
Remarks	Manual control should always be possible. Gradually heavier set of requirements for heavier categories. Flights to be documented in log book.

Switzerland

Weight Limit	150 kg for Annex 1, else no limit
Categories	Yes, “Open” & “Specific” “Open” = max. 30 kg 100 m outside of crowds VLOS “Specific” = everything else
License	Required “Pilot Skills” is part of the Total Hazard and Risk Assessment (GALLO)
VLOS	Yes
BVLOS	Yes, GALLO required
Height Limit	No limit. Depending GALLO
Operational limitations	> 100 m away from crowds & BLOS requires FOCA authorisation (GALLO process) > 5 km from airfields & < 150 AGL in CTR requires authorisation from ANSP or airport manager
Remarks	VLOS above or closer than 100m to crowds and BLOS can be approved Operator approval based on total hazard and risk assessment (GALLO). All RPAS for GALLO approved operations have an identification plate (e.g. SUI-5678)

UK

Weight Limit	150 kg
Categories	Yes, 20 kg or less >20-150kg
License	>20kg or BVLOS - Case by case basis 20kg or less (VLOS) - pilot competency assessment required if requesting a Permission, which can be obtained via an RPL, NQE assessment, or through AMC
VLOS	Yes
BVLOS	Yes, with D&A, segregated airspace or if OSC demonstrates that there is no 'aviation threat'
Height Limit	>7kg-20kg - 400 ft 7kg or less, must be able to be seen adequately for VLOS
Operational limitations	>20-150kg - Dependent on Operating Safety Case assessment 20kg or less - Unless specific permission is granted: • Not over or within 150m of 1000+ persons • Not over or within 150 meter from congested area • Not within 50 meter from person, object, vehicle not under control of operator • >7-20kg • ATC permission required for flight within controlled airspace or within active ATZ • Not over 400ft agl unless flying in controlled airspace or ATZ
Remarks	20 kg or less - CAA Permission required if conducting aerial work Fuller guidance is contained within CAP722 www.caa.co.uk/cap722

Index of Acronyms

ACAC-Xu – Airborne Collision Avoidance System X
ADS-B – Automatic Dependent Surveillance – Broadcast
ATM – Air Traffic Management
B2B – Business to Business
BVLOS – Beyond Visual Line Of Sight
C2 – Command and Control
ATC – Air Traffic Control
CAGR - Compound Annual Growth Rate
CAP – Common Agricultural Policy
CE Marking – "Conformité Européene" marking
D&A – Detect and Avoid
DESIRE II – Demonstration of Satellites enabling the Insertion of RPAS in Europe
DG GROW – Directorate-General for Internal Market, Industry, Entrepreneurship, SMEs
DG MOVE – Directorate General for Mobility and Transport
DoD – Departement of Defence
EASA – European Aviation Safety Agency
EDA – European Defence Agency
FAA - Federal Aviation Administration
HALE – High Altitude Long Endurance
IFR – Instrument Flight Rules
MALE – Medium Altitude Long Endurance
MIDCAS – Mid Air Collision Avoidance System
NASA – National Aeronautics and Space Administration
OECD – Organisation for Economic Co-operation and Development
PPP – Public Private Partnership
RPAS – Remotely Piloted Aircraft Systems
SATCOM – Satellite Communication
SESAR JU – Single European Sky ATM Research Joint Undertaking
SME – Small and Medium Enterprises
UAS – Unmanned aircraft system
UAV – Unmanned aerial vehicle
UTM – Unmanned Aircraft Traffic Management
VFR – Visual Flight Rules
VLL – Very Low Level
VLOS – Visual Line of Sight

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