Master Plan Companion Document on the Performance Ambitions and Business View

European ATM Master Plan Edition 2020

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Abstract

This document includes an overview of the methodology and main underlying assumptions supporting the SESAR performance ambitions and the business view as outlined in the European ATM Master Plan 2020 edition.

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Document history

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1.1	19/07/2019	Released	Correction of numerical values in Table 8 and Table 10
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2.0	19/12/2019	Released	Update to fully align with the endorsed version of the Master Plan

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1 Introduction

This document includes an overview of the methodology and the main underlying assumptions supporting SESAR performance ambitions and business view as outlined in the ATM Master Plan Edition 2020. This document should be read together with the Chapters 3 and 6 in the ATM Master Plan. It focuses on presentation of additional supporting information for experts - to assist with reading and understanding of the Master Plan chapters.

2 Performance view

This chapter outlines further details of the European ATM Master Plan performance ambitions linked to the implementation of SESAR for controlled airspace and airports within the 2035 timeframe (see Master Plan Chapter 2). The performance ambitions are outlined according to several key performance areas (KPAs) including those instigated by SES High-Level Goals and defined in the SES Performance Scheme.

As the "technological pillar" of SES, SESAR is a key contributor to SES High-Level Goals, through the delivery and deployment of SESAR solutions with demonstrable and measurable performance gains. It must be noted that the SESAR project must take into account lengthy investment lead times common for infrastructure industries (like the ATM) and the need for sustained R&D activities in the future, and therefore the performance ambitions are not binding in contrast to the performance targets set by the performance scheme for the performance reference periods (RPs).

By definition, longer look-ahead times bring increased uncertainty to the levels of performance. In particular, and regardless of the steady growth foreseen in the medium to long term, there is a perceptible degree of uncertainty with evolution of traffic that is accommodated in the SES legislative package through the risk-sharing mechanism.

Therefore, the contribution to performance ambitions should be confirmed and adapted as and when SESAR solutions are delivered and in some cases should be supported by changes to the way in which services are provided, so as to reach their full potential.

The SESAR project is expected to contribute to achieving performance targets of the SES Performance Scheme[1]. Nevertheless, its contribution to the various KPAs described in this chapter will need to be validated on the basis of research results for each SESAR Solution and reviewed in the context of the deployment activities that may depend on local circumstances and availability of sufficient deployment capacity to bring the changes into operation.

The performance ambitions published in the Master Plan recognise that SESAR solutions covering phases A-C (and excluding U-space) are made available through R&D activities, deployed in a timely and synchronised way and used to their full potential.

1 Commission Implementing Regulation No. 409/2013 [6], Article 4(2): Common projects shall be consistent with and contribute to the European Union-wide performance targets. See also Article 15a of EC Regulation 550/2004 as last amended [7].

2.1 The Master Plan Performance Ambitions supported by a data-driven approach

The Master Plan performance ambitions provide a common reference for the ATM stakeholder community with which to define development and deployment priorities. Unless specified otherwise, the numerical values of the performance ambitions refer to the European Civil Aviation Conference (ECAC) area as a whole (geographical scope as defined by STATFOR; including the North Atlantic oceanic airspace managed by the European ANSPs, see Figure 1 below) while being linked to the 2035 timeframe. The reference point against which the performance ambitions are measured is 2012, which is also the start of the SES Performance Scheme. This also aims at ensuring continuity between Master Plan Editions without giving the impression of being a "moving target".

Lastly, unless otherwise specified, all financial values are expressed in EUR 2012 (in real-term / deflated currency).

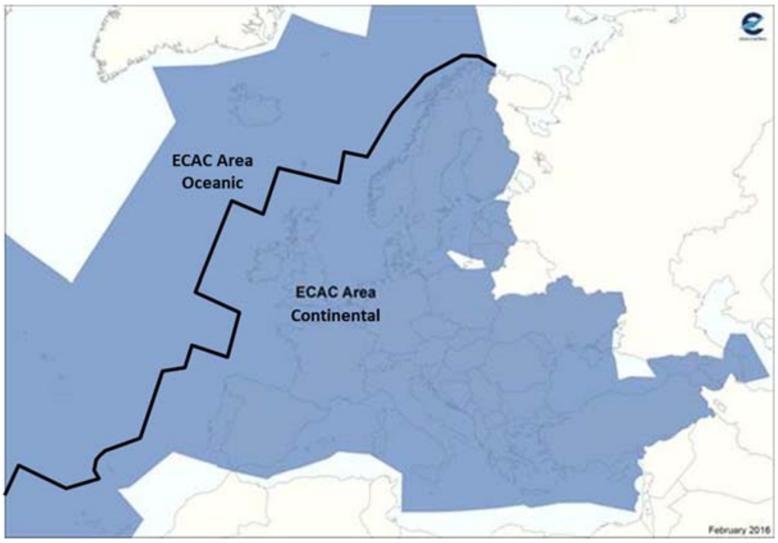

Figure 1. Geographic scope

The performance ambitions are categorised in accordance with SES KPAs of safety, environment, capacity, cost-efficiency and include two additional KPAs, operational efficiency and security which have been identified as key within the SESAR performance framework. These performance ambitions, which are aligned with the SES High-Level Goals, also reflect the evolution of European aviation since 2005 - the year in which the SES High-Level Goals were formulated.

For the preparation of this edition of the Master Plan, the ECAC area has been characterised in terms of a consistent set of several hundred different performance parameters to serve as indicators used to define performance ambitions. For these parameters, statistical data is available to evaluate performance evolution over the past 7 years (2012-2018)[2]. For 2035, the “Regulation & Growth” scenario for the Challenges of Growth 2018 traffic forecast was used.

To get a better understanding of the impact of traffic forecast on ambitions, a status-quo scenario has been defined for 2035. This scenario incorporates not only the growth of the number of flights, but also other aspects of traffic evolution which are part of the forecast; such as progressive increase in average flight distance and duration, continued evolution towards larger aircraft, predictions that intercontinental traffic will grow faster than internal ECAC traffic etc. (see Figure 2). These traffic assumptions are combined with a what-if assumption - that all performance indicators will maintain the same value as that for the baseline year 2012. Together this set of assumptions constitute the status-quo scenario.

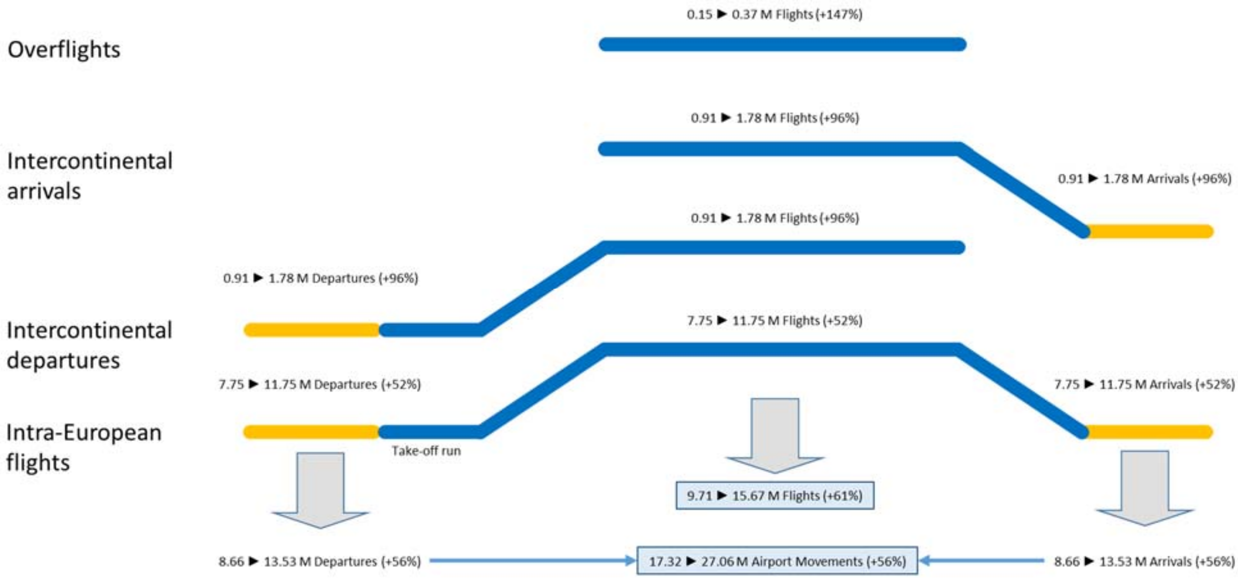

Figure 2. ECAC controlled traffic evolution details

Next, a second scenario for 2035 has been defined for the same performance indicators to combine traffic forecasts with a select set of improvements resulting in a set of ambitions that are mutually consistent and linked to lower level performance parameters. These ambitions and performance parameters can then be compared to the 2012 performance levels and the values in the status-quo scenario to measure performance benefits associated with ambitions.

Achieving performance ambition levels for 2035, outlined in Figure 3, requires optimal development and deployment of operational changes and essential operational changes made possible through implementation of SESAR solutions, as detailed in the Master Plan. These ambitions also take into account the evolution in ATM service provision, which should further facilitate SESAR deployment.

[2] With exception of ANS costs, for which 2017 and 2018 data is not yet available. Where data is missing, the assumption has been made that there is no change with respect to the previous year.

Key Performance Area	SES high-level goals vs. 2005	Key Performance Indicator	Baseline value (2012)	Ambition value (2035)	Performance ambition vs. baseline: Absolute improvement	Relative improvement
Capacity	Enable 3-fold increase in ATM capacity	Departure delay[4], min/dep	9.5 min	6.5-8.5 min	1-3 min	10-30%
		IFR flights at congested airports[5]	4 million	4.2-4.4 million	0.2-0.4 million	5-10%
		Network throughput IFR flights[5]	9.7 million	~15.7 million	~6.0 million	~60%
		Network throughput IFR flight hours[5]	15.2 million	~26.7 million	~11.5 million	~75%
Cost efficiency	Reduce ATM services unit cost by 50% or more	Gate-to-gate direct ANS cost per flight[1], EUR(2012)	EUR 960	EUR 580-670	EUR 290-380	30-40%
Operational efficiency		Gate-to-gate fuel burn per flight, kg/flight	5280 kg	4780-5030 kg	250-500 kg	5-10%
		Additional gate-to-gate flight time per flight[2], min/flight	8.2 min	3.7-4.1 min	4.1-4.5 min	50-55%
		(Within the: Gate-to-gate flight time per flight[3], min/flight)	(111 min)	(116 min)		
Environment	Enable 10% reduction in the effects flights have on the environment	Gate-to-gate CO_2 emissions, tonnes/flight	16.6 tonnes	15-15.8 tonnes	0.8-1.6 tonnes	5-10%
Safety	Improve safety by factor 10	Accidents with direct ATM contribution[6], #/year. Includes in-flight accidents as well as accidents during surface movement (during taxi and on the runway)	0.7 (long-term average)	no ATM related accidents	0.7	100%
Security	-	ATM related security incidents resulting in traffic disruptions	unknown	no significant disruption due to cyber-security vulnerabilities	unknown	-

1 Unit rate savings will be larger because the average number of Service Units per flight continues to increase.
2 "Additional" here means the average flight time extension caused by ATM inefficiencies
3 Average flight time increases because the number of long-distance flights is forecast to grow faster than the number of short-distance flights
4 All primary and secondary (reactionary) delay, including ATM and non-ATM causes
5 Includes all non-segregated unmanned traffic flying IFR, but not the drone traffic flying in airspace below 500 feet or the new entrants flying above FL600
6 In accordance with the PRR definition: where at least one ATM event or item was judged to be DIRECTLY in the causal chain of events leading to the accident. Without that ATM event, it is considered that the accident would not have happened

Figure 3. Performance ambition for 2035 for controlled airspace and airports (categorised by KPA)

The sections hereafter detail the 2035 performance ambition at KPA and KPI levels. For the purposes of strategic deployment planning set out in the Master Plan, the European ATM service provision has been categorised into four operating environments: airport, terminal airspace, en-route, and network[3]. For the purposes of detailed planning, further subdivisions recognise divergent requirements for units with differing traffic and complexity levels.

The operational performance ambitions have been derived by means of an influence model which links current/forecast data and its contributing factors to compute KPI values. The use of intermediate data items is used to enhance consistency and plausibility of the results. In addition to the performance ambitions, reference values are now available for all KPIs. Whilst value ranges, similar to the previous edition of the Master Plan, have been used for the presentation of high-level ambition, in Figure 3, the data-driven approach provides specific values for KPIs and their contributing factors.

2.2 Capacity

This KPA evaluates ambitions at two levels: network traffic throughput and accommodation of additional flights for a subset of the most congested airports.

[3] For the military, there are corresponding military operating environments, which are the same as above but with different types of operations.

The capacity KPA performance ambition, in Figure 3, includes departure delay. Because the full scope of ambition for departure delay extends beyond capacity, departure delay is discussed in the context of flight efficiency, in section 2.4.3.

2.2.1 Terminal airspace, en-route and network capacity

The ambition is to increase network traffic throughput in order to accommodate forecast demand within a sufficient margin.

More specifically, the capacity ambition is to accommodate all traffic forecast, presented in the "Regulation & Growth" scenario for the Challenges of Growth Study 2018, along with additional "recovered" unaccommodated demand at the most congested airports, through SESAR-enabled capacity improvements.

Terminal airspace capacity will need to be tailored in accordance with arrival and departure peak periods at airports while accommodating additional traffic during periods of runway capacity reductions. The lower the runway capacity/demand variability, the lower the need for terminal airspace capacity adjustment, thus optimising the use of resources.

SESAR solutions are expected to enable capacity enhancements through the following means:

- In terminal airspace and en-route environments, capacity improvements are primarily enabled by performance-based CNS, optimised ATC sectorisation including cross-border sectorisation coupled with flexible rostering together with network and local complexity management and enhanced conflict resolution management supported by high-accuracy information for advanced automation, thereby releasing controllers from routine tasks in order to focus on value-added tasks. Additionally, flight-centric approach (sectorless concept) is expected to provide additional potential for an increase in ATM en-route capacity. Extended AMAN and multiple airport AMAN are considered to be major enablers for terminal airspace capacity.
- In airspace management and air traffic flow and capacity management (ATFCM), a more dynamic airspace configuration is foreseen to enable optimum application of available airspace structure, adaptation of ATC sectorisation and management of ATFCM constraints. An enhanced and progressively dynamic demand-capacity balancing approach is expected. In addition, more integrated ATFCM/ATC planning is foreseen by the coupling of ATFCM/ATC planning via specific processes/tools. Equally, military airspace requirements are also growing, due to new manned and unmanned aircraft. SESAR solutions will be fundamental to the optimisation of network performances and fulfil military needs.

The ambition of SESAR is to increase the capability across all these areas so that anticipated growth can be accommodated. It also aims to provide sufficient scalability at key bottlenecks in the network to enable reductions in ATFCM delays and enhance the potential for more fuel-efficient trajectories.

2.2.2 Capacity ambition at congested airports

Between today and 2035, increasing number of bottlenecks are expected to develop in locations where there is insufficient terminal airspace and airport capacity. The Challenges of Growth Study anticipates that approximately 0.9 million flights will be unaccommodated in 2035. The issue is not so much a lack of overall capacity, but more a lack of capacity at a location, time and potential. This lack of airport capacity will have a knock-on effect on associated operating environments and will need to be managed. Intensive use of saturated airport capacity will adversely impact predictability and punctuality, making performance ambitions all the more challenging.

The ambition is to enable a 5-10% improvement in capacity at the most highly congested airports (altogether handling up to 4 million flights p.a. in 2012). This will allow an additional 0.2-0.4 million flights on top of the forecasted STATFOR value[4].

This is expected to be achieved in three ways - all of which will be addressed by SESAR solutions:

- enabling an increase in runway throughput (per busy/peak hour) so that the airport is able to improve its declared capacity;
- reducing capacity degradation (and consequent impact on flight operations) in non-nominal operating conditions such as low visibility, strong winds, system and/or infrastructure issues. This can also be addressed by airport operations planning through the introduction of the concept of total airport management (TAM). TAM enhances predictability enabling increasingly efficient planning, even when disruption is inevitable;
- reducing the variability of traffic load to provide more efficient queuing with fewer delays.

The targeted capacity increase will require enhancements to traffic sequencing, reduced separation, departure /arrival planning in cooperation with the network functions, reduced and more predictable runway occupancy times and enhanced management of taxiway throughput for both, arrivals and departures. At airports where capacity is constrained by runway throughput, these enhancements will enable a greater number of arrivals and departures to be scheduled by airline operators.

There are several means of enhancing capacity at airports, which is not covered by or in the scope of SESAR. The construction of additional runways and terminal infrastructures will make significant contributions to the overall European airport capacity. However, this is a subject for local decision-making. Since the baseline year 2012, the construction and inauguration of the new Istanbul airport is one example of new infrastructure making a contribution to meeting the ECAC-wide capacity ambition. Between now and 2035 there are a few additional airport infrastructure projects in the pipeline (e.g. new Berlin airport, Heathrow 3rd runway, etc.).

[4] 5-10% of 4 million flights = 0.2-0.4 million additional flights in the ECAC area. These numbers are unchanged from the Master Plan edition 2015. In the data driven approach we have used a value of 0.5 million additional flights. This corresponds to 0.85 million extra airport movements at those congested airports which in 2035 are responsible for generating 8.5 million movements without the extra capacity. We are basically talking about the top-20 airports in Europe, i.e. the airports which each had more than 210 000 IFR movements in 2017. So in principle we are talking about increasing the capacity of LFPG EDDF EGLL EHAM EDDM LEMD LTBA LIRF LEBL LSZH LOWW EGKK EKCH ENGM LFPO EBBR EDDL ESSA EIDW LFTJ by approximately 10% on top of what is already planned. Note that the vast majority of the ECAC traffic growth (increase of nearly 6 million flights or 9.5 million airport movements) will need to take place at new airports such as Istanbul and the thousands of smaller existing airports which are assumed not to be capacity constrained in 2035, hence able to accept the additional traffic without requiring implementation of capacity-related SESAR solutions. Nevertheless the implementation of SESAR solutions at these airports could still be beneficial.

2.2.3 Airspace and network capacity ambition

At ECAC-wide level, the network will need to accommodate a growth to 15.7 million IFR flights p.a., that is, an increase of 61% compared to 2012. These flights correspond to 27 million network-wide IFR airport movements, a growth of 56%.

Airspace capacity needs are better expressed in terms of IFR flight hours. In 2035, there will be a need for the ATM system to control 26.7 million IFR flight hours due to a slow but steady increase of average flight distance, which is an increase of 75% with respect to 2012. In terms of the distance flown, this is an increase of 80%. Sufficient capacity margins must also be provided to allow for the achievement of the other performance ambitions.

2.3 Cost efficiency

SESAR delivers a portfolio of solutions capable of enhancing ANS productivity. With regard to this, the ambition is to provide essential technical system changes at reduced lifecycle costs, whilst continuing to develop operational concepts to enhance the overall productivity of ANS provision.

In 2012, gate-to-gate direct ANS cost for the ECAC area was approximately EUR 9.3 billion for 9.7 million flights, which corresponds to 960 EUR/flight.

By 2035, the performance ambition for the ECAC area is to achieve a reduction by 30-40% (equivalent to 290-380 EUR/flight) in the cost per flight compared to 2012. The performance ambition for ANS cost, applied by the data-driven approach, is a reduction of 370 EUR/flight - which translates to a direct gate-to-gate ANS cost of 590 EUR/flight. Notwithstanding significant traffic growth with traffic volume projected to reach 15.7 million flights, the annual gate-to gate direct ANS cost of flights in the ECAC area needs to be maintained at constant levels. Improvements in cost-efficiency involve initiatives to address ANS productivity and significant organisational changes.

The extent to which these gains can be realised are subject to how the SESAR solutions are deployed, evolution in traffic growth and the validation of the performance potential for SESAR solutions. It should also be noted that this cost efficiency ambition does not take into account the cost of change or the possible costs incurred in restructuring.

SESAR solutions address improvements of ANS productivity and infrastructure costs. The benefits to ANS productivity are mainly expected from tasks with higher automation, improvements in working methods and technologies, virtualisation of ANS enabling optimal use of resources across the ATM network, new operational concepts like flight-centric operations and widespread use of data communication. Meeting current ANS productivity ambitions, however, need additional solutions yet to be identified.

The cost-efficiency challenges related to ANS infrastructures and their maintenance is mainly related to the investments (within their existing depreciation and operational cost envelope) required to transform the ATM system. Investment costs should be offset by benefits expected from CNS rationalisation, digitalisation and consequent reduction of assets and amortisation costs. Lean and efficient use of ANS infrastructure, based on interoperable standards and services decoupled from system specifics will ultimately allow lower ATM system-related operational, maintenance and depreciation costs.

Contributors to improvements in cost-efficiency ambitions are detailed in Figure 4. In order to determine ambitions for contributing factors, traffic growth needs to be analysed.

Due to expected increase in flight distance per flight, the total chargeable flight distance is growing at a rate higher than the number of flights. Furthermore, considering that the average take-off weight per flight is expected to grow, the number of service units is expected to double. This implies that a reduction of 38% of ANS cost per flight means a reduction of 50% in cost per en-route service unit.

Therefore, to achieve the ambition for ANS costs, the total ANS cost in 2035 needs to be at the same level as in 2012. Assuming that contributing factors will not change and that the cost contribution ratios for contributing factors are the same as in 2012, this implies that an improvement of 75% in ANS productivity is needed.

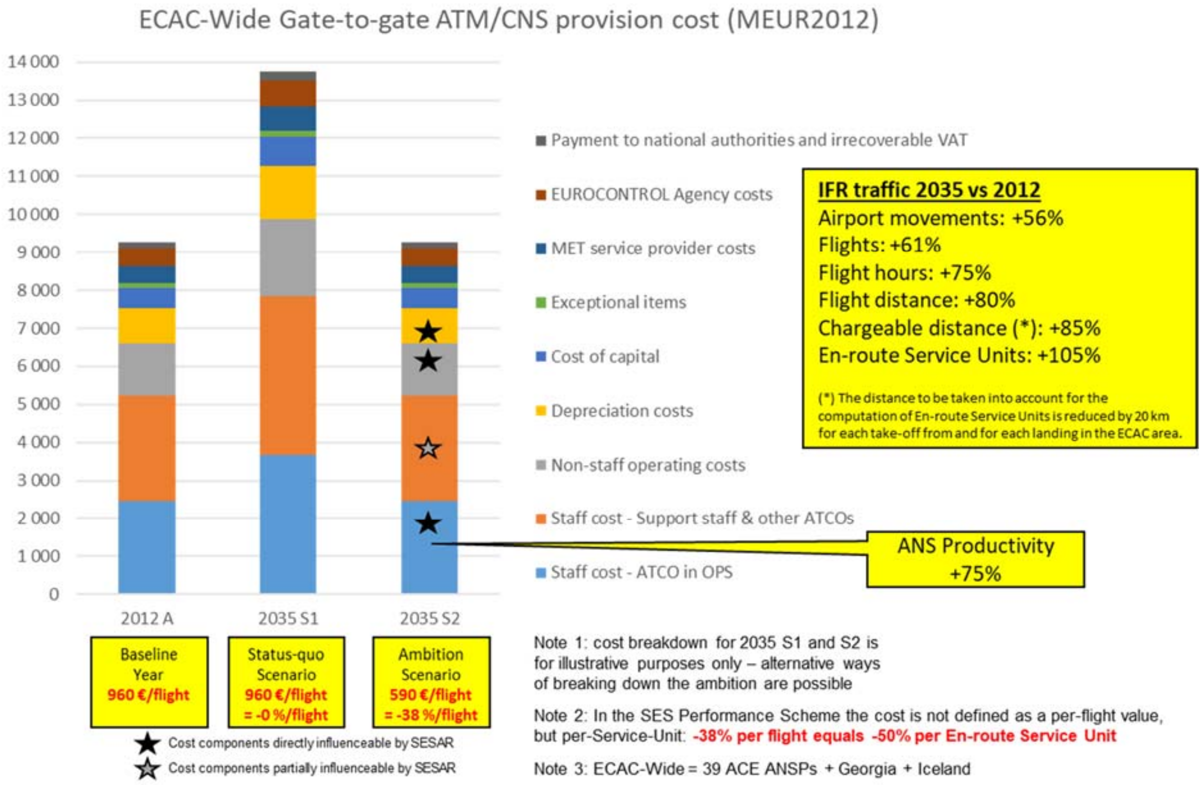

Figure 4. Cost-efficiency ambition contributing factors

2.4 Operational efficiency

In addition to the direct gains in terms of cost efficiency, SESAR will also bring indirect economic benefits for flight operations, mainly through reduction and better management of departure delays and more efficient flight paths; reducing both additional fuel consumption attributable to ATM and gate-to-gate flight time and increasing predictability. It will also significantly reduce the need for intervention of operators (traffic controllers, airlines, ground operators, flight crews …) which however, are assessed in other KPAs. For the military, operational efficiency is an enabler for mission effectiveness.

2.4.1 Fuel efficiency

The fuel efficiency performance ambition in Figure 3 addresses average fuel consumption per flight within a gate-to-gate scope. The evolution of this parameter is driven by a number of different factors: evolution of the average size of the aircraft operating in the ECAC area, evolution of the fuel efficiency of these aircraft, evolution of the average (city-pair) distance per flight, and evolution of the trajectory efficiency. This includes efficiency on the airport surface as well as flight trajectory efficiency (horizontal, vertical and time).

The high-level ambition is to achieve a reduction in the total gate-to-gate fuel burn of 250-500 kg, from a baseline of 5280 kg for an average flight in 2012. This ambition is challenging when viewed in the light of historical and projected trends in fleet composition and traffic patterns that impact fuel burn regardless of ATM performance. For example, in the last six years (period 2012 – 2018) the average maximum take-off weight (MTOW) of aircraft flying IFR in the ECAC area has increased from 77 tonnes to 86 tonnes (+12%), and the average distance flown has increased from 1120 km to 1210 km (+8%). As a result the average gate-to-gate fuel burn per flight has increased from 5280 kg to 5790 kg (+17%). However, in terms of average fuel burn per tonne-kilometre there is a notable improvement: a decrease from 61.1g to 55.5g (-9%).

The aim of ATM improvements is to act on the 'trajectory efficiency component' of the high-level ambition, i.e. to achieve a significant reduction in fuel inefficiency induced by ATM-related trajectory constraints while maintaining the ability to accommodate traffic increases safely and simultaneously and ensuring the achievement of punctuality objectives of airspace users. Therefore, in contrast to the previous edition of the Master Plan, the following analysis of contributing factors is based on fuel efficiency being measured as additional ATM-related gate-to-gate fuel burn per flight, instead of relative reduction of total fuel burn. This focus on the *additional fuel burn* component is a level of detail not shown in Figure 3.

As shown in Figure 5, there is also a significant difference between internal ECAC traffic and the other (intercontinental) traffic flows which are generally flown with much larger aircraft, where ATM-related inefficiencies translate into much larger fuel penalties – and hence opportunities to achieve significant fuel savings. The diagram also shows how the fuel saving ambition is attributed to the different flights – arrivals from outside ECAC, departures to outside ECAC, ECAC overflights and ECAC-internal flights, see Figure 2 for the expected traffic growth per each of these categories.

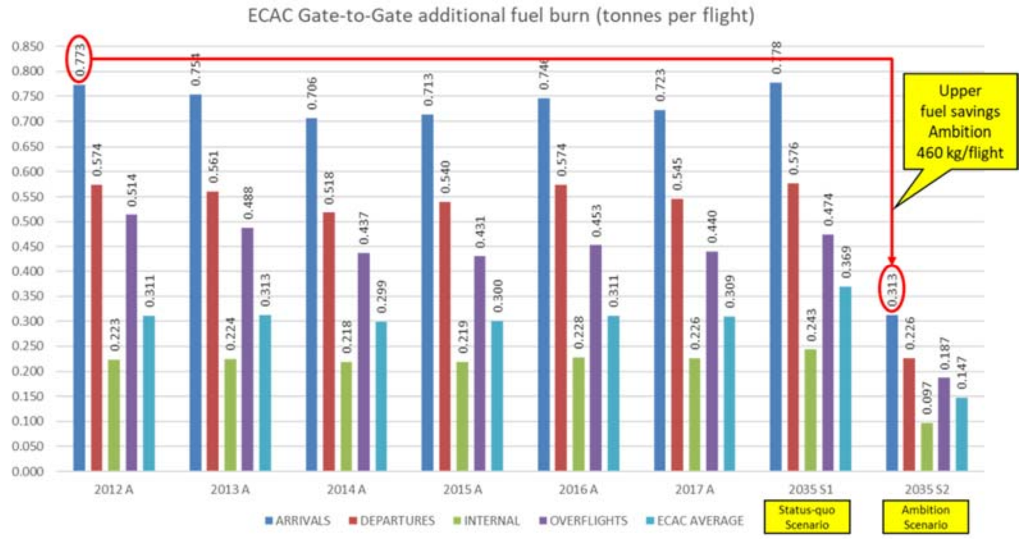

Figure 5. Gate-to-Gate additional ATM-related fuel burn (ECAC-wide, breakdown by DAIO)

The performance ambition is to reduce the gate-to-gate additional ATM-related fuel burn for all traffic flows within the confines of ECAC airspace, with the highest ambition for the ECAC arrivals (traffic departing from outside ECAC with a destination inside ECAC). For this traffic flow the aim is to enable an average fuel saving of 460 kg per flight. These routes are generally flown with larger aircraft.

Other traffic flows (ECAC departures, overflights and internal flights) are flown with different aircraft sizes (e.g. ECAC internal traffic is flown with much smaller aircraft) and are subject to different efficiency constraints. Hence their potential for fuel savings is different. Each traffic flow has been broken down into its individual flight phases to evaluate inefficiency and the potential for improvement. The results for individual traffic flows have then been recombined to produce ECAC-wide average values, per flight phase.

From this, a set of sub-ambitions have been derived to address airport surface operations, terminal airspace climb and descent operations (both vertical profile efficiency and arrival queuing effects leading to path stretching and holding) and en-route vertical and horizontal flight efficiency. The scope of the envisaged performance improvement is more comprehensive than currently addressed by the SES Performance Scheme, which in terms of target setting focuses on the horizontal en-route flight extension only and aims to achieve 2.6 % in flight extension by 2019 (end of RP2) and 2.4 % in 2024 (end of RP3), with a 2012 (RP1) baseline of 3.2 %[5].

The performance ambition for the additional average ATM-related fuel burn per flight, as provided by the data-driven approach, is a reduction of 173 kg or 55%, while the remaining performance ambition

[5] Source: PRR 2013 [8] — Horizontal En-route flight efficiency (EUROCONTROL area) based on RP2 KEA metric (the average horizontal En-route flight efficiency of the actual trajectory, defined as the comparison between the length of the En-route part of the actual trajectory derived from surveillance data and the corresponding portion of the great circle distance, summed over all IFR flights within or traversing the European airspace (Commission Implementing Regulation 390/2013 [9])).

will come from a reduction of 330 kg of unimpeded[6] gate-to-gate fuel burn per flight. Note that performance improvements delivered by the programme are to be evaluated as benefits with respect to a "Without SESAR" scenario in the business view, not with respect to performance in 2012. Details for the contributing factors from ATM are shown in Figure 6 and explained in more detail in the remainder of the section.

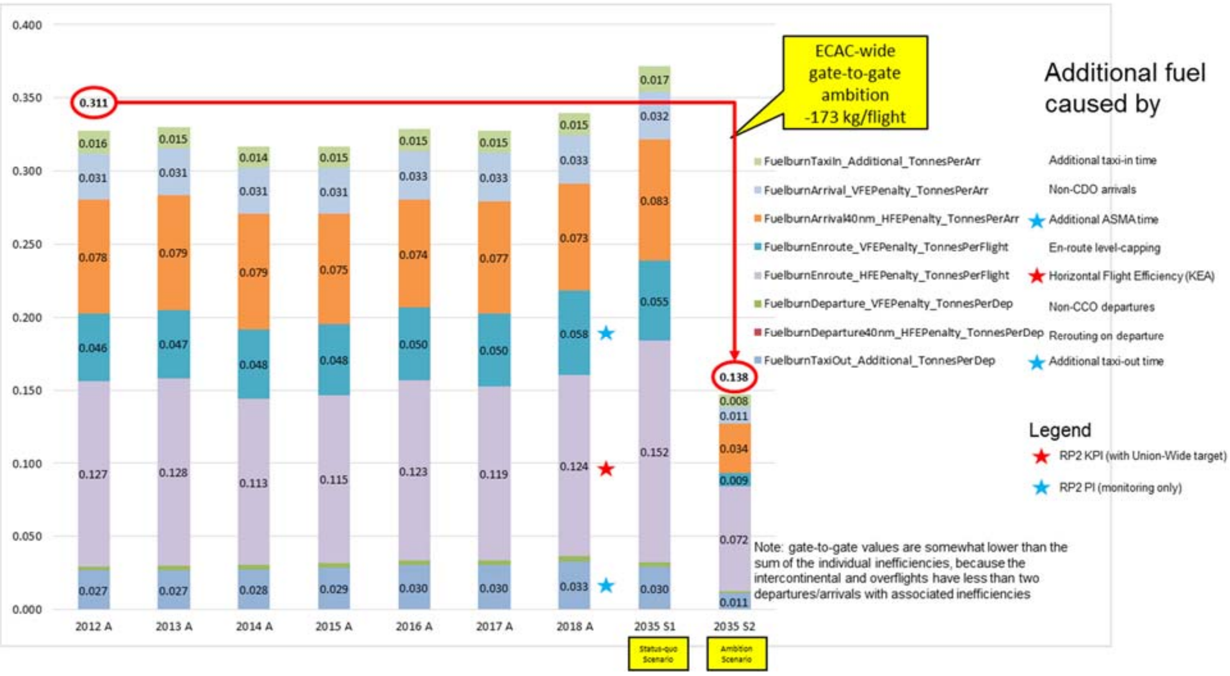

Figure 6. Breakdown of Gate-to-Gate additional ATM-related fuel burn (ECAC-wide averages per flight)

The ambition for enabling an ECAC-wide average reduction of 173 kg additional fuel burn per flight is most likely to be facilitated across operating environments as follows:

Airport surface operations: Approximately an average 15 kg fuel burn reduction per flight due to more predictable and efficient taxi-out operations, and 8 kg due to more efficient taxi-in. This represents almost 60 % reduction in the ATM-related additional taxi fuel burn.

Terminal airspace and climb/descent operations: Approximately an average 44 kg fuel burn reduction per flight due to reduction in use of stacks, holding patterns and vectoring in terminal airspace upon arrival; 21 kg savings in the descent phase (more CDO operations); and an average 2 kg saving per flight due to more efficient climb profiles. It should be noted that a significant portion of the ECAC-wide total improvement relates to terminal airspace serving the busiest and highly congested airports in Europe.

En-route cruise operations: Approximately an average 55 kg fuel burn reduction per flight due to flying shorter routes, and an estimated average 37 kg savings due to less level capping in the cruise

[6] Unimpeded trajectories are characterised by: zero additional taxi-out time, no level-off during climb (full fuel CCO), no sub-optimal cruise level, en-route actual distance equal to great circle distance, no level-off during descent (full fuel CDO), no additional time in the Arrival Sequencing and Metering Area (ASMA), zero additional taxi-in time.

phase representing an about 50 % reduction in the average ATM-related additional en-route cruise fuel burn per flight.

The individual contributions do not sum up to the ECAC-wide average number because for intercontinental flights (ECAC arrivals, departures and overflights, representing ±20 % of all flights) the departure and/or arrival inefficiencies take place outside the ECAC area; hence they are not included in the ECAC-wide average value per flight.

Benefits for airport surface operations from enhanced taxi-out are expected particularly at airports where both runway and stand capacity are highly utilised and require extended and variable taxi times for efficiently managing the trade-off between queuing delays and runway capacity utilisation. In economic terms, it means trading the commercial value of operating an airport slot (no wastage of slots, ideally) with the cost of guaranteeing continuous demand through queuing and consequential delays.

In terminal airspace operating environments, benefits are expected from the reduction in use of path extension, and stacks and/or holding patterns during the descent phase. The reduction is achieved mutually through enhanced traffic predictability and queuing based on speed reductions and/or optimising take-off times, rather than through extending horizontal distance. In some cases the benefit will not be a shorter flight but lower cost of delay due to a more efficient trajectory. Further benefits can be gained through increased use of continuous climb and descent profiles with fewer level-off flight segments, particularly in busy terminal airspaces.

In en-route and cruise operations, fuel burn can be reduced through the use of Free Route Airspace and fewer vertical profile restrictions, particularly at cross-border boundaries. Meeting the horizontal flight efficiency ambitions however needs additional solutions, yet to be identified.

SESAR will enable minimal impact on the fuel consumption of trajectory revisions needed for separation.

2.4.2 Time efficiency — shorter flight times

With SESAR, improved gate-to-gate flight trajectories will result in more than 50% reduction in additional flight times by 2035 compared to 2012. This represents an average gain of about 4.5 minutes in the block-to-block time. This 'additional time' driven approach decouples the ATM-related ambition from an expected significant increase in the average unimpeded gate-to-gate flight time. The ambition will be achieved by a reduction in additional taxi-out and taxi-in time, increase in direct routing in en-route airspace, and reduced holding and vectoring upon arrival. The shorter times contribute to fuel savings explained in the previous section.

2.4.3 Time efficiency — improving on-time performance

Figure 7 illustrates the evolution of the causes of delay from 2012 to 2018 followed by en-route ATFM delays as shown in the Master Plan 2020 document. In the baseline year 2012, the departure delays, per flight in the ECAC area averaged approximately 9.5 minutes (primary and reactionary delays of all causes)[7]. Of this total, approximately 40 % (or up to 3.7 minutes) are directly or indirectly influenced by weather-related and ATM factors such as the ATFM en-route delays (which contributed just 0.6 minutes of delay in 2012). The residual time delay is associated with airline operational or technical issues, industrial actions and airport security. To achieve a significant reduction in 'departure delay versus the 2012 baseline', additional causes of delay must be addressed besides ATFM en-route delay.

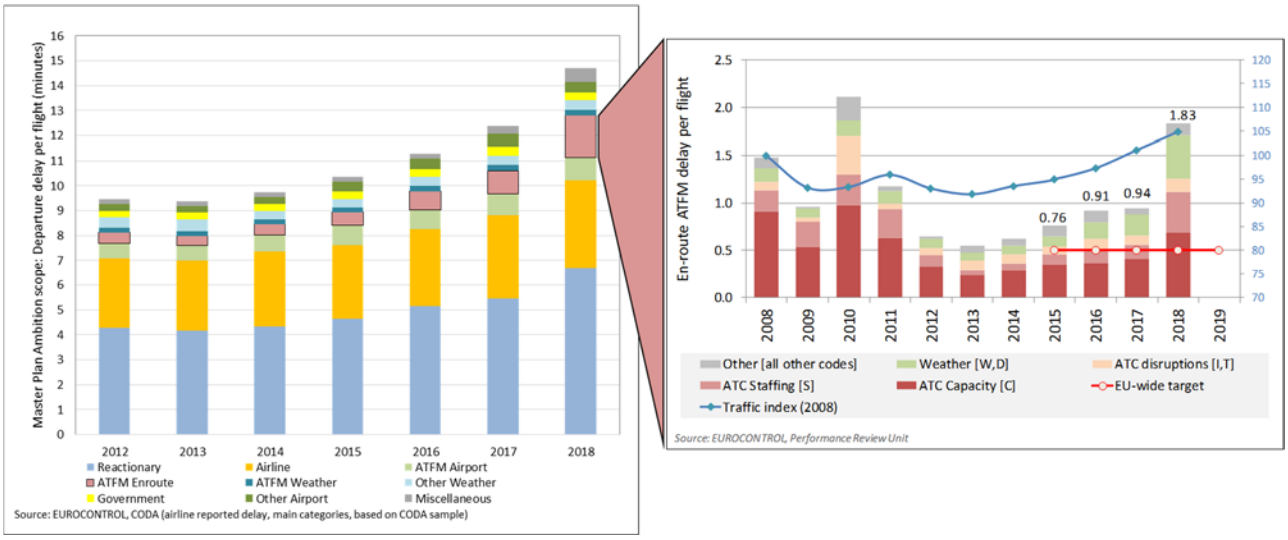

Figure 7. All departure delay causes and en-route ATFM delay details

[7] Source: Central Office for Delay Analysis, CODA (part of EUROCONTROL NMD).

Figure 8. Breakdown of departure delay (ECAC-wide averages per flight)

The performance ambition is to reduce the 2012 baseline delay of 9.5 minutes per flight to 7.0 minutes, which is a reduction of 2.5 minutes or 26% (note that in 2018 the delay had increased to almost 15 minutes per flight). As shown in Figure 8, these improvements are expected to come, to a large extent, from a reduction in reactionary delay (-2.26 min) and, to a lesser extent, from a reduction in airport ATFM delay (-0.16 min) and in ATFM weather delay (-0.04 min). Note: to reduce reactionary delay it is essential to improve the level of predictability, which is addressed in the next section.

2.4.4 Increased predictability

In addition to reductions in departure delay, the performance ambitions aim to increase predictability of flight arrivals in accordance with commonly agreed reference business trajectories prior to push-back. This predictability is expected to be a key outcome from the deployment of the SESAR Target Concept, which anticipates a move to trajectory-based operations (TBO), highly advanced network operations planning processes and extensive information exchange.

Specifically, more predictable arrivals are expected to result from enhanced capabilities for managing limitation factors, such as adverse weather conditions and variability in queuing for access to congested runways (both arrival and departure).

This in turn will have a beneficial effect on reduction of ‘buffer time’, which airlines factor into their schedules in order to add robustness to tactical time variations. The key phases of flight for enhancing predictability are taxi out and terminal airspace arrival.

Reduction in flight time variability will be facilitated by: application of business trajectory; delivery of predictable capacity in normal operating conditions; comprehensive application of free route airspace;

queue management; resilience procedures; exchange of ATFCM/ATC planning information and constraints between all ATM actors; reconciliation between ATFCM/ATC constraints coming from different sources; and advanced use of automation to support tactical air traffic control to enable optimisation of traffic flows to and from busy airports.

In addition the introduction and implementation of Total Airport Management (TAM) will optimise landside, terminal and airside procedures and processes. This will have a positive effect on the on-time performance and predictability of the entire airport operation involving all operational stakeholders.

2.5 Environment

An average reduction in fuel burn per flight, attributable to operational efficiency, has a consequential benefit for the environmental KPA in terms of reduced emissions; each tonne of kerosene saved, saves 3.15 tonnes of CO_2 emissions. The performance ambition for ECAC arrivals is a reduction of 460 kg in additional fuel burn per flight, attributable to ATM. This corresponds to an average reduction of around 1.4 tonnes of CO_2 emissions for ECAC arrivals.

The environmental impact of aviation (noise and emissions) is local and bespoke for each airport due to airspace constraints, traffic mix, local land use, local geography, and therefore the regulation of environmental factors remains local. However, environmental constraints will increasingly limit traffic growth at airports and play a significant role in aviation environmental footprint. It is important that greater emphasis is given to innovative solutions to: enable airports, ANSPs, and airspace users to optimise trajectories; take into account the different trade-offs between noise and emissions on arrival and departure; include innovation in airframe manufacture and retrofit; and design principles for multi criteria decision making so that local constraints can best be met. SESAR solutions for airport and terminal airspace such as, continuous climb and descend operations, curved and/or segmented approaches or noise preferential routes are being considered for deployment to address noise reduction in aviation.

Evaluation tools, the development of which was initiated during SESAR1, are now available to support the assessment of the overall contribution to the sustainability of European aviation and should be applied to SESAR solutions where applicable.[8]

2.6 Safety and security

The approach to safety and security ambitions is different to that of other performance ambitions. On the one hand, ambitions in Figure 3 are of a political nature, i.e. particularly challenging and aspirational (by 2035 totally eliminate all ATM related accidents and quasi totally protect aviation against all ATM-related cyber-attacks) and on the other hand, the scope of these ambitions – particularly in the safety KPA – is very narrow. Historically, ATM-related accidents[9] have been only a

[8] Environmental assessments are addressed in the European Aviation Environmental Report [10].

[9] The term *ATM-related accident* is to be interpreted in accordance with the formal PRR definition: where at least one ATM event or item was judged to be DIRECTLY in the causal chain of events leading to the accident. Without that ATM event, it is considered that the accident would not have happened.

very small portion (< 1%) of the total number of aviation accidents. Ultimately, this means that if the focus is on just these niche-oriented ambitions, only a small improvement in the overall level of safety and security in the European aviation system will be achieved. However, the improvements contained in the Master Plan could bring many safety and security benefits that are not currently within the scope of listed ambitions.

In practice, the main objective is to ensure that system changes introduced by the Master Plan do not degrade today's safety levels and where possible improve them. In terms of security, the ambition implies appropriation of all necessary measures to ensure security that is taken into account in the design of each system development lifecycle and that a holistic approach is used to assess risks.

2.7 Military contribution to network performance

No additions are to be made to the discussion of the military contribution to network performance; please refer to Section 3.3 in the Master Plan document.

3 Phase D Options

As outlined in Chapter 2, the performance ambitions will be accomplished by the implementation of improvements proposed in Master Plan 2020 Edition vision. These changes will be implemented through a number of evolution phases as outlined in Figure 9. Phase D will ultimately transform the European ATM system to deliver the SESAR end-state vision. It will enable the move from the current monolithic and product oriented system to one where distributed and service oriented system is in place. Automation instead of the human will be put at the epicentre of information integration.

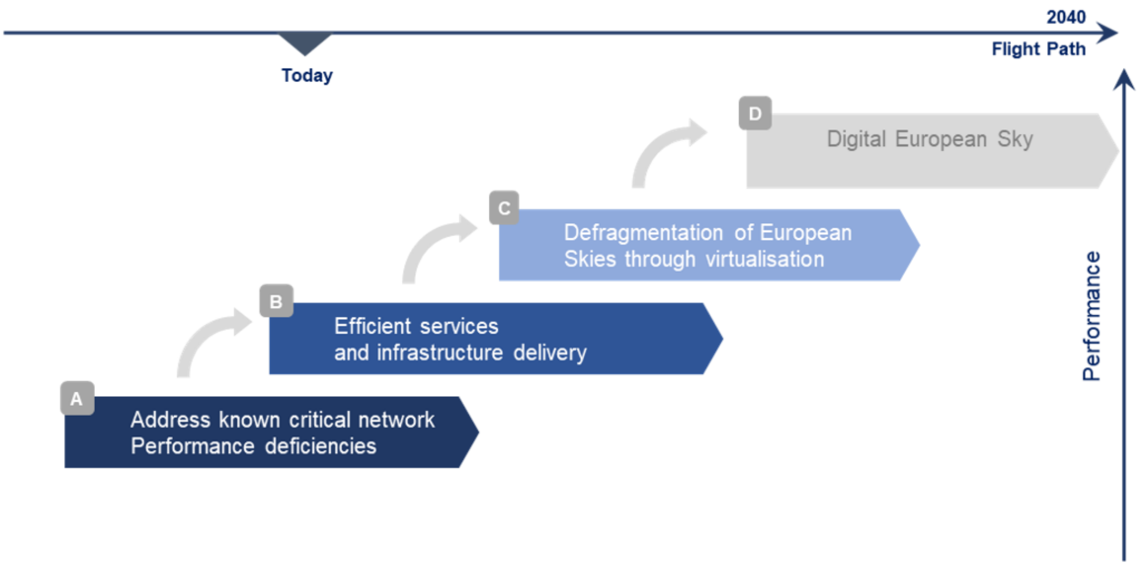

Figure 9. Phases of Master Plan roll-out

However, phases A-C will not be adequate beyond 2035. The successful deployment of a fully scalable system necessitated by phase D may take place according to two different options: by 2040 with Option 1 or by 2050 with Option 2 as illustrated in Figure 10.

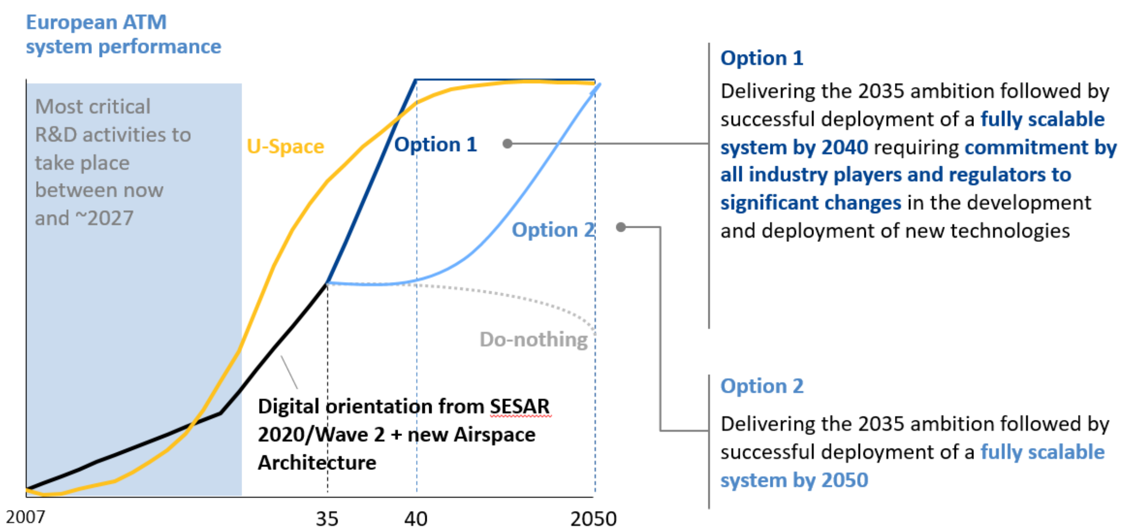

Figure 10. Two different options for Phase D roll-out

Option 1, the most ambitious, requires a commitment to significant changes in the development and deployment of new technologies, by all industry players and regulators. It requires an introduction of a new way of working within SESAR based on agility, openness and increased coordination. Development and deployment cycles will need to shrink from approximately 30 to 5-10 years and focus will need to be on disruptive not incremental innovations. Regulation to promote innovation will need to evolve in parallel with institutional and regulatory landscape, acting as a vehicle for innovation through market take-up incentives for early movers, and a focus on effective delivery of future services. A summary of building blocks for Option 1 may be found in Figure 11.

Building blocks of Option 1		Description
New way of working within SESAR	More agility	▪ Development of solutions through **prototypes and demos** performed in **smaller teams** with **shorter time frames**. ▪ Development of solutions through **addressing service related challenges** without prejudging upfront what the optimal technical solution is. ▪ Creation of **SESAR innovation labs** for fast-track R&D, quick prototyping and incubate new ideas
	Openness	▪ Openness through increased collaboration between **"traditional" engineering domains** and **new entrants** that are now likely to attract more capital.
	Coordination	▪ Coordination to **reduce innovation cycles** from about 30 years to about 5-10 years, focusing on disruptive innovation. ▪ Development and deployment of **drones' integration into the airspace** and in particular the development and implementation of U-space services may be used as a "laboratory" that may support faster lifecycles in the manned aviation environment. ▪ "Sandboxing" between organisations may allow faster time to market.
Regulatory framework to support innovation	Market take-up Incentives	▪ Provision of incentives for **early movers**
	Service orientation	▪ **Focus on delivery of services**, putting emphasis on **what services** should be provided and **how** rather than on what technologies should be implemented

Figure 11. Building blocks for Option 1

If all conditions are put in place, Option 1 in comparison with Option 2, would enable significant benefits. First, it would bring a faster accomplishment of the end-state Master Plan vision with rationalisation of investments. Agile principles, openness and coordination through a common programme management approach will allow completion of the end-state faster than in the current state (i.e., by 2040 instead of in 2050) whilst benefiting from continuous investment rationalisation opportunities. Secondly, infrastructure service providers will be able to scale up or down according to demand in a more flexible and resilient manner, reducing exposure to major drivers of uncertainty (drone and manned air traffic forecast, and evolution of technology). Finally, Option 1 will allow release of the full value associated with drones and new mobility services.

4 Holistic view of SESAR net benefits for manned aviation

This chapter provides details of investment costs, benefit data and assumptions underpinning the results presented in section 6.1 – Holistic view of SESAR net benefits for manned aviation – in the European ATM Master Plan Edition 2020 (MP2020) [1].

For clarification on the data and assumptions included in section 6.2 – Holistic view of SESAR net benefits for drones – in the Master Plan, please refer to the 2016 Drones Outlook Study [2].

The Holistic Business View considers both the direct impact to the ATM value chain as well as the indirect impacts on suppliers of the value chain, passengers and society. The key direct benefits considered in the Business View are the monetisation of the performance ambitions described in Chapter 2. For this reason, the key assumptions are consistent, e.g. the geographical scope is ECAC, and the traffic forecast is the STATFOR "Regulation & Growth" scenario from the 2018 Challenges of Growth study.

The Business View takes a year-by-year view on the benefits and investments within the 2012-2050 horizon, with differing assumptions for Options 1 and 2 post-2035. All benefit data is expressed in real 2012 terms. No assumptions have been made regarding the effect of inflation.

The assessment of the impact of SESAR ("With SESAR" scenario) is measured versus a "Without SESAR" scenario where no further[10] deployment of SESAR solutions occur.

The Airspace Architecture Study [4] has established that the current capacity plans are insufficient to cope with increased traffic demand. This would result in the current delays continuing to deteriorate exponentially until reaching a level which results in flight cancellations and unaccommodated demand. NM simulations for the "as-is" scenario are considered to be a good substitution for the "Without SESAR" scenario. It was concluded that with only PCP solutions implemented, only 24 ACCs (most of them located at the edges of the European airspace) are expected to have operationally acceptable performance by 2030.

The projections show that – without the implementation of SESAR – "*extremely high delays will result with significant traffic disruptions, impact on the network resulting in major re-routing workload"*. This is translated into en-route ATFM delay forecasts of more than 6 minutes/flight, in 2030.

Bearing in mind that en-route ATFM delay is only a part of the total delay experienced by passengers and as a result of consultation with stakeholders contributing to the Master Plan 2020, the Business View presumes that in the case of "Without SESAR" a traffic cap will be required.

The Business View assumes that by 2028, without SESAR, the degradation in passenger experience would be such that AU would simply decide not to file additional flights and traffic would therefore, stagnate. This projected saturation would discourage passengers from flying, thereby, leading to a serious loss of passenger value.

[10] No further deployment of SESAR except from PCP deployment which has already occurred.

4.1 Holistic view on investments

This chapter provides further detail and assumptions underpinning the investment costs required to deploy SESAR solutions, e.g. acquisition of systems, testing, training, regulatory approval, etc. It should be read together with section 6.1.1 – Holistic view on investment – in the Master Plan.

Table 1 lists the stakeholders[11] who are included in the Business View. All stakeholders, with the exception of MET, were actively involved in reviewing and updating investment costs to develop the Master Plan 2020 Business View.

Unless otherwise explained, figures are provided undiscounted in EUR billion or EUR million. Any deviation in the total sum is due to rounding-up of decimals. Importantly and in line with the Master Plan Edition 2015 (MP2015), restructuring and financing costs are not taken into account for investments in the Business View. No specific perspective is taken on the requirement for additional financing for deploying SESAR technologies and hence on the potential financing costs.

Table 1: Overview of stakeholders considered in the MP2020 Business View model – Investments

Stakeholders
• Air Navigation Service Providers (ANSPs) • Airspace Users (AU) composed of Scheduled Airlines (SA), Business Aviation (BA), General Aviation (GA) & Rotorcraft (RC) • Military (MIL) • Airport (APT) • Network Manager (NM) • Meteorological Service Providers (MET)

4.1.1 Addressing uncertainty

Cost ranges have been used to address the inherent degree of uncertainty associated with future investment needs. This uncertainty reflects that many SESAR solutions are still in R&D and that for Phase D the solutions are not yet defined.

- **Median**: building on the cost estimations of Master Plan 2015 and where possible, updating with more recent and reliable information, a series of most-likely values have been agreed with the stakeholder experts participating in various consultation groups.
- **Minimum** and **Maximum**: following on from the median values proposed, a range of minimum and maximum values are derived using the logic in Table 2 below.

As described in the previous chapter, two deployment options have been defined for Phase D.

- **Option 1:** where the SESAR full vision is deployed by 2040 with a lower cost resulting from a faster and more efficient deployment.
- **Option 2:** where the SESAR full vision is gradually deployed and achieved by the end of 2050.

[11] ATM equipment and avionics manufacturers have been excluded from the investment assessment. Please note that development costs are out of the scope of this exercise and we only look at the costs of deploying SESAR Solutions. In the holistic view on benefits however, the impacts on ATM equipment and avionics manufacturers are included.

Table 2: Addressing uncertainty with two criteria

	SESAR 1 PCP and Non-PCP	SESAR 2020 Wave 1 and 2	Phase D
Range considered	• +/- 20% of Median value	• +/- 50% of Median value	• 2 different options depending on the deployment date. • Investments between EUR 5 and EUR 10 billion.
Rationale	• Many PCP solutions are being deployed and a sufficiently reliable picture is available. • Still some margin is considered for next Non-PCP solutions investment needs.	• Most of SESAR 2020 solutions are in R&D phase still and the uncertainty in investment levels is higher.	• Scalability and defragmentation of services are expected to bring costs down.

4.1.2 Investments overview – all stakeholders

The investment costs included in the 2020 Business View model for Phases A to C (up to 2035) are built on cost data from previous cost and benefit exercises while Phase D (2035 to 2050) values have been calculated using a top-down approach. These investment costs are spread across the relevant deployment periods to reflect a ramp-up of deployments followed by a tail-off. There are no assumptions included about the order or phasing of deployments at specific locations.

Unless otherwise specified, investment figures in this section refer to the Median values of Option 1 which are compared with the Median values from the Master Plan 2015.

Estimating realistic high-level figures for the investment levels is challenging as many of the SESAR Solutions are still in the early stages of R&D and SESAR Solutions for phase D are not yet in R&D. To address this uncertainty numerous industry experts from across the whole ATM and aviation value chain have provided their insight. To capture this inherent risk, a series of level ranges for investment have been provided. Following on from the median value proposed by various experts, a range of minimum and maximum values are derived. Unless otherwise specified, values provided for investments are the median and refer to the option 1 that will be presented in the next paragraphs.

In addition to the values envelope, the investment levels have also been calculated for two distinct high-level options (see section 3) for rolling out SESAR:

- **Option 1 — Deployment of the full vision by 2040:** Total cumulative investment is estimated to be between EUR 23 and 51 billion over the period 2012-2040, of which almost 90% will be invested by 2035. The median expectation being in the order of EUR 37 billion.
- **Option 2 — Deployment of the full vision by 2050:** Total cumulative investment fluctuates between EUR 25 and 53 billion over the period 2012-2050, of which about 80% is invested by 2035. The median level of investment is around EUR 39 billion.

Table 3 and Figure 12 below provide further details of the values used to produce the values described in section 6.1.1 – Holistic view on investment – of the MP2020. When applicable, the equivalent cost estimations from the MP2015 are shown.

Table 3: Investments overview – Cumulative investments Phases A to D – Per SESAR Phase

	MP2015			MP2020		
Units in EUR billion	Minimum	Median	Maximum	Minimum Option 1	Median Option 1	Maximum Option 2
SESAR 1	**7.5**	**7.5**	**7.5**	**7.8**	**9.7**	**11.7**
SESAR 2020	**10.7**	**14.6**	**18.5**	**10.3**	**20.7**	**31.4**
SESAR2020 Wave **1**	3.9	5.3	6.6	4.1	8.4	12.7
SESAR2020 Wave **2**	6.8	9.3	11.9	6.1	12.3	18.7
TOTAL Phases A to C	**18.2**	**22.1**	**26.0**	**18.1**	**30.5**	**43.1**
Phase D	Not addressed			5.0	6.3	10.0
Total SESAR Vision	**Not addressed**			**23.1**	**36.8**	**53.1**

For SESAR1 PCP and Non-PCP Solutions there is a reasonable certainty in the budgetary needs. As we enter the period where most of the S2020 Solutions are expected to be deployed the uncertainty widens. The values proposed above consist of the cost of deploying SESAR from phase A to phase D for manned aviation: scheduled airlines, business aviation, general aviation, rotorcraft, ANSPs[12], Network Manager, airports and the military[13].

[12] The civil ANSP investment assessment does not include investment costs of Remote Towers for small airports because its deployment depends on very local decisions. Furthermore, it has been assumed that some key regional virtual centres (i.e. 9 FABs) will require the highest investment costs

[13] The military investment assessment does not include non-SESAR SES airborne equipage costs stemming from specific SES regulations such as performance based navigation (PBN), surveillance performance and interoperability (SPI), voice communications systems (VCS), datalink services (DLS), etc.

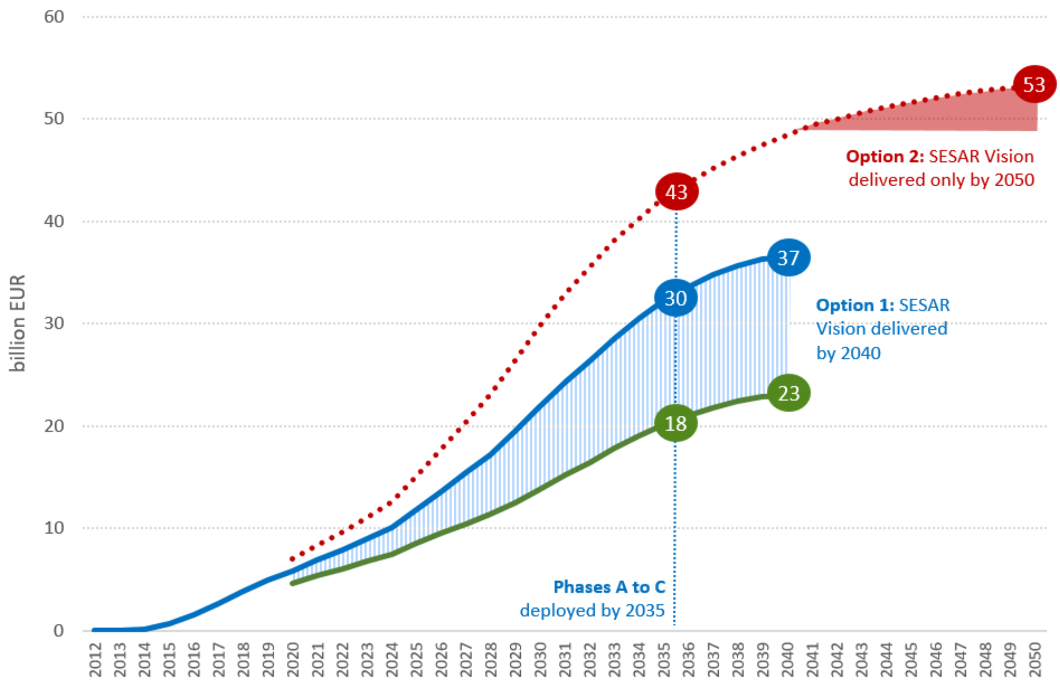

Figure 12. Total cumulative investments for delivering SESAR Vision – manned aviation

A closer look at the values provided, offers an approximate picture of the investment levels considered in the business view for phase A to phase C, per stakeholder.

billion EUR	Option 1		Option 2
	18.1	**30.5**	**43.1**
ANSP	8.0	13.1	18.2
AU	5.0	9.0	13.1
MIL	3.6	6.1	8.6
APT	0.8	1.2	1.7
NM	0.5	0.9	1.2
MET	0.2	0.2	0.2

Figure 13. Total cumulative investments per Stakeholder for SESAR Phases A to C – manned aviation

- ANSPs invest in the order of EUR 13.1 billion with a considerable level of uncertainty because of the anticipated need to adapt to the future paradigm of TBO and virtualisation.
- Airspace users, including scheduled airlines, business aviation, general aviation and rotorcraft, foresee investments of around EUR 9.0 billion. Most of their upgrades are expected in phases B and C, adding more uncertainty to their cost assessment.
- Military have applied a top-down approach to estimate their costs which are in the region of EUR 6.1 billion.

Investments for airports, Network Manager and MET providers are of a smaller order of magnitude, as expected.

4.1.2.1 Phases A to C: main differences Master Plan 2015 vs Master Plan 2020

Figure 31 in the Master Plan 2020 document is further explained in Table 4 below and compared with previous cost estimations in Master Plan 2015. Values shown are the Median in MP2015 and the Median in Option 1 for MP2020.

Table 4: Summary of investment differences – Per Stakeholder

(billion EUR)	MP2015	MP2020	Delta	What has changed between MP2015 and MP2020?
ANSPs	12.7	13.1	+0.4	• ANSPs need to invest in GNSS augmentation ground stations[14] as well as related procedures for development and training, etc. The related cost values, including those for Scheduled Airlines below, come from recent CBA work and therefore, were not available in 2015.
AU	5.8	9.0	+2.1	• The Business Aviation, Rotorcraft and General Aviation stakeholders have increased their investments, considering, among other elements, the avionics roadmaps and the integration of drones into airspace where they currently operate. • Scheduled Airlines need to equip their airframes with multi-mode receivers as well as provide related training for multi constellation GNSS related aspects
MIL	1.4	6.1	+4.7	• MIL have used their experience gained from the PCP to improve their previous estimates (already reported as underestimated in MP Edition 2015).
APT	1.3	1.3	-	• No change
NM	0.8	0.9	+0.1	• Update following better cost estimates.
MET	0.2	0.2	-	• No change
TOTAL Phases A to C	**22.1**	**30.5**	**8.4**	

4.1.2.2 Phase D: cost approach

The expected features of the digital ecosystem in Phase D – scalability, automation and defragmentation of service provision – are expected to drive the cost of development and deployment of new systems downwards. While it is not possible to have a clear view of the solutions, systems and technologies that will be needed, it has been possible to approximate investment values for Option 1 and Option 2. As these values are high-level and have a long time horizon, there is an inherent low confidence in their accuracy.

A value of EUR 8.4 billion was used for Option 2 (full deployment by 2050) while option 1 (full deployment by 2040) is lower; by 25% to EUR 6.3 billion. This reduction reflects cost savings seen in other industries where coordination and agile principles are implemented. The values in Table 5 below are aligned with information provided in Figure 30 in the Master Plan 2020.

[14] At some locations Airports may also invest in the augmentation ground stations, however, all costs are allocated to ANSPs for simplicity.

Table 5: Phase D cost approach

(billion EUR)	MP2015	MP2020			
	Median	Minimum Option 1	Median Option 1	Median Option 2	Maximum Option 2
TOTAL Phases A to C	22.0	18.1	30.5	30.5	43.1
Phase D	-	5.0	6.3	8.4	10.0
Total SESAR Vision Phases A to D	-	23.1	36.8	38.9	53.1

4.1.3 Investments for Phases A to C – per stakeholder

The investment costs for Phases A to C (up to 2035) can be analysed per stakeholder type.

4.1.3.1 ANSPs

The overall ANSP investment value for Phases A to C is EUR 13 083 million. This corresponds to EUR 12 730 million in the MP2015. The difference of EUR 354 million is due to:

- the inclusion of GNSS augmentation systems related costs in SESAR 1 that were not available for the Master Plan 2015.
- minor revisions in the numbers for investments related to terminal airspace which are considered for SESAR 2020 in the Master Plan 2020

Table 6: Breakdown of Master Plan 2015 and Master Plan 2020 investment costs for ANSPs

million EUR	MP2015	MP2020	Delta
SESAR 1	4 715	4 846	+131
SESAR 2020	8 015	8 238	+233
SESAR2020 Wave 1	2 975	3 053	+78
SESAR2020 Wave 2	5 040	5 185	+145
TOTAL Phases A to C	12 730	13 083	+354

ANSP costs were assessed in various exercises through bottom-up and top-down approaches involving ANSPs and their Ground Industry partners. Bottom-up approaches produced ranges of per-unit costs for control centres handling en-route and/or terminal airspace as well as those for towers (i.e. ANSP investments at Airports). The per-unit costs were combined with the relevant deployment assumptions which tended to focus on higher complexity locations. These bottom-up cost assessments have then been revised from a top-down perspective to take account of savings that could be made through value engineering, collaboration between industry and ANSPs and economies through delivering a co-ordinated programme of work throughout SESAR.

Table 7 shows the inputs underlying the SESAR 2020 costs[15].

Table 7: ANSP deployment locations and investments for SESAR 2020

SESAR 2020 Wave 1 / Wave 2 Implementation in:	Number of units (deployment locations)	Per-unit cost (m EUR)	Total (m EUR)
ANSP investments at airports			
Very High Complexity / High Complexity Tower	31	80	2 480
Medium Complexity Tower	8	60	480
Low Complexity Tower	16	40	640
Control centres handling en-route and/or terminal airspace			
Very High Complexity en-route airspace	9	160	1 440
High / Medium Complexity en-route airspace	47	25	1 175
Low Complexity en-route airspace	11	23	248
Very High / High Complexity terminal airspace	20	35	700
Medium Complexity terminal airspace	42	18	735
Low Complexity terminal airspace	40	8.5	340
		TOTAL	**8 238**

4.1.3.2 Airspace Users

The overall civil Airspace User (AU) investment value for Phases A to C is EUR 8 968 million. This corresponds to EUR 5 760 million in the Master Plan 2015. These values include Scheduled Airlines (Mainline and Regional), Business Aviation, Rotorcraft and General Aviation. The division of EUR 3 208 million difference across the Airspace Users is shown in the final four columns with further explanation in the following AU sections.

Table 8: AU – All types: Breakdown of MP2015 and MP2020 investment costs

EUR million	MP2015	MP2020	Delta	SA	BA	RC	GA
SESAR 1	**1 496**	**1 881**	**+384**	+773	-113	-	-277
SESAR 2020	**4 264**	**7 088**	**+2 824**	-338	+1 680	+798	+684
SESAR2020 Wave 1	1 923	3 155	+1 232	-178	+790	+278	+342
SESAR2020 Wave 2	2 341	3 933	+1 592	-160	+890	+520	+342
TOTAL Phases A to C	**5 760**	**8 968**	**+3 208**	+435	+1 567	+798	+407

[15] Noting that deployments for local development of traffic were not included (e.g. ANSP investments at secondary airports) and that Remote Tower implementations were maintained in line with the Master Plan 2015 assumptions.

The following values are those used in the SESAR 2020 (Wave 1 and Wave 2) investment calculations.

Table 9: AU – SA and BA Retrofit and Forward Fit costs per aircraft

SESAR 2020 Wave 1 / Wave 2 (in million EUR)	Scheduled Airlines		Business Aviation
	Mainline	Regional	
Retrofit Cost per aircraft	1.0	1.0	1.0
Forward Fit Cost per aircraft	0.5	0.5	0.5

The investment calculations consider only the number of aircraft that need to be forward fitted and retrofitted to meet the equipage requirement which was 50% equipage by the end of the deployment period. For the calculations, it is assumed that new aircraft deliveries during the deployment period will be equipped. If this is not sufficient to reach the 50% equipage then the number of required retrofits during the deployment period is calculated and their costs included.

4.1.3.2.1 Scheduled Airlines

The overall Scheduled Airline (Mainline and Regional) investment value for Phases A to C is EUR 5 423 million. This corresponds to EUR 4 988 million in the Master Plan 2015. The difference of EUR 435 million is due to the inclusion of multi-mode receiver related costs in the SESAR 1 (non-PCP) values along with the impact of revised fleet values on the SESAR 2020 values.

Table 10: AU – SA: Breakdown of MP2015 and MP2020 investment costs

(million EUR)	MP2015	MP2020	Delta
SESAR 1	**901**	**1 674**	**+773**
SESAR 2020	**4 087**	**3 749**	**-338**
SESAR 2020 Wave 1	1 847	1 669	-178
SESAR 2020 Wave 2	2 240	2 080	-160
TOTAL Phases A to C	**4 988**	**5 423**	**435**

Scheduled Airlines optimised their investments by evaluating the fleet to consider the anticipated age of aircraft and the regularity of their flights in European airspace, as these factors impact the number of aircraft to be retrofitted and hence retrofit costs. The number of aircraft to be forward fitted was estimated based on assumptions relating to the evolution of the fleet and target equipage rate needed to achieve required performance.

The airborne costs were based on the Airbus Single Aisle family for Scheduled Airlines (Mainline) and on the ATR-72/ATR-42 family for Scheduled Airlines (Regional). SA costs also include investments at Flight/Airline Operation Centres, as well as training costs (e.g. simulator or computer-based training), other ground costs (e.g. new certificates) and changes in operating costs.

The SESAR 2020 airborne investments cover elements of the Master Plan 2020 edition avionics roadmap including upgrades to the fleet to incorporate CNS upgrades, ACAS Xo, ASAS/A-IM and FMS upgrades (PBN/4D etc.).

Reviewing the assumptions for Master Plan 2020 has led to higher per-unit airborne costs for SESAR 2020 in comparison to the values used in Master Plan 2015. However, the review of the fleet assumptions led to a reduction in the number of aircraft to be equipped and the overall cost has remained stable.

Figure 14 shows the values (figures shown for every five years) used for the Scheduled Airline fleet, this reflects 5 482 Mainline aircraft and 989 Regional aircraft.

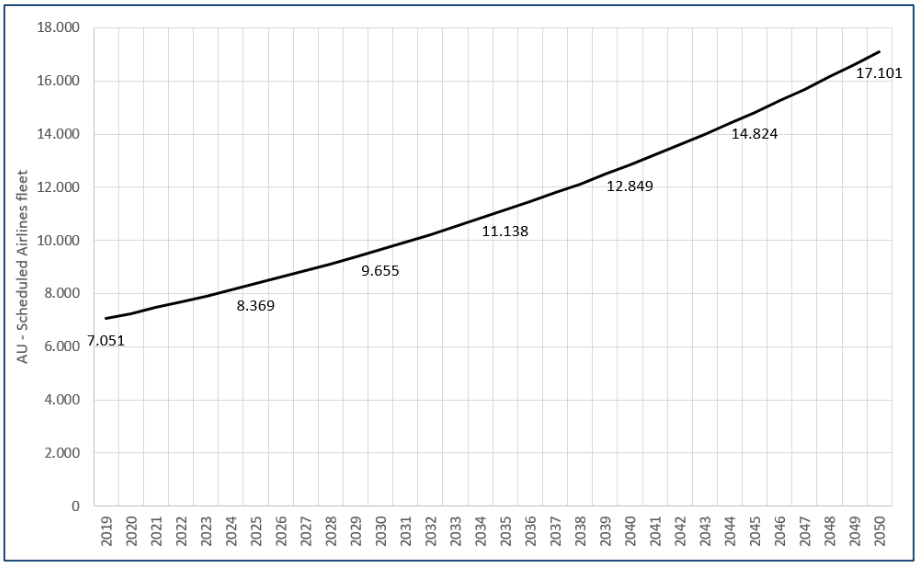

Figure 14. Scheduled Aviation (Mainline and Regional) fleet

4.1.3.2.2 Business Aviation

The overall Business Aviation (BA) investment value for Phases A to C is EUR 2 011 million. This corresponds to EUR 443 million in the Master Plan 2015. The difference of EUR 1 568 million is due to the alignment of SESAR 2020 BA per-unit costs and equipage assumptions with those of Scheduled Airlines[16].

Table 11: AU – BA: Breakdown of MP2015 and MP2020 investment costs

EUR million	MP2015	MP2020	Delta
SESAR 1	**318**	**206**	**-112**
SESAR 2020	**125**	**1 805**	**+1 680**
SESAR 2020 Wave 1	54	844	+790
SESAR 2020 Wave 2	71	961	+890
TOTAL Phases A to C	**443**	**2 011**	**+1 568**

[16] Noting that BA cost experts cite cases where BA per-unit costs are actually higher than those for SA due, in part, to the smaller number of aircraft across which manufacturers recover the development costs.

Business Aviation fleet values, see Figure 15, were used to calculate the forward fit and retrofit costs needed to equip 50% of the fleet. The per-unit investment values and the deployment periods were aligned with those used for SA.

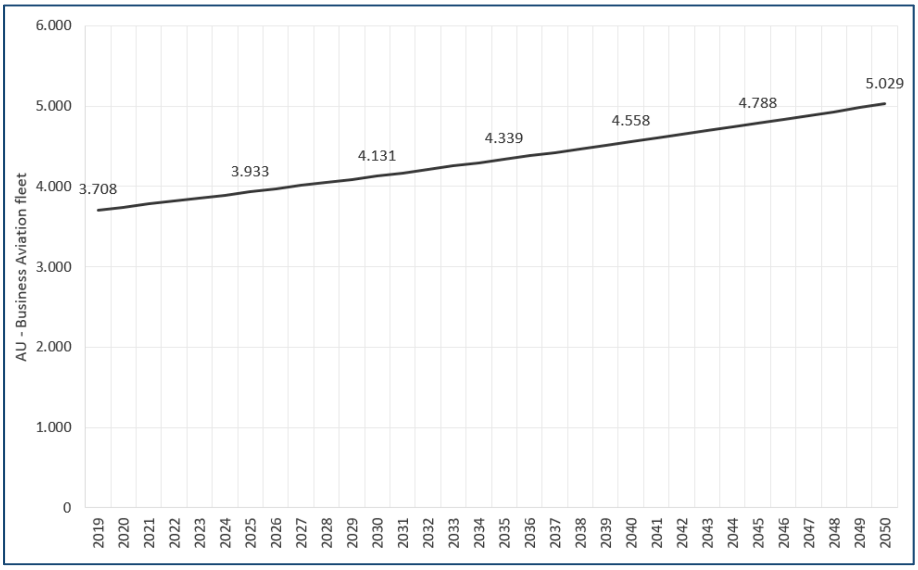

Figure 15. Business Aviation fleet

The European business aviation fleet is extremely varied and customised to operate varied missions in different ATM environments with the same aircraft. Therefore, there is a need for BA aircraft to be equipped with the latest SESAR technologies in order to maintain their current level of access to airports and airspace. Considering that the BA fleet is relatively young and that life expectancy of a business aircraft is in the range of 40-50 years, this implies that a significant number of aircraft will need to be retrofitted with various avionics. Additionally, the Business Aviation fleet flies five to ten times less than the Scheduled Airline fleet, which leads to complexity in calculation of depreciation for avionics and for multiple avionics retrofit programmes, over its lifespan.

4.1.3.2.3 Rotorcraft

The overall Rotorcraft (RC) investment value for Phases A to C is EUR 850 million, which includes training. This corresponds to EUR 52 million in the Master Plan 2015. The difference of EUR 798 million is due to a significant underestimation of Rotorcraft related costs in the Master Plan 2015. One reason for this is that the operating environments considered in Master Plan 2015 mainly focused on higher complexity environments while Rotorcraft operations usually take place in lower complexity environments.

Table 12: AU – RC: Breakdown of MP2015 and MP2020 investment costs

(million EUR)	MP2015	MP2020	Delta
SESAR 1	-	-	-
SESAR 2020	52	850	+798
SESAR 2020 Wave 1	22	300	+278
SESAR 2020 Wave 2	30	550	+520
TOTAL Phases A to C	**52**	**850**	**+798**

The Rotorcraft considered here include IFR Rotorcraft (twin-engine) only. The fleet is around 2000 airframes with an expected growth rate of 1.8% year. Single-engine RC are included with General Aviation.

These investments will enable RC to be compliant with new CNS requirements and standards (according to the CNS roadmap) including digitalization, automation and additional services enabling integration with drone operations. In addition, the investments will provide the required number of technological enablers as well as airspace and ground infrastructures needed to secure the implementation of RC specific concepts, such as Low Level PBN Routes, Point in Space procedures and simultaneous non interfering operations across Europe.

4.1.3.2.4 General Aviation

The overall General Aviation (GA) investment value for Phases A to C is EUR 684 million. This corresponds to EUR 277 million in the Master Plan 2015. The difference of EUR 407 million is due to the need for GA IFR and VFR to equip with GA specific SESAR related technologies, especially with the fresh focus on the integration of drones.

Table 13: AU – GA: Breakdown of MP2015 and MP2020 investment costs

(million EUR)	MP2015	MP2020	Delta
SESAR 1	**277**	**-**	**-277**
SESAR 2020	**-**	**684**	**+684**
SESAR 2020 Wave 1	-	342	+342
SESAR 2020 Wave 2	-	342	+342
TOTAL Phases A to C	**277**	**684**	**+407**

The GA fleet is made up of different types of airframes; fixed-wing (IFR/VFR), rotorcraft (VFR), gliders, microlights, paragliders, hang-gliders and balloons. When all the types are added together, the current fleet is around 160 thousands units with an expected growth rate of around 2%.

The revised GA cost assessment takes into consideration that Master Plan 2020 now includes the drone community and therefore includes the impact of GA of drones operating in Class G airspace. To reflect this, the GA cost assessment has accounted for wider 'electronic conspicuity' across the GA fleet (considering appropriate equipage rates for IFR and VFR depending on the technology). The objective of equipage is to ensure that data will be available to all operators to provide a view of other users operating in their vicinity.

The costs include only essential technologies deemed necessary to deliver network benefits, although only small direct benefit for GA is foreseen. In establishing costs, GA compliance is assumed with essential technologies (e.g. ADS-B out) despite the absence of any existing regulatory instrument making such demands on the majority of GA aircraft. It is expected that certification standards will be proportionate, thereby assisting in cost reduction. Innovative and tailored solutions will be required for smaller GA aircraft to support the objectives of required technologies (e.g. datalink, i4D etc.). It should be noted that GA technical solutions are not yet in existence nor in development within Europe to address the technological needs.

4.1.3.3 Military

The Master Plan 2015 highlighted that Military investment values included were significantly underestimated[17]. This has been supported by the costs of recent, current and proposed SES/SESAR military implementation projects. Based on these assessments the Military investment costs included in the Master Plan 2020 for each Phase have been set at 20% of the civilian stakeholder values.

The overall Military investment value for Phases A to C is EUR 6 089 million. This value was EUR 1 367 million in the Master Plan 2015. The difference of EUR 4 722 million is broken down below.

Table 14: MIL: Breakdown of MP2015 and MP2020 investment costs

(million EUR)	MP2015	MP2020	Delta
SESAR 1	**209**	**1 986**	+1 777
SESAR 2020	**1 158**	**4 103**	**+2 945**
SESAR 2020 Wave 1	75	1 658	+1 583
SESAR 2020 Wave 2	1 083	2 445	+1 362
TOTAL Phases A to C	**1 367**	**6 089**	**+4 722**

4.1.3.4 Airports

The overall Airport investment value for Phases A to C is EUR 1 246 million. This is equal to that used in Master Plan 2015.

Table 15: APT: Breakdown of MP2015 and MP2020 investment costs

(million EUR)	MP2015	MP2020	Delta
SESAR 1	**477**	**477**	-
SESAR 2020	**769**	**769**	**-**
SESAR 2020 Wave 1	256	256	-
SESAR 2020 Wave 2	513	513	-
TOTAL Phases A to C	**1 246**	**1 246**	**-**

[17] See footnote (51) in the MP Edition 2015

Table 16 shows the inputs underlying the SESAR 2020 costs.

Table 16: Airport deployment locations considered for SESAR 2020 in Master Plan 2020

SESAR 2020 Wave 1 / Wave 2 Implementation in:	Number of units (deployment locations)	Unit cost (million EUR)	Total (million EUR)
Airport investments			
Very Large and Large Airport	31	20	620
Medium Airport	8	7	56
Small Airport	31	3	93
		Total	**769**

4.1.3.5 Network Manager

The overall Network Manager (NM) investment value for Phases A to C is EUR 877 million. This corresponds to EUR 757 million in the Master Plan 2015. The difference of EUR 120 million is associated with SESAR 2020 related costs as shown below in Table 17:

Table 17: NM: Breakdown of MP2015 and MP2020 investment costs

(million EUR)	MP2015	MP2020	Delta
SESAR 1	**357**	**357**	-
SESAR 2020	**400**	**520**	**+120**
SESAR2020 Wave 1	50	250	+200
SESAR2020 Wave 2	350	270	-80
TOTAL Phases A to C	**757**	**877**	**+120**

For SESAR 1, the cost of the current and planned status of PCP implementation in NM is in line with the PCP CBA estimation.

Network Manager costs for SESAR 1 Non-PCP and for SESAR 2020 were assessed using a bottom-up approach, combining inputs and expert judgement from NM staff, operational stakeholders and manufacturers. Costs were provided for Network Manager tasks relevant to SESAR/SES. The bottom-up costs were revised from a top-down perspective to take into account savings that could be made through value engineering, and collaboration between operational stakeholders. These values were reviewed for Master Plan 2020 and NM experts updated the values based on the maturity of the elements that NM needs to deploy to make the solutions operational. Due to the long time horizon there is still significant uncertainty attached to the value of the investments as well as to their precise timing.

A general caveat for NM costs is that the future role of NM may evolve with time and the cost of future changes to NM functions is therefore not included in the NM costs provided here.

4.1.3.6 Meteorological service providers

Meteorological Service Providers (MET) are included in the PCP CBA with respect to iSWIM functionality, with a cost of EUR 201 million. This stakeholder was not included in subsequent SESAR 1 (non-PCP) or SESAR 2020 CBAs.

Table 18: MET: Breakdown of MP2015 and MP2020 investment costs

(million EUR)	MP2015	MP2020	Delta
SESAR 1	**201**	**201**	-
SESAR 2020	**-**	**-**	**-**
SESAR2020 Wave 1	-	-	-
SESAR2020 Wave 2	-	-	-
TOTAL Phases A to C	**201**	**201**	**-**

4.2 Holistic view on benefits

This chapter encapsulates the methodology and assumptions taken for monetisation of the performance view in section 2 of this document. It explains the benefits described in section 6.1 – Holistic View of SESAR net benefits for manned aviation – of the Master Plan Edition 2020 (MP2020).

While Chapter 2 of this document provides the overall performance ambition for the 2035 horizon, this section provides a view on the benefits of SESAR for the 2050 horizon. The benefits are expressed as a difference in performance between a “Without SESAR” scenario and a “With SESAR” vision up to 2050.

Unless otherwise explained, figures provided are undiscounted in EUR billion or EUR million. Any deviation in the total sum is due to rounding-up of decimal values.

4.2.1 Different scope Master Plan 2015 vs Master Plan 2020

The scope of benefits generated by SESAR, considered in the Master Plan 2020, have grown noticeably in comparison to the evaluations performed in the Master Plan 2015 Edition. Whereas in the 2015 campaign effort was focused on understanding the SESAR contribution to performance ambition, the 2020 campaign has focussed on providing a comprehensive economic assessment. In practical terms, this means that only one type of impact was considered in Master Plan 2015 – direct impact on the ATM value chain – whereas in the Master Plan 2020 campaign up to three types of impact have been measured. Furthermore, the monetisation factors have been updated with the most recent inputs. Figure 16 below shows the extended scope of Master Plan 2020 compared with that of Master Plan 2015.

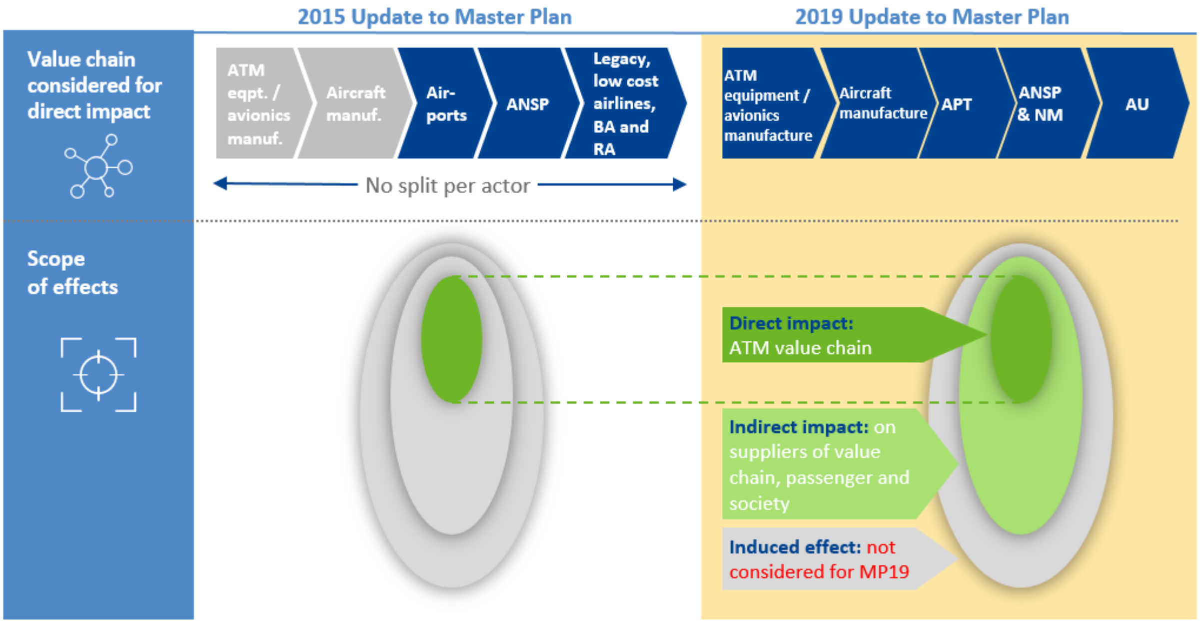

Figure 16. Scope of benefits considered – Master Plan 2015 vs Master Plan 2020

4.2.2 What economic effects have been accounted as benefits? And which stakeholders benefit from them?

The economic value created by SESAR and stakeholders considered for the monetisation of the holistic benefits are summarised in Table 19 below. The Business View monetises two types of quantified impacts which are splitted into 3 main drivers.

1. **Direct impact on the ATM value chain.** This includes total gross domestic product (GDP) created by SESAR along with direct value chain (ATM equipment manufacturers, aircraft manufacturers, military[18], airspace users, ANSPs, NM and airports). It quantifies value created through additional activities enabled by SESAR (both through capacity increase and investments linked to the various solutions). The direct impact considers cost savings for the industry (cost efficiency leading to lower ANS unit costs per flight, operational efficiency, and environmental efficiency). It also takes into account SESAR solutions that have safety as a primary objective with implications on costs and benefits, although the latter se are not monetised.
2. **Indirect impact on suppliers** . This includes the total GDP created by increased activity of those supplying the direct value chain. This counts, for example, the GDP created by airline suppliers, following direct impact on airlines described above.
3. **Indirect impact on passenger and society**. This includes quantified impact on passengers and society, driven by SESAR. Passengers benefit from additional flights and time savings (driven by lower delays and shorter flights). Other quantified SESAR impacts included lower air pollution and climate change (driven by lower fuel burn), per flight.

18 While the military is one of the actors with a direct economic impact, this impact has been limited to industry manufacturers producing military products (aircraft and/or avionics) due to limited information available on the quantitative connection of the military to direct GDP

There are other impacts SESAR is expected to bring that have not been monetised . For a non-exhaustive list please consult section 6.1 – Holistic View of SESAR net benefits for manned aviation – of the Master Plan 2020 [1].

When analysing the full economic impact on industry/economic sector, some macroeconomic studies consider additional types of effect – known as **induced effects**. These correspond to effects beyond direct value chain and the indirect effect on suppliers and citizens. Induced effects typically include increased consumer spending. As already highlighted in Figure 16 please note that induced effects have not been assessed in the Master Plan 2020 exercise.

Table 19: Overview of stakeholders considered in the Master Plan 2020 Business View model – Benefits

Impact type	Driver		Stakeholders considered
Direct	A	**Benefits to the ATM Value Chain**	
	A.1	Additional activities enabled by SESAR	• ATM equipment and Avionics manufacturers • Aircraft manufacturers • ANSPs • AU • MIL • APT • NM • MET
	A.1.1	Profit generated by SESAR	
	A.1.2	Labour cost generated by SESAR	
	A.2	Cost savings enabled by SESAR	
	A.3	Additional benefits delivered by Option 1	
Indirect	B	**Benefits for suppliers to the ATM Value Chain**	
	-	Benefits for the suppliers of the ATM Value Chain based on Multiplier Methodology	• ATM equipment and Avionics manufacturers • Aircraft manufacturers
	C	**Benefits for passengers and European citizens**	
	C.1	Reduction in climate change (CO_2) effect per flight	• Passenger • European citizens
	C.2	Reduction in air pollution per flight	
	C.3	Value of additional flights for passengers	
	C.4	Direct passenger time savings	

4.2.3 Monetisation of benefits

As described in section 4.2.2, SESAR benefits can be split in two main types of impact, direct or indirect. In this section, each impact category is explained using a two-step approach. First, the applied principles and formulae are described and second, the key results are presented.

4.2.3.1 Driver A – Direct benefits on the ATM value chain

Added value is assessed via two main drivers summarised in Figure 17 below:

1. The additional economic activity enabled by SESAR (e.g., additional flights) drives both, a profit increase across the value chain and an increase in total labour costs (e.g., airlines personnel).
2. The cost savings associated with SESAR as envisaged by the Performance Ambition. This can be a reduction in the cost of provision of service or monetisation of the operational improvements associated with SESAR.

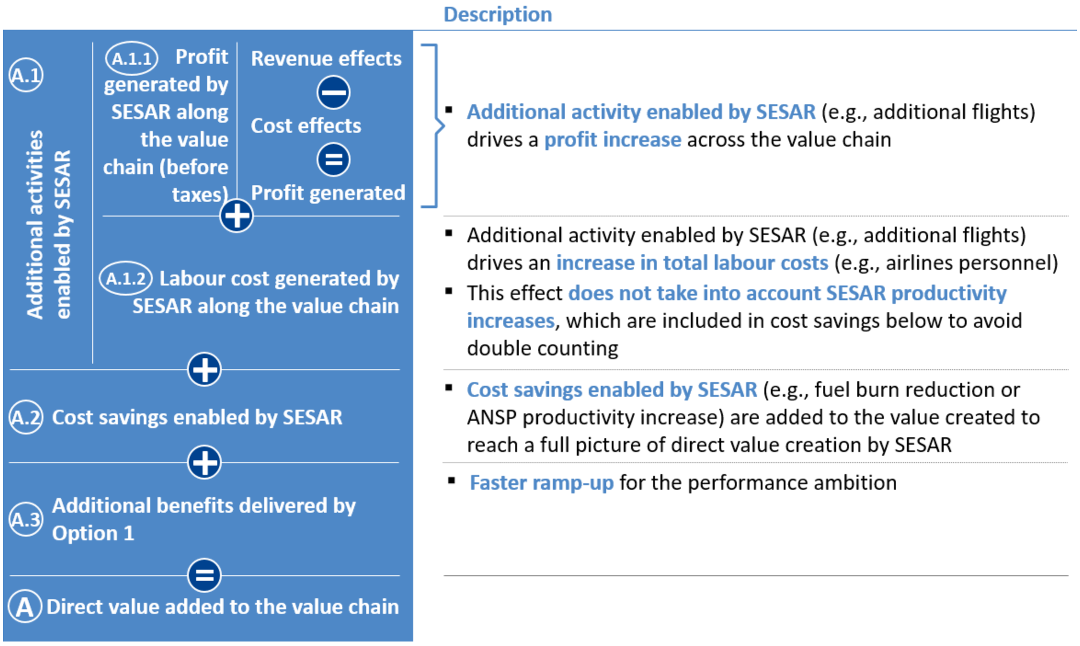

Figure 17. Driver A – Direct benefits on the ATM value chain – Economic principles

The overall results of monetisation benefits for Driver A are found in Figure 18 and the principles and formulae used are split into their constituents (Driver A.1 and A.2) in the following sub-sections.

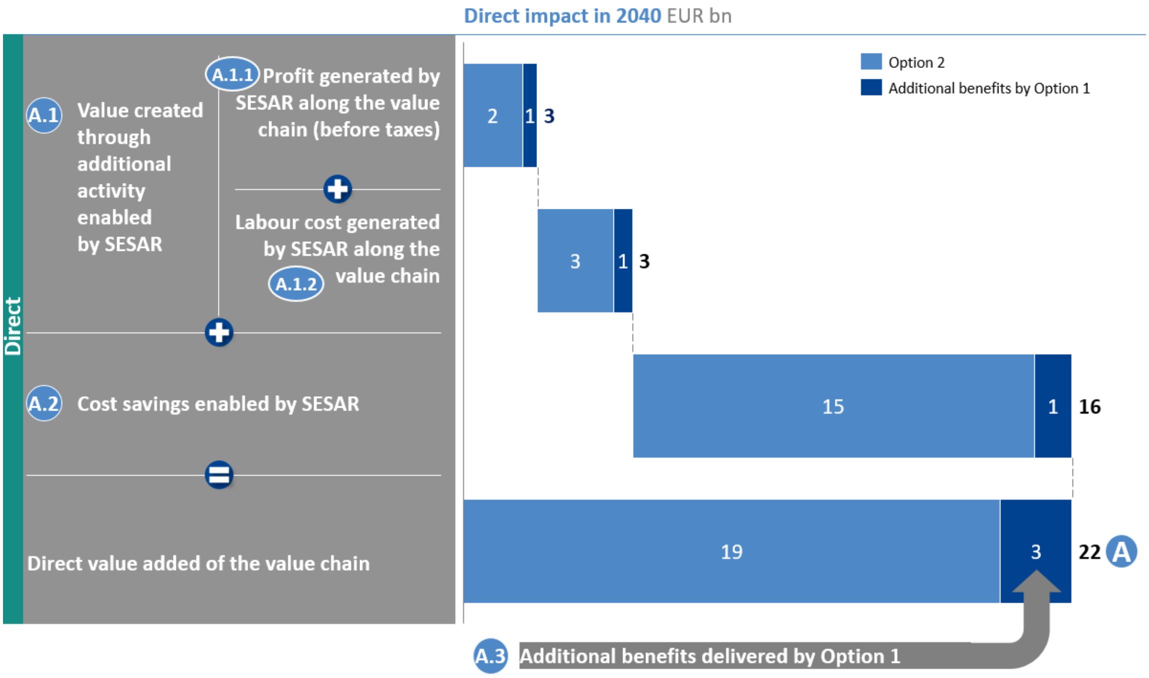

Figure 18. Driver A – Direct benefits on the ATM value chain – Key results

4.2.3.1.1 Driver A.1 – Value created through additional activities enabled by SESAR

Additional activities enabled by SESAR (e.g., additional flights) drives both a profit increase across the value chain and an increase in total labour costs (e.g., airlines personnel).

Driver A.1.1 – Profit generated by SESAR

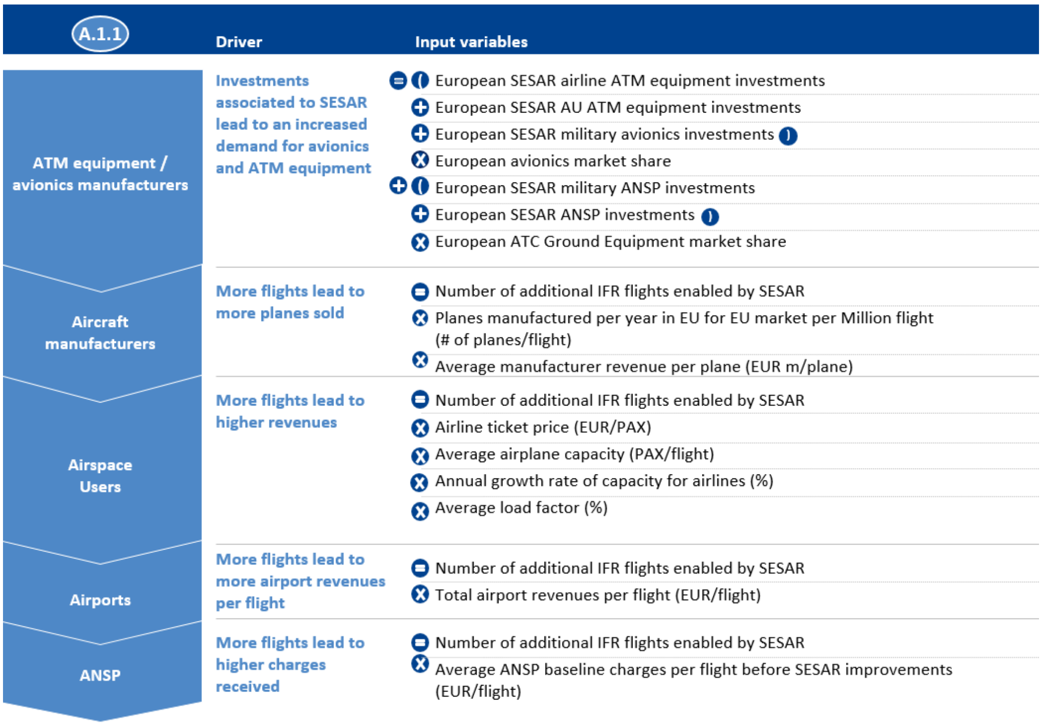

Figure 19. Driver A.1.1 – Direct benefits on the ATM value chain – Increased activity – Profit generated

Driver A.1.2 – Labour cost generated by SESAR

For labour costs, the effect does not take into account SESAR productivity increases, which are included in the section 0 ("Cost savings"). In Figure 20, the profit increases considered for each category of actors in the value chain can be found together with the formulas used.

A.1.2	Driver		Input variables
ATM equipment / avionics manufacturers	Investments associated to SESAR lead to an increased demand for avionics and ATM equipment so more jobs	=	Additional revenue generated
		×	Turnover per FTE in ATM eqpt/avionics industry
		×	ATM eqpt/avionics gross labour cost per employee
Aircraft manufacturers	More flights lead to more planes sold so more jobs	=	Number of additional IFR flights enabled by SESAR
		×	Planes manufactured per year in EU for EU market per million flight
		×	FTE required in manufacturing per plane manufactured per year
		×	Average gross labour cost for aircraft manufacturing industry
Airspace Users	More flights lead to more jobs	=	Number of additional IFR flights enabled by SESAR
		×	Share of AU type flights
		×	Airline FTE required per flight per year
		×	Airline employees average gross labour cost per year
Airports	More flights lead to more jobs	=	Number of additional IFR flights enabled by SESAR
		×	Airport FTE required per flight per year
		×	Airport labour cost per airport employee
ANSP	More flights lead to more jobs	=	Baseline ANSP labour cost – En-route vs. terminal airspace
		× (	1
		+	Growth in total number of flights including flights enabled by SESAR (%)
		×	Cost elasticity – En-route vs. terminal airspace)

Figure 20. Driver A.1.2 – Direct benefits on the ATM value chain – Increased activity – Labour

4.2.3.1.2 Driver A.2 – Cost savings enabled by SESAR

SESAR enables a series of operational improvements and cost savings that can be monetised.

Performance ambitions in the performance view chapter can be translated into cost savings through comparing a scenario with and without SESAR: flight time efficiency (excluding fuel savings), ANS cost efficiency, departure delay reduction, fuel efficiency and CO_2 emissions reduction.

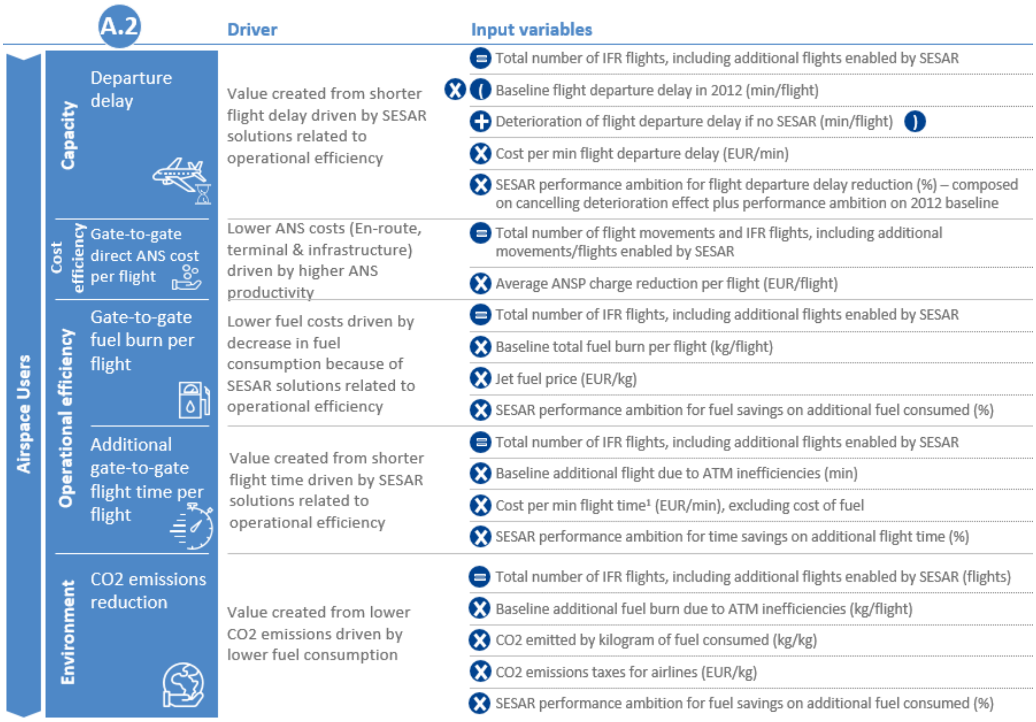

Figure 21. Driver A.2 – Direct benefits of the ATM value chain – Cost savings – Principles and formulae

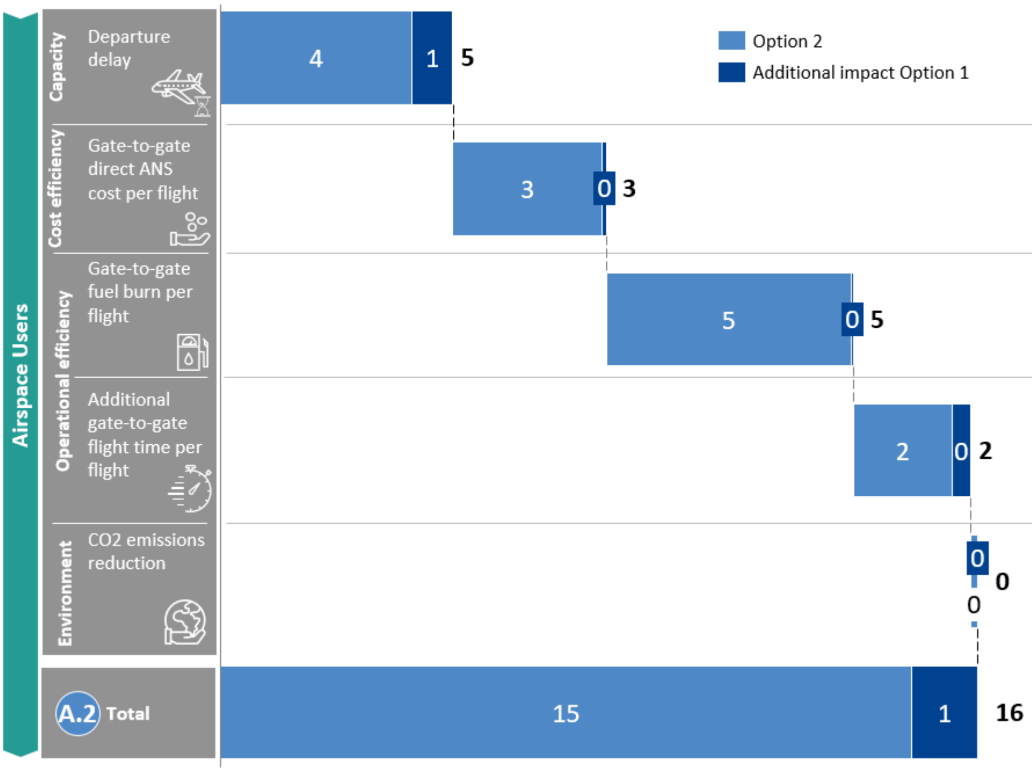

Figure 22. Driver A.2 – Direct benefits of the ATM value chain – Cost savings – Key results

4.2.3.1.3 Driver A.3 – Additional benefits delivered by Option 1

As explained in section 3, Option 1 allows accomplishment of phase D earlier, whilst securing rationalization opportunities for investments. This factor has been quantified in the holistic view assessment by assuming that the ramp-up to end-state will be completed by 2040 instead of 2050 (including increased ANS cost efficiency, fuel burn and flight time savings, departure delay, additional flights at congested airports) and that the total amount of phase D investments will be 25% lower than for Option 2, through increased rationalization. Additionally, Option 1 is expected to unlock full value associated with drones and new mobility services. This has been quantified assuming a freeze in benefits 2035-2045 to account for slower uptake of SESAR deployments in Option 2. From 2045, Option 2 benefits would follow Option 1 uptake from 2035 onwards.

4.2.3.2 Driver B – Indirect benefits for suppliers to the ATM value chain

4.2.3.2.1 Principles and formulae applied

The indirect benefits for suppliers to the ATM value chain includes total GDP created by increased activity of those supplying the direct value chain. In order to capture the indirect impact of SESAR, the so-called GDP multiplier methodology based on OECD input-output tables is applied.

This multiplier represents change in GDP (i.e., value added) that occurs in all industries, for each additional unit value of gross output (e.g., sales or revenues) that is delivered to a final user by the focus industry. The scope of the analysis was EU-27 with the year for multipliers being 2011 and the source Eurostat.

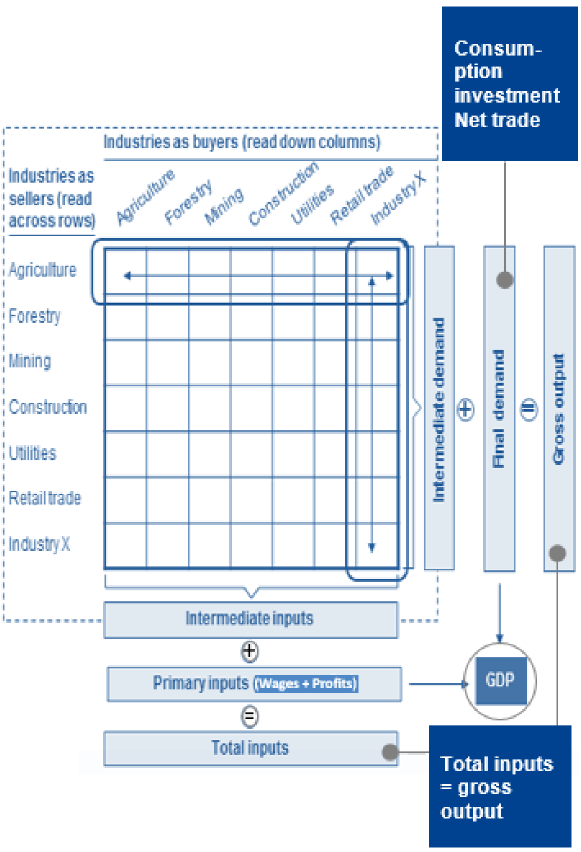

Figure 23. Illustrative input-output table

As illustrated in Figure 23, the input-output (IO) framework consists of tables or matrices that describe industry interactions including the buying and selling relationships between them and the product composition of industries. The tables show how industries are directly linked to each other and to the components of GDP (e.g., consumption, investment, trade). Looking down the columns of an IO table, the cost structure of an industry is described; the sales distribution of an industry is captured by looking across the rows.

Multipliers built from IO tables illustrate production changes in each industry, and which result from a production change in a single industry. With IO multipliers, not only the direct effect of a change in industry production is captured, but also the indirect effects are captured which can be traced all the way back through the supply chain.

The multiplier methodology applied is found in Figure 24. Two main drivers of additional activity that have been considered are: increased flights and increased investment in equipment.

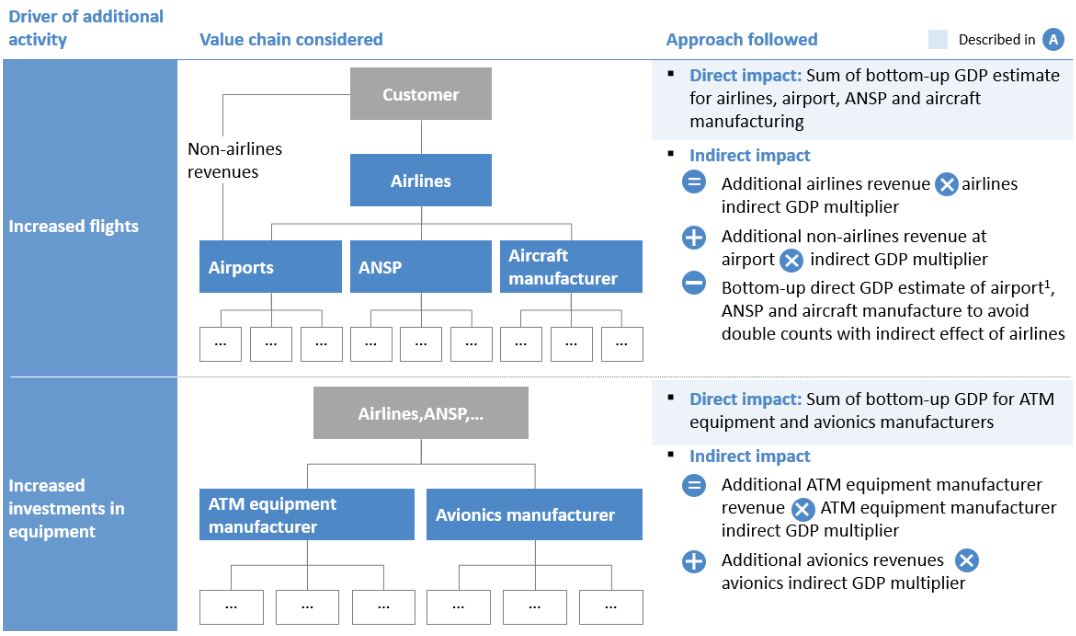

Figure 24. Multiplier methodology applied

4.2.3.2.2 Key results

The monetised value of indirect benefits due to the suppliers of ATM value chain can be translated from value added to GDP. Figure 25 summarises the values.

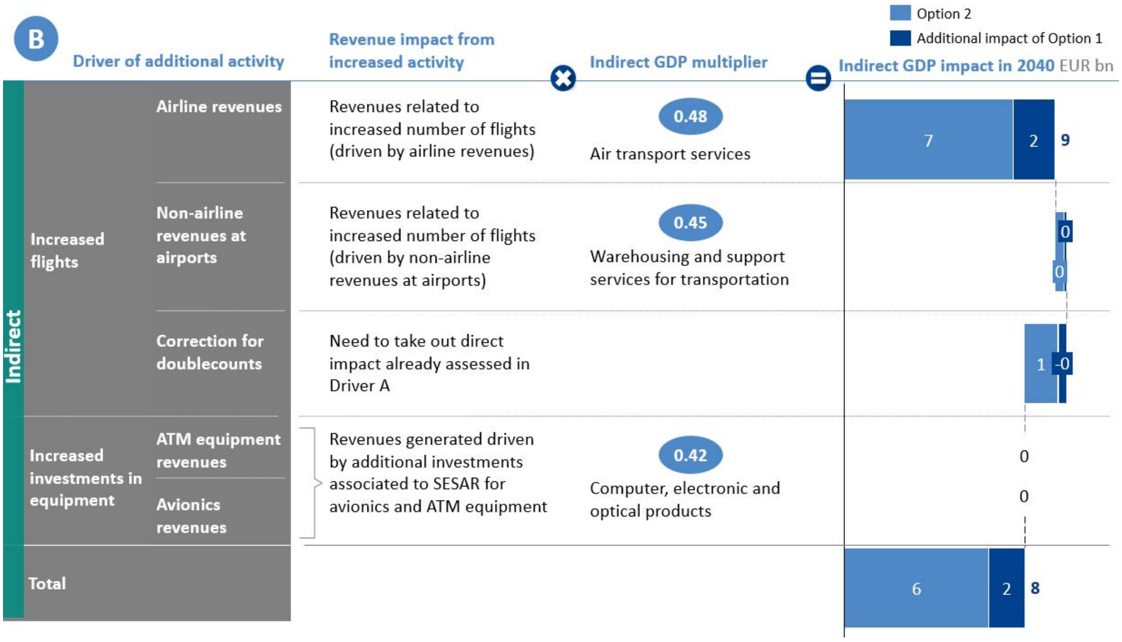

Figure 25. Indirect benefits for suppliers of the ATM value chain

4.2.3.3 Driver C - Indirect benefits for passengers and European citizens

Passengers benefit from the additional flights enabled (C.3) and time savings driven by lower delays and shorter flights (C.4). European society also benefits from lower air pollution (C.2) and lower climate change impact (C.3) - driven by lower fuel burn - per flight.

4.2.3.3.1 Principles and formulae applied

C	Driver	Input variables
Climate change C.1	Decrease in CO_2 impact on society driven by decrease in fuel consumption due to SESAR solutions related to operational efficiency	Total number of IFR flights, including additional flights enabled by SESAR (# flight) Cost for society of CO2 per flight (EUR/flight) SESAR performance ambition for fuel savings[1] (%)
	Increase in CO_2 costs due to an increase of flights enabled by SESAR	Number of additional flights enabled by SESAR (# flight) Cost for society of CO2 per flight (EUR/flight)
Air pollution C.2	Decrease in air pollution costs driven by decrease in diverse fuel related emissions related to operational efficiency	Total number of IFR flights, including additional flights enabled by SESAR (# flight) Cost of air pollution per flight for society (EUR/flight) SESAR performance ambition for fuel savings (%)
	Increase in air pollution costs due to an increase of flights enabled by SESAR	Number of additional IFR flights enabled by SESAR (# flight) Cost of air pollution per flight for society (EUR/flight)
Value of additional flights C.3	Passenger benefits from additional flights enabled by SESAR	Number of additional IFR flights enabled by SESAR (# flight) Value of an average passenger flight (EUR/flight)
Direct passenger time savings C.4	Effect of shorter flight time	Total number of IFR flights, including additional flights enabled by SESAR (# flight) Baseline additional time flown due to ATM inefficiencies (min/flight) Average plane capacity (pax/flight) Average load factor (%) Value of passenger time (EUR/passenger min) SESAR performance ambition for additional time savings (%)
	Effect of less departure delays	Total number of IFR flights, including additional flights enabled by SESAR (# flight) Baseline departure delay per flight 2012 (min/flight) Deterioration of flight departure delay if no SESAR (min/flight) Average plane capacity (pax/flight) Average load factor (%) Value of passenger time (EUR/passenger min) SESAR performance ambition for flight departure delay reduction (%) – composed of cancelling deterioration effect plus performance ambition on 2012 baseline

Figure 26. Driver C – Indirect benefits for passengers and European citizens – Economic principles

4.2.3.3.2 Key results

The projected saturation in a "Without SESAR" scenario has been monetised in the Business View. The estimated economic value in 2040 is described in Figure 27:

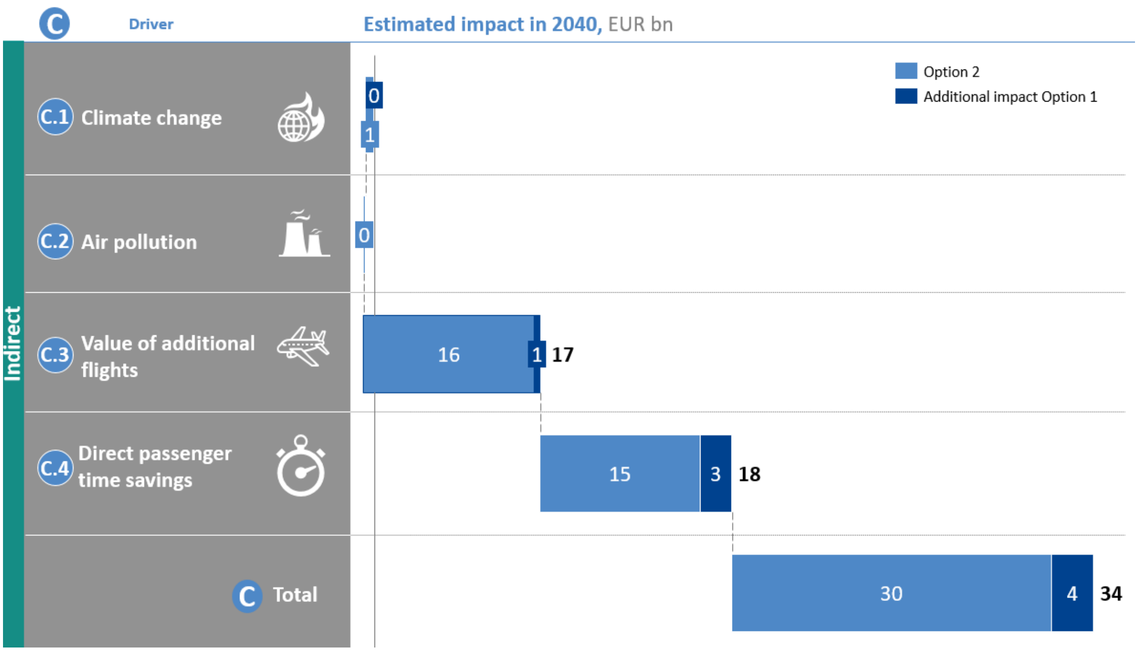

Figure 27. Driver C – Indirect benefits for passengers and European citizens – Key results

(C.1) Climate change

When looking at climate change (C.1) in Figure 27 above, the impact of SESAR in monetary terms appears as a negative value. This counterintuitive effect at first sight is explained by the nature of the two scenarios compared in the Business View.

As it has been described in section 4, without SESAR there is an irreparable loss to EU Economy as traffic could not continue growth after 2028. The additional flights that SESAR delivers by 2040 compared to a without SESAR scenario come at the cost of a slightly higher overall CO_2 emissions.

Whereas SESAR efficiency initiatives in fuel (2.4.1) and flight times (2.4.2) reduce the environmental effect of flights in the environment, just the ATM-related improvements are not enough to compensate the overall effect of the additional flights enabled in the with SESAR scenario.

The SESAR contribution to environmental efficiency is remarkable though. Without SESAR and – assuming we could satisfy the traffic demand – the Network would release additional CO_2 Tonnes. Below some figures to illustrate:

- Considering only emissions in 2040, SESAR saves 28 million CO_2 Tonnes to the European Network which is roughly comparable to the Tonnes of CO_2 equivalent per capita [11] produced by 3.2 million average EU28 citizens. A figure comparable to the population in the metropolitan area of a city like Madrid [12].
- If CO_2 savings delivered by SESAR are cumulated by 2040, this adds up to 400 million CO_2 Tonnes. This amount is equivalent to the emissions of around 46 million EU28 citizens in 2018. As an example, these savings would be comparable to the emissions for a whole year of the entire population of Spain or 4 years that of Belgium [13].

To summarise, although the increased traffic growth will increase overall CO_2 emissions, SESAR undoubtedly helps the predicted traffic growth to be more sustainable.

(C.2) Air pollution

Similar to CO_2 emissions, the big number of additional flights enabled by SESAR increases the overall amount of other pollutants, however the impact in monetary value in 2040 is of a small proportion, less than EUR 0.2 billion.

(C.3) Value of additional flights

The benefit of consumer/passenger having additional flights is assessed at a value of EUR 17 billion in 2040, compared to a situation where they cannot fly. The benefit input considered is conservative as the additional flights are all valued as domestic flights (consumer benefits of EUR 4667 per domestic flight) [5]. The value of an international flight between two EU Member States is roughly 5 times higher.

With SESAR we can accommodate 2.4 million additional flights by 2035 if compared with a situation where SESAR is not deployed. The figure becomes 3.6 million flights by 2040 and 6.7 by 2050.

(C.4) Direct passenger time savings:

The time savings generated by SESAR are valued in excess of EUR 18 billion per year in 2040 or roughly 870 million of minutes. The order of magnitude is better understood when compared with daily metrics easier to put in perspective. SESAR saved minutes in year 2040 are equivalent to the yearly working hours[19] of up to 9 000 EU citizens [12].

If we have a look at the cumulative minutes saved between 2012 and 2040, the figure reaches up to 7 billion of minutes. The minutes saved for passengers would account for the yearly working hours of up to 70 000 EU citizens.

4.2.4 Summary of benefits

When all benefits are combined, the overall picture for SESAR benefits is clear. The Figure 28 below shows the breakdown of annual benefits in 2035 and 2040, as shown in the Business View chapter for the Master Plan 2020 document.

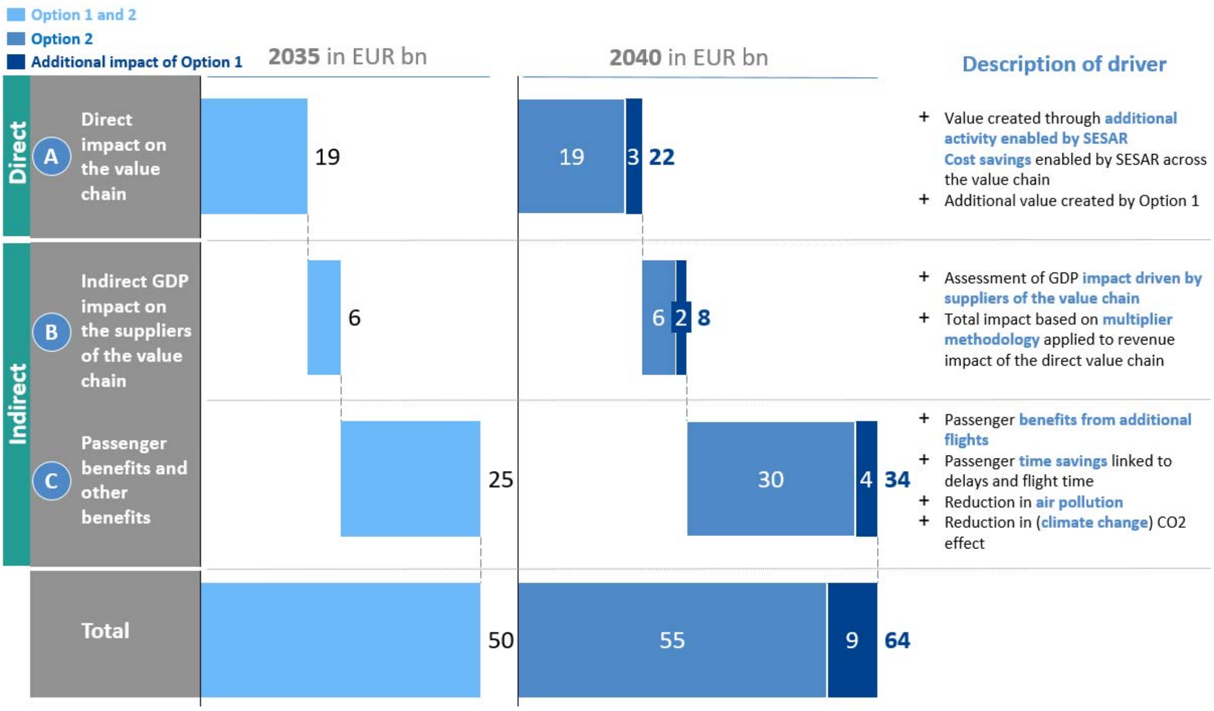

Figure 28. Breakdown of yearly benefits and description of benefit driver

[19] Assuming one year is 210 working days and a working day of 8 hours.

4.3 Net result of the Holistic view

Figure 29 below – corresponding to Figure 33 of the Master Plan 2020 – shows that SESAR delivers substantial value for Europe with required investment of just between 2 and 4% of the overall expected benefits. The magnitude of the expected benefits rapidly outgrow investments. Figure 29 also shows the additional value brought by Option 1 compared to Option 2 (blue shaded bars).

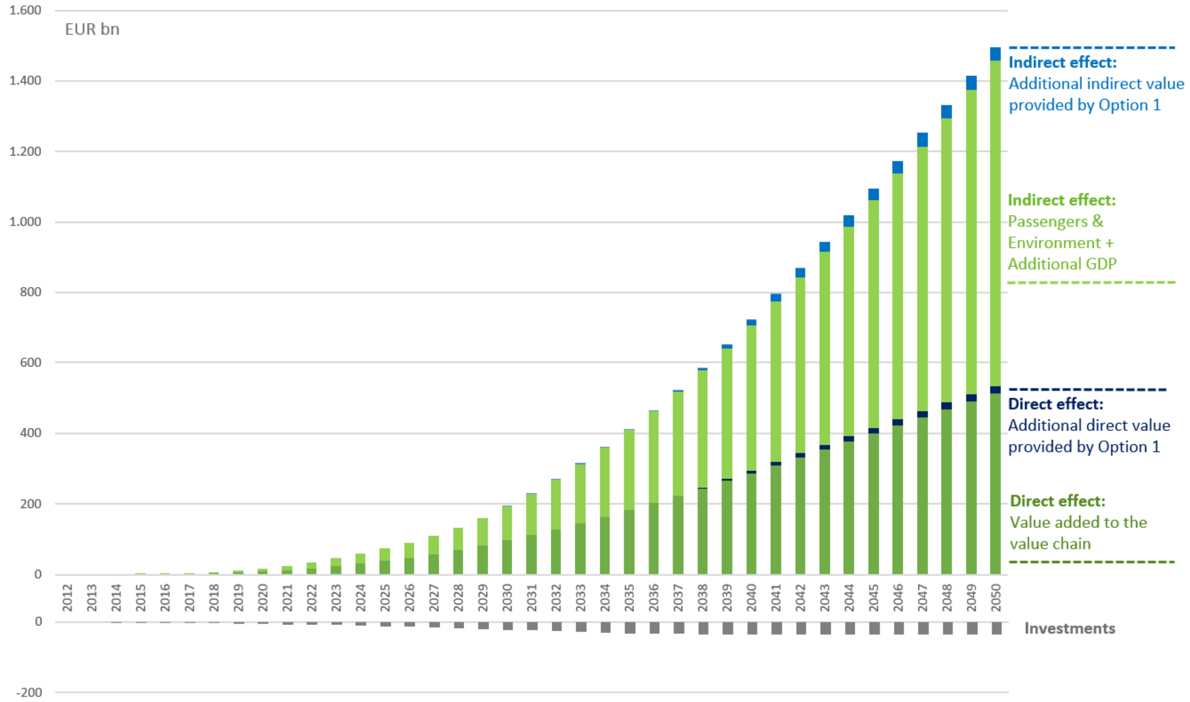

Figure 29 SESAR delivers significant value for Europe (undiscounted)

As presented in Figure 12 in section 4.1, the deployment of the full SESAR vision by 2040 (Option 1) necessitates a cumulative investment in the order of EUR 37 billion (median expectation). This investment would return performance benefits for European ATM industry and citizens as described in Table 20 below. The figures help to further clarify the differences between Option 1 and 2 as described in section *6.1.3 Net result of the Holistic view* of the Master Plan 2020 document are further. Only median values are shown and digits are rounded.

Table 20: SESAR delivers significant value for Europe – Underlying figures

	Option 1	Option 2
Total **investment**	37	39
Total benefits	1 440	1 383
A: Direct benefits on the ATM Value Chain	510	490
B: Indirect benefits for suppliers to the ATM value chain as additional GDP	170	160
C: Indirect benefits for passengers and European citizens	760	730
Net result	**1 403**	**1 344**
Net advantage for Option 1 (undiscounted)	**59**	-
NPV advantage for Option 1 (discounted)	**7**	

5 Holistic view of SESAR net benefits for drones

This chapter provides details of investment costs, benefit data and assumptions underpinning the results presented in section 6.2 – Holistic view of SESAR net benefits for drones – in the European ATM Master Plan Edition 2020 (MP2020) [1]. The information and level of detailed contained in this chapter is similar to that in the drones section of the Master Plan. For further clarification on the data and assumptions, please refer to the 2016 Drones Outlook Study [2].

This section provides an estimate of the investments required to support the safe and efficient deployment of drones[20] in Europe, in addition to the foreseen benefits arising from this future drone ecosystem. Both benefits and investment levels are covered in detail, with the benefits largely drawn from the previously released 2016 Drone Outlook Study[21].

European demand within the drone marketplace is valued at in excess of EUR 10 billion annually[22], in nominal terms, leading to a cumulative benefit of over EUR 140 billion by 2035[23]. Civil missions for government purposes and commercial businesses are expected to generate the majority of this value on the basis of multi-billion product and service industries. Defence and leisure industries will continue to contribute to this marketplace and remain a source of high value in the near term, representing together nearly EUR 2 billion in annual product-related turnover for the industry over the long term[24].

The minimum infrastructure investment required to ensure safety and unlock the value at stake for Europe is attainable through relatively low investments, leveraging existing infrastructure and scaling-up through investments in automated and smart systems. The assessment has identified key investments by stakeholders amounting to nearly EUR 4.5 billion by 2035 (Figure 30).

20 In line with the Drones Outlook Study and drone roadmap, this document uses the term “drones” as a generic term to cover all types of unmanned aircraft systems , be they remotely piloted (RPAS - remotely piloted aircraft system) or automated. By exception, the term RPAS may be used when a specific aspect of such vehicles (the fact that it is operated by a pilot instead of being automated) is addressed.

21 The 2016 Drone Outlook study can be found on the SESAR website

22 2016 Drone Outlook study, section 4.2 covering urban air mobility addition

23 Composed of commercial, governmental, and leisure drones (excluding defence)

24 Although the 2016 Drone Outlook Study assessed the economic impact for defence, as noted above, these figures have been excluded from the overall benefits illustrated throughout this document, as limited data was available on the investment needs and therefore illustrating full benefits without full anticipated investments was deemed misleading to represent.

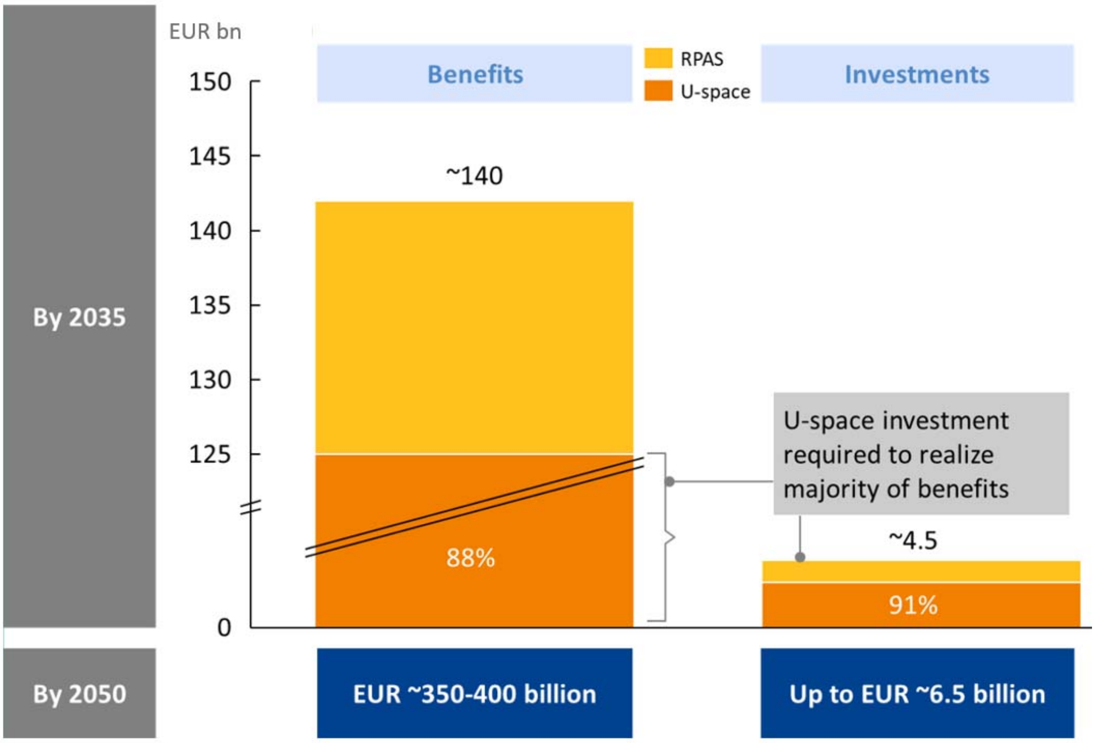

Figure 30 Overview of investment associated to the safe integration of drones and benefit levels25

The investment in U-space should be viewed as critical to unlocking the future potential benefits from the drone ecosystem, accounting for >85% of the anticipated benefit by 2035.

5.1 Holistic view on investments

This assessment aims to identify the required investments related to ATM for the safe and efficient integration of drones into European airspace. These are based on a number of assumptions that carry significant uncertainty. As a result, the overall investment figures should be interpreted in terms of their order of magnitude only.

The anticipated investments have been structured into three categories: Infrastructure and services, airborne investments and human resources. Investment levels associated to each category and subcategory are provided in Figure 31, in addition to a deployment view showing investments over time in Figure 32.

[25] Source: 2016 Drone Outlook Study; SESAR and stakeholder assessments. Investments cover only changes related to the safe integration of drones. In order to realise the benefits, additional investments that are not safety-related will have to be made by stakeholders but are not accounted for here (e.g. investments related to commercial service delivery).

Investment category and sub category	Investment (2035)
Infrastructure & Services	**~€ 3.4B**
ATC Interface & airport adaptations	~€ 1.28
Drone traffic management	~€ 0.9B
Protection of airports & sensitive sites	~€ 0.3B
Telecom & Satcom	~€ 0.6B
Geo-fencing database	~€ 0.1B
Enhanced data provision and info sharing	~€ 0.1B
Drone traffic management oversight	~€ 0.1B
e-registration and identification	~€ 0.1B
Systems Hardware and Software	**~€ 0.7B**
Drone systems	~€ 0.6B
On other aircraft	~€ 0.1B
Human resources	**~€ 0.4B**
Procedure development	~€ 0.3B
ATC personnel training	~€ 0.1B
Total	**~ € 4.5B** (~6.5B by 2050)

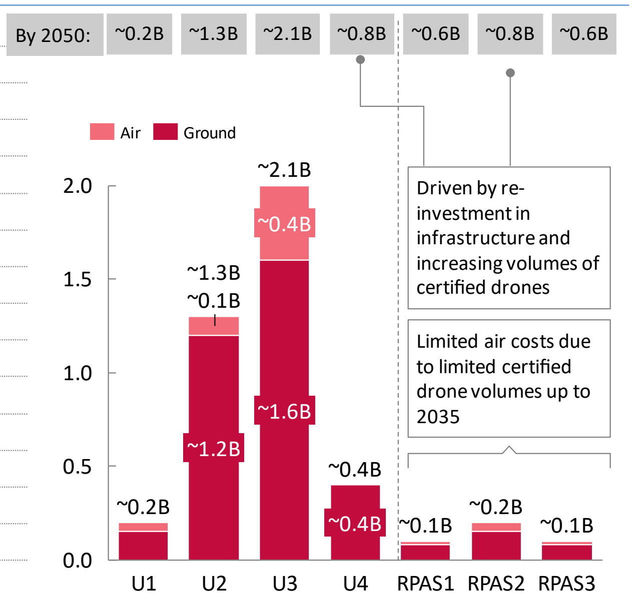

Figure 31 Breakdown of investment level by category and associated with each phase26

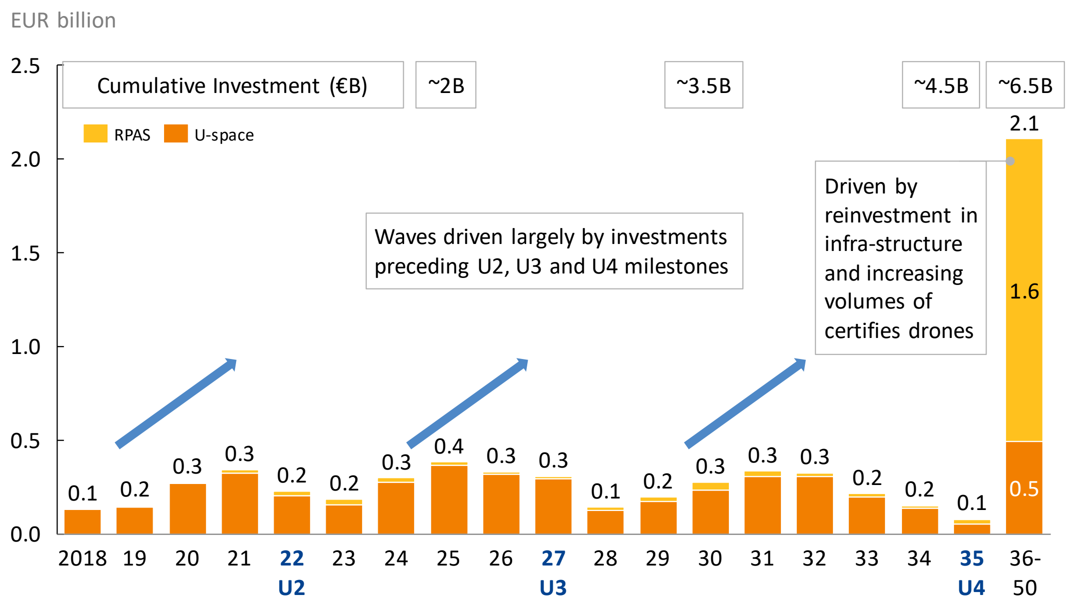

Figure 32 Investment needs of drone deployment in Europe (undiscounted)

For each identified investment sub-category, a high-level assessment and assumption base were developed to provide a view on the potential investment level for stakeholders. The split between the

26 Investment associated to a particular phase, regardless of the point in time the investment occurs (e.g. investment to support all U3 services regardless of whether investment started in U2

assessment and associated stakeholder is expected to evolve as the drone ecosystem maturity level increases. To facilitate this exercise, primary, secondary, and tertiary stakeholders were identified for each investment category and high-level assumptions drove a percentage split across the stakeholders. This assessment should not be interpreted as exhaustive or final, but rather as a directional view to be further refined.

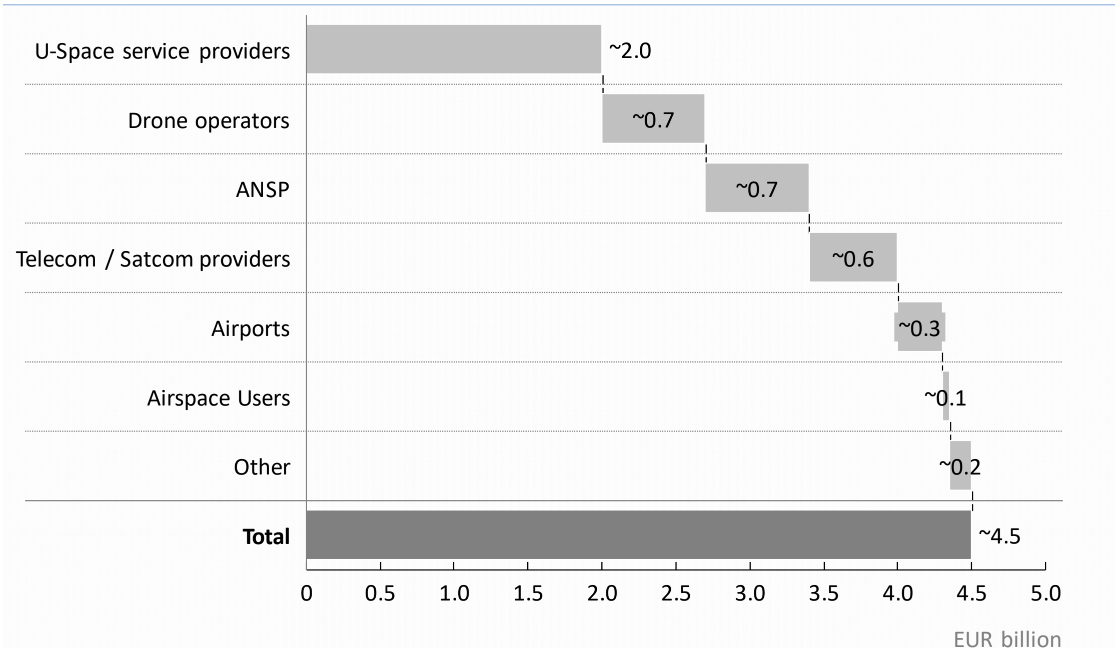

Figure 33 Preliminary stakeholder investment breakdown for 2035

U-space service providers and drone operators are expected to invest the most across stakeholder groups[27]. For U-space service providers, this is driven by the investments required to support new services in the ecosystem, while large investments for drone operators are required to ensure the drones are appropriately equipped to enable the required services. The scale of operations and growth in drones are expected to grow substantially, making the associated investment meaningful (the specific category fleet size will evolve from under 10 000 drones in 2015 to nearly 400 000 drones in 2050). The military performs all the roles of the different stakeholders, i.e. airspace user, ANSP, airport operator, regulator and drone operator. A standalone assessment of available military data indicates that partial investment levels are in the order of EUR ~400 million[28].

Investment levels are assumed to not vary significantly between the two distinct high-level options (see section 3) for rolling out SESAR, even if the slower evolution of the ATM system after 2035 might lead to a resulting lower investment amount under option 2.

27 It is expected that traditional airspace users should not incur major additional investments for the development of U-space.
28 Unit level airborne investment for certified drones were used as a proxy and applied to the anticipated military drone fleet. Ground investments for airport adaptations and ATC interface requirements, were applied to 10 military air bases in Europe. Additional investments may be required and this assessment will be updated as more data becomes available.

5.2 Holistic view on benefits

An economic impact analysis of the entire value chain for each demand area revealed the yearly potential for a European market would exceed EUR 10 billion by 2035 and would further grow to approximately EUR 15 billion by 2050, with agriculture expected to drive EUR 4-5 billion of this market by 2035. A market of this size will also drive new job creation throughout all Member States, as each will need localised operations, pilots, maintenance contractors and insurers among other specific occupations. In short, over 100 000 direct jobs are expected to be generated by this significant market[29], in addition to many other indirect benefits.

In addition to the aforementioned benefits, the business assessment also takes into account benefits stemming from the growth and adoption of urban air mobility[30]. It is envisaged that this form of mobility will result in market value of at least EUR 2 billion annually by 2031 with a market take-off in 2027[31]. The value is calculated by estimating adoption across the following three use cases:

- City to airport travel – based on actual airport passengers and price sensitivity analysis;
- Taxi use – based on actual origin-destination figures, focusing on long-distance trunk routes;
- Commuting – typically high volume routes.

Volumes were determined by considering 25-30 European cities among an initial assessment based on the 130 largest cities worldwide.

Benefit levels have been assessed for two distinct high-level options (see section 3) for rolling out SESAR:

- **Option 1 — Deployment of the full vision by 2040:** Under option 1, it is assumed that the total value associated to drones can be unlocked given that the required ATM system would be installed with the full vision, including phases A to D, achieved by 2040
- **Option 2 — Deployment of the full vision by 2050:** Under option 2, it seems reasonable to assume at least part of the drone value will not be unlocked given a slower transition towards the targeted ATM system

The total annual economic value under option 1 across the indicated landscapes has been summarised in Figure 34.

29 Based on data by the Organisation for Economic Cooperation and Development (OECD)

30 Urban air mobility refers to an envisaged future state where people and/or goods can be transported around densely populated urban areas within very short timeframes, leveraging airspace to do this

31 Urban air mobility figures based on an assessment performed by BCG in collaboration with Airbus

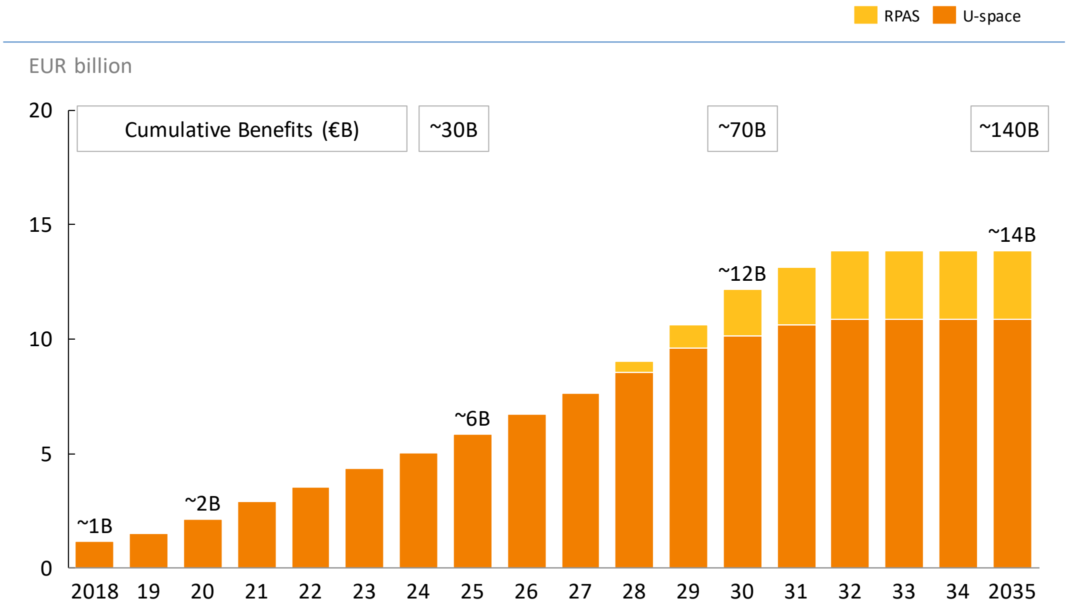

Figure 34 Economic benefits of drone deployment in Europe (undiscounted)32

5.3 Incentivisation strategy

The existing SES framework already contains incentive schemes aiming at supporting a timely and synchronised deployment of technology. In particular:

- The existing SES regulations provide several mechanisms to incentivise deployment including modulation of charges to support avionics equipage and different treatment of restructuring costs within the performance scheme.
- The common project legislation provides public funding via the relevant Union funding Programmes, "to encourage early investment from stakeholders and mitigate deployment aspects for which the cost-benefit analysis is less positive".
- The European Investment Bank (EIB) has developed a range of financial instruments to support SESAR deployment.

However, within the scope the SESAR project seen as a whole, the scale of the necessary transformation and the need for synchronisation are much greater than for the individual ATM functionalities of common projects. For this reason, it was recommended in the context of the Airspace Architecture Study to review the existing incentivisation framework, also using the experience gained from the Pilot Common Project, and to develop and adopt an overall incentivisation policy that will provide genuine incentives to early movers.

Specific incentives should be offered for those stakeholders that implement the European ATM Master Plan or that shift towards innovative delivery models with a focus on early movers in order to initiate the transition.

[32] Source: 2016 Drone Outlook Study ; Urban Air Mobility input from external BCG project in collaboration with Airbus

6 References

The following references have been used along the document.

[1] European ATM Master Plan Edition 2020.

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[6] Commission Implementing Regulation (EU) No 409/2013 of 3 May 2013 on the definition of common projects, the establishment of governance and the identification of incentives supporting the implementation of the European Air Traffic Management Master Plan

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[11] EUROSTAT, 2016 Greenhouse gas emissions per capita, Tonnes of CO_2 equivalent per capita for a series of EU28 countries. Downloadable via: https://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&language=en&pcode=t2020_rd300&plugin=1

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[14] EUROCONTROL, Performance Review Unit with the ACE working group. ATM Cost-Effectiveness (ACE) 2016 Benchmarking Report with 2017-2021 outlook. Downloadable via: https://www.eurocontrol.int/prc/publications