The value for money for a temporary reinstatement of EGNOS

Prepared for

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Executive summary

The European Geostationary Navigation Overlay Service (EGNOS) improves the integrity and precision of GPS services. In particular, the EGNOS safety-of-life (SoL) service is used in safety-critical applications, for example in the aviation sector. EGNOS enables users of GPS services to be confident that the information being supplied to them is precise and correct.

The UK's participation in the EGNOS Programme ended on 25 June 2021, leading to a withdrawal of legal indemnity for the use of EGNOS. As a result, the UK is no longer able to use the EGNOS SoL service. This affects a range of different sectors, including agriculture, surveying and maritime, but it especially affects aviation. Airports across the UK will be affected. Medium-sized airports that have an alternative precision navigation system will still see a loss of resilience and higher costs. Smaller airports, which are unable to invest in costly ground-based navigation systems, will be left without any high-precision navigation alternatives, leading to reduced safety and more unreliable services.

Based on conversations we have had with Inmarsat, we understand that while a UK alternative to EGNOS is being developed, it remains in the initial stages of testing, and it will require additional time, investment and regulatory approval before it can be used. Therefore, a UK alternative is still a number of years away from being available.

This report assesses the business case for a temporary reinstatement of EGNOS until a UK alternative is developed. The box below sets out the key finding of this report.

Based only on impacts on the aviation sector, assessed conservatively, EGNOS delivers high value for money, with a benefit–cost ratio of 2.6. This means that **for every £1 spent by the UK government, £2.60 of benefit would be delivered to the UK public**. In addition, EGNOS provides non-monetised benefits, including improved safety and reliability of emergency-response helicopter services, increased competitiveness of UK flight training schools, and increased resilience of precision navigation systems for major UK airports.

Expanding the analysis to other sectors of the economy only increases the benefits, while the costs to Government are unchanged.

EGNOS leads to improved safety, access to essential services, connectivity and UK competitiveness

To understand the potential benefits of EGNOS, we have engaged with stakeholders across a range of different sectors in the UK. This includes organisations representing 17 airports, Transport Scotland, the National Farmers' Union, the Royal Institute of Chartered Surveyors (RICS) and the Royal Institute of Navigation. We have also spoken with a number of peers and MPs, including Lord Tony Berkeley, Lord Byron Davies and Angus MacNeil MP, who have received concerns from different organisations about the loss of EGNOS.

We find that EGNOS leads to a wide range of benefits, as summarised in the figure below. By supporting remote communities, a temporary reinstatement of is in line with the Government's Levelling Up programme.

Improved access to essential services. With EGNOS, those living in UK islands with poorer access to NHS hospitals will miss around 1,200 fewer appointments every year, which tend to be for urgent treatment or diagnosis. These patients would have had to wait on average one month to rearrange their appointments, with around 12% waiting up to three months.

Improved reliability of search and rescue (SAR) and helicopter emergency (HEMS) services. EGNOS enables Point in Space (PinS) technology, allowing helicopters to operate in poor weather. The CAA has stated that a number of HEMS and SAR operations have experienced accidents and incidents due to poor visibility, and EGNOS was required to reduce these risks.

Improved flight safety. EGNOS reduces controlled flight into terrain (CFIT), one of the CAA's 'Significant Seven' risks, by a factor of four to eight. This means reduced loss of life and damage to aircraft, as well as improved public trust in UK aviation.

More reliable services, including at the Isles of Scilly, which has no other option but to travel by air in winter. Around 105,000 fewer passengers every year across the UK will experience delays or cancellations if EGNOS is reinstated.

Addressing the loss of flight training schools. The UK's flight training schools can no longer offer a complete training suite, and they are already losing business and revenues to competing European schools.

Even if an airport has alternatives, they are far more expensive to operate. The yearly maintenance cost of an instrument landing system (ILS), the alternative to EGNOS, is approximately equal to the **one-off** cost of enabling EGNOS.

Greater resilience. Even airports that have an ILS, e.g. Exeter Airport, have invested in EGNOS to improve safety and provide back-up in case of ILS unserviceability.

Improved safety and efficiency in the maritime sector, supporting UK trade. Seaborne trade is expected to double by 2030. EGNOS would enable ships to navigate safely and efficiently in crowded areas, e.g. ports, and therefore support UK trade

Improved yields and lower costs in the agriculture sector. EGNOS enables precision farming, which improves the efficiency of field working, fertiliser and pesticide use. This leads to higher crop yields and lower costs.

The temporary reinstatement of EGNOS does not preclude the development of a UK alternative

As part of our stakeholder engagement, we discussed with Inmarsat its development of a UK alternative to EGNOS. We understand from Inmarsat that

the temporary reinstatement of EGNOS does not prevent a UK-based alternative from being developed. Inmarsat indicated that working together with EGNOS on such issues is quite normal. In addition, the infrastructure used for EGNOS will be fully compatible with that of a UK alternative.

Therefore, this report does not evaluate the value for money of a UK alternative (which we understand may lead to additional benefits over and beyond those delivered by EGNOS). Instead, our focus is on whether temporarily reinstating EGNOS delivers good value for money.

EGNOS is likely to deliver high value for money

We base our monetised assessment of benefits on a study commissioned by the European Commission.[1] We update the Commission's methodology based on information gathered from our engagement with stakeholders to better reflect the UK's experience of EGNOS.

We monetise benefits where there is sufficient data. In particular, our analysis looks at ten airports in the UK that have invested in EGNOS but are now unable to use it, and are left without any alternatives (e.g. ILS).[2] We quantify how much time would be saved by passengers and airlines due to fewer delays and cancellations after the reinstatement of EGNOS, and we monetise this by considering the passenger value of time and the direct costs of operating aircraft. We also provide an estimate of the value of improved safety in the aviation sector from avoided fatalities and loss of aircraft. Furthermore, we estimate the value of health benefits to patients and cost savings to the NHS from fewer missed appointments.

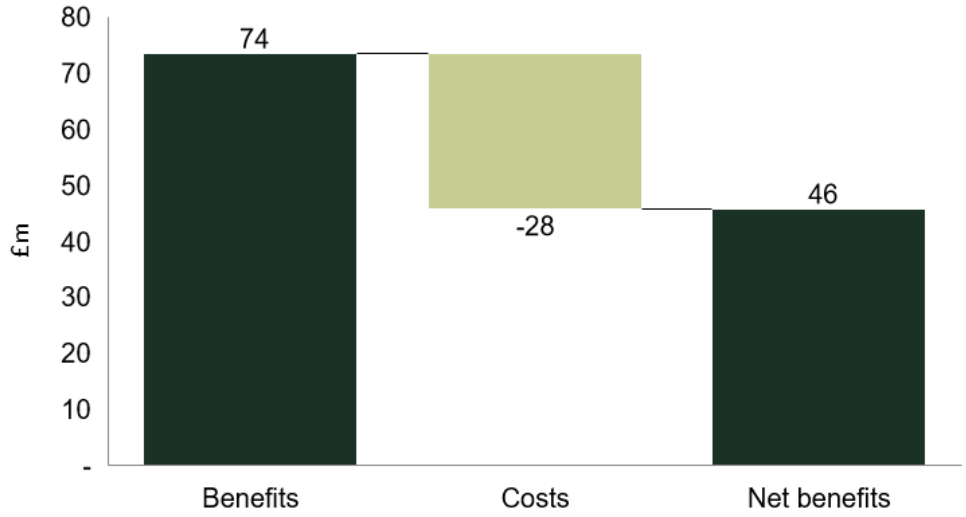
Our analysis requires information on EGNOS's benefits (e.g. fewer delays and cancellations) compared to a counterfactual where no comparable alternatives are available. We base this on data from Land's End airport, and apply them to other UK airports. While different airports operate under different circumstances and Land's End experiences may not be representative of all airports, we have received consistent qualitative evidence from a range of airports that the loss of EGNOS has led to a significant worsening of services.

We quantify the benefits on an annual basis as we do not have a firm date as to when a UK alternative to EGNOS will be available. Overall, the combined benefits of EGNOS amount to approximately £77m per year.

The costs of participating in EGNOS range between £25.5m and £29.8m per year, and we take an average of this range at £27.6m per year.[3] There could be additional costs to get EGNOS re-instated at airports. However, we understand that since the airports considered in the monetised analysis of benefits have already invested in EGNOS, these additional costs may not be significant.[4]

[1] L.E.K. (2009), 'EGNOS Cost Benefit Analysis in Aviation', 27 July.
[2] Eighteen airports in total have invested in EGNOS, including: Barra, Barrow, Bristol, Campbeltown, Cardiff, Doncaster Sheffield, Dundee, Exeter, Islay, Kirkwall, Land's End, Newcastle, Prestwick, Southampton, Sumburgh, Tiree and Wick, although Barrow and Yeovil did not have any passenger traffic in 2019 (according to CAA data). Of these, Barra, Campbeltown, Dundee, Islay, Kirkwall, Land's End, Sumburgh, Tiree and Wick do not have an ILS alternative. This is based on a written response from the Department of Transport, https://www.theyworkforyou.com/wrans/?id=2022-03-03.HL6599.h, and NATS (2022), 'United Kingdom Aeronautical Information publication', 19 May, p.30-33, for information on which airports have an ILS. In addition, industry stakeholders told us that general aviation airports including Kemble Airport and Sywell Airport have also invested in EGNOS. We have not included these airports in our monetised assessment of benefits.
[3] UK Parliament. https://questions-statements.parliament.uk/written-questions/detail/2022-01-13/HL5379
[4] For example, Land's End Airport told us that all the survey work and safety case to introduce EGNOS-assisted procedures has already been done. They highlighted that the EGNOS signal is still currently

The figure below compares the annual benefits and costs of EGNOS. It shows that the net benefit of enabling EGNOS would be around £46m per year, with a benefit–cost ratio of 2.6.[5] Under the Department for Transport's value for money framework, reinstating EGNOS would deliver 'high' value for money.[6] Furthermore, as the net benefits have been calculated on an annual basis, we note that the longer the time it takes to develop a UK alternative, the greater the total net benefits of temporarily re-instating EGNOS.



Moreover, there are a number of non-monetised benefits, including:

- improved reliability of emergency helicopter responses and search and rescue operations (SAR);
- improved competitiveness of flight training schools;
- improved resilience for airports that have installed EGNOS in the event that other precision navigation systems are unserviceable or installed only at one end of their runway;
- cost savings from airports that wanted to switch from ILS to EGNOS.

There are also benefits for other sectors, including maritime and agriculture. Within maritime, new EGNOS services, expected to be deployed in 2026, would further improve navigation in areas where there is dense maritime traffic, such as at ports. This would improve safety, avoiding accidents that lead to considerable costs, as well as improving the speed and efficiency of trade flows. It also enables more accurate location of offshore structures, reducing costs and time delays. In agriculture, EGNOS leads to better field working and monitoring of crops and livestock, leading to improved yields and reduced costs.

available to pilots to use, but pilots are unable to legally use it as the UK has stopped participating in EGNOS. Land's End also told us that they do not believe an Airspace Change Process (ACP) would be needed as EGNOS would just be an overlay to improve existing approaches.

[5] We have carried out a number of sensitivities to test the robustness of our results. See section 4 for further details.

[6] Department for Transport (2017), 'Value for money framework', 30 July.

1 Introduction

The All Party Parliamentary General Aviation Group asked Oxera to assess the business case for a temporary reinstatement of the European Geostationary Navigation Overlay Service (EGNOS).

EGNOS is a Satellite-based Augmentation System (SBAS) that improves the precision and integrity of global positioning systems (GPS). In particular, the EGNOS Safety-of-Life (SoL) service is used in safety-critical applications, such as in the aviation sector.

The UK's participation in the EGNOS Programme ended on 25 June 2021, leading to a withdrawal of legal indemnity for the use of EGNOS. As a result, the UK is no longer able to use the EGNOS SoL service. This affects a range of different sectors—particularly the aviation sector, but also the agriculture, surveying and maritime sectors.

In particular, prior to leaving the EU, the UK civil aviation sector invested heavily into satellite-based approaches because of the significant safety and reliability advantages that satellite-based approaches offer compared to traditional approaches (i.e. non-precision navigational aids). In addition, we were told that in addition to investments to EGNOS by airfields, NATS provided a direct contribution of £15m into the EGNOS Infrastructure development and an indirect contribution of 10 person-years of effort into the European Space Agency Project Team in Toulouse. NATS also invested into the creation of the European Satellite Services Provider (ESSP), the EGNOS service provider.

Despite these investments, the UK is currently the only state in the G20 without useable access to a precise satellite-based navigation system, whereas other countries are increasingly moving towards relying on precision satellite-based approaches.[7]

Reinstating EGNOS would lead to benefits by improving the safety of UK aviation and improving the reliability of vital lifeline and essential services (and particularly vital lifeline services to island and remote communities in the UK). It will also improve resilience and reduce costs for airports, even if they have an alternative precision navigation aid available. In addition, reinstating EGNOS would also lead to benefits in other sectors, including agriculture and maritime.

This report quantifies the benefits of reinstating EGNOS and compares them against the costs of participating in EGNOS.

This report is structured as follows.

- Section 2 provides an overview of EGNOS and sets out our findings based on our stakeholder engagement.
- Section 3 provides a summary of the methodology that we have used to carry out a monetised assessment of the costs and benefits of EGNOS in the aviation sector.
- Section 4 sets out our results and main conclusions.
- Appendix A1 provides a detailed description of the methodology and calculations behind our results.

[7] Angus MacNeil SNP (2021), 'MP urges UK Gov to retain EGNOS membership to protect island air services', https://angusmacneilsnp.com/2021/04/14/mp-urges-uk-gov-to-retain-egnos-membership-to-protect-island-air-services/, accessed 12 May 2022.

2 Overview of EGNOS and its applications

To inform this report, we have engaged with a number of different stakeholders to better understand the benefits of EGNOS and the impact of the loss of access to EGNOS. This includes organisations representing 17 airports, Transport Scotland, the National Farmers' Union, the Royal Institute of Chartered Surveyors (RICS) and the Royal Institute of Navigation. We have also spoken with a number of peers and MPs who have received concerns from different organisations about the loss of EGNOS.

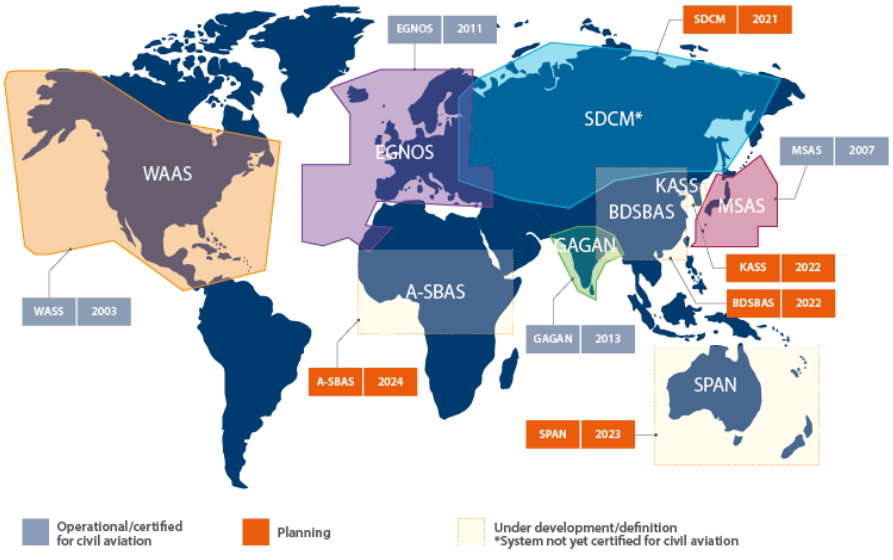
This section is structured as follows.

- Section 2.1 describes EGNOS and how it affects the aviation sector.
- Section 2.2 sets out the benefits of EGNOS for the aviation sector.
- Section 2.3 sets out the benefits of EGNOS for other sectors.

2.1 How does EGNOS affect the aviation sector?

EGNOS is a Satellite Based Augmentation System (SBAS). A SBAS improves the accuracy and reliability of global navigation satellite systems (GNSSs), which enables it to be used in safety-critical applications, such as in aviation. SBASs are used throughout the world, as shown in Figure 2.1. For example, the United States' SBAS is the Wide Area Augmentation System, or WAAS.

Figure 2.1 Use of satellite-based augmentation systems (SBAS) in different parts of the world



Source: European Union Agency for the Space Programme, 'What is SBAS?', https://www.euspa.europa.eu/european-space/eu-space-programme/what-sbas, accessed 01/06/2022.

The primary impact of the loss of EGNOS on the aviation sector is that airspace users are now no longer able to use Localiser Performance with Vertical Guidance (LPV) approach procedures at airports. LPV offers pilots precise three-dimensional approaches that provide both course and glidepath deviation information.

Using EGNOS lowers the 'decision height', which is the point at which the pilot has to decide whether or not to undertake a 'missed approach' (i.e. when a landing cannot be accomplished).[8] This means that EGNOS enables fewer missed approaches in poor weather and low visibility.

Instrument Landing System (ILS) approaches are an alternative precision approach. An ILS requires expensive ground-based infrastructure, which requires high upfront investment costs and annual maintenance costs. This means that smaller airports, such as Land's End, St. Mary's and airports on Scottish islands, are unable to afford ILS.[9]

For example, Land's End airport told us that it would be difficult to finance, given the small size of their airport. We consider that this is likely to be the case, given that an ILS is very costly. For example, one paper suggests that the costs of installing an ILS at one runway is around $1m.[10] Another airport notes that replacing an ILS at the end of its life costs around £500k. Furthermore, the annual maintenance cost of an ILS is around €32,000.[11] In comparison, Land's End airport in 2019 had a turnover of £18.5m, with an operating loss of £4.5m.[12] Therefore, it is unlikely that these airports would be able to undertake such a large capital expense.

EGNOS is a low-cost alternative to ILS. The European Global Navigation Satellite Systems Agency (EGSA) estimates that the one-off CAPEX cost of implementing LPV approaches based on EGNOS is roughly equal to the yearly maintenance cost of ILS.[13]

Airports that are unable to afford ILS are left with considerably more restrictive approaches. This includes lateral navigation (LNAV) approaches (these are 2D approaches, meaning that pilots do not receive vertical guidance for a controlled descent to the runway) and non-directional beacons (NDBs), which also have no 3D capability, have existed since the 1930s and are becoming obsolete, and can be distorted by environmental conditions.

The consequence of using these more restrictive approaches is that flights will be less safe and less reliable (i.e. there will be more delays and cancellations).[14] These are discussed in further detail below.

2.2 The benefits of EGNOS in the aviation sector

EGNOS improves flight safety

Controlled Flight into Terrain (CFIT) occurs when an airworthy aircraft under the complete control of the pilot is inadvertently flown into terrain, water or obstacle. The UK Civil Aviation Authority (CAA) has identified CFIT as one of the 'Significant Seven', the top seven safety risks identified by the CAA safety risk process, based on analysis of worldwide fatal accidents and high-severity occurrences to UK aircraft.[15] Similarly, in its 2017–19 Global Aviation Safety

[8] We were told by industry stakeholders that LPV decisions heights are potentially as low as 200' above the runway. This is comparable to that achieved by a Category 1 ILS.
[9] Based on our engagement with stakeholders in the aviation industry.
[10] Cabler. H. and DeCleene. B. (2002), 'LPV: New, improved WAAS Instrument Approach', Proceedings of the 15th International Technical Meeting of the Satellite Division.
[11] EGSA (2015), 'Aviation powered by EGNOS. EGNOS as an enabler of PBN', 7 April, slide 10.
[12] Isles of Scilly Steamship Group (2019), 'Annual report 2019', https://www.islesofscilly-travel.co.uk/wp-content/uploads/2019/09/IOST-Annual-Report-2019.pdf, accessed 01/06/2019.
[13] EGSA (2015), 'Aviation powered by EGNOS. EGNOS as an enabler of PBN', 7 April, slide 10.
[14] Using EGNOS lowers the 'decision height', which is the point at which the pilot has to decide whether or not to undertake a 'missed approach'. This means that with EGNOS, there will be fewer missed approaches under low visibility.
[15] Civil Aviation Authority (2011), 'CAA "Significant Seven" Task Force Reports', March, https://publicapps.caa.co.uk/docs/33/2011_03.pdf.

Plan, the International Civil Aviation Organisation (ICAO) included CFIT as one of three high-risk accident categories.

ICAO studies have shown that once some form of vertical guidance is used (e.g. LPV approaches enabled by EGNOS), the risk of CFIT is reduced by a factor of eight.[16] The CAA also notes that 'non-precision approaches have been shown to increase the CFIT risk'.[17]

Consequently, ICAO recommended all its participating countries to implement procedures with vertical guidance at all instrument runways[18] by the end of 2016, either as primary or as backup approach procedures. The main objective of this was to improve safety.[19]

To address the safety risk of CFIT, the CAA's recommendations 'included the introduction of more Global Navigation Satellite System (GNSS) approaches'. In particular, the CAA recommended the introduction of EGNOS, 'which will give greater accuracy both horizontally and vertically'.[20] A report from Land's End airport notes that EGNOS is likely to reduce the occurrence of CFIT by improving a pilot's situational awareness.[21]

Therefore, the use of precision satellite-based navigation aids such as EGNOS is an important part of the strategy to ensure aviation safety in the UK. Leaving the UK without access to precision satellite-based navigation aids significantly increases the risks of serious and fatal accidents, a large financial loss for companies due to hull loss (irrecoverable damage to aircraft), and reduced public trust in UK aviation safety.

EGNOS improves access to essential services, including healthcare access

On many UK islands, air travel provides vital lifeline services to communities on the islands. In our discussions with stakeholders, we were told airports facilitate the transfer of critically ill patients, medical supplies, passengers attending crucial medical appointments on the mainland, and support Search and Rescue (SAR) operations. This is in addition to routine but essential cargo, mail and passenger operations.

In particular, delays in access to healthcare could have significant adverse consequences. In a survey carried out on medical travel from the Isles of Scilly in the winter of 2016, Healthwatch noted that patients routinely travel from the Isles of Scilly to Land's End Airport via air travel. 69% of all respondents said that they travelled for 'urgent diagnosis or treatment'.[22]

Even though many patients on the Isles of Scilly travel well in advance of their appointments to avoid poor weather, there is still a significant proportion of people who are unable to attend their appointments (19%), 75% of whom were

[16] International Civil Aviation Organisation (2007), 'Assembly – 37th session. Technical Commission. Performance-based navigation – the implementation challenge', para. 2.1, https://www.icao.int/Meetings/AMC/Assembly37/Working%20Papers%20by%20Number/wp148_en.pdf.
[17] Civil Aviation Authority (2011), 'CAA "Significant Seven" Task Force Reports', March, p. 37, https://publicapps.caa.co.uk/docs/33/2011_03.pdf.
[18] A non-instrument runway is one that is intended for the operation of aircraft using visual approaches. An instrument runway is equipped with electronic or visual air navigation aids to permit aircraft landing under restricted visibility conditions.
[19] ICAO resolutions 36-23 and 37-11.
[20] CAA (2011), 'CAA 'Significant Seven' Task Force Reports', March, p. 38, https://publicapps.caa.co.uk/docs/33/2011_03.pdf.
[21] Land's End Airport (2021), 'Overview: GNSS EGNOS Instrument Approach Procedures', March, p. 2.
[22] Healthwatch (2016), 'Medical travel from the Isles of Scilly. Winter travel survey report', May, https://www.healthwatch.co.uk/sites/healthwatch.co.uk/files/reports-library/20181002-LHW_Isles_of_Scilly_Winter_Travel_Survey.pdf, p.12.

unable to attend due to flight delays or cancellations. Of those who could not attend, the average waiting time for a rearranged appointment was around one month, with 37% waiting two months or longer.

Missed NHS appointments also waste NHS resources that could have been used for other patients—each hospital outpatient appointment costs the NHS approximately £120,[23] and an inpatient hospital stay costs around £400 per day according to the Department for Health and Social Care.[24]

In addition, one industry stakeholder told us that NHS Scotland incurred disruption and costs from delayed returns to the mainland of medical professionals from island surgeries.

EGNOS may also have an impact on other time-critical operations in which flight delays and cancellations may be very costly. The Department of Business, Energy and Industrial Strategy (BEIS) noted that the loss of EGNOS could be significant for time-critical operations such as the transport of organs. BEIS stated that it was 'aware of airports that use EGNOS which have NHS contracts for human organ transportation'. One industry stakeholder told us that this includes Haverfordwest airport, who submitted an Airspace Change Proposal to the CAA in May 2021.[25]

Improved service reliability

One airline told us that due to the loss of EGNOS, it has 'had the worst summer on record with diversions and flight cancellations'. This led to increased costs, customer disruption, overnight hotel stays, and use of alternative transport due to the escalating number of cancelled flights.

This is exacerbated by the fact that the communities served by EGNOS are reliant on air travel to access the mainland. For example, there is no ferry service between the Isles of Scilly and the mainland during the winter months, meaning that air travel is the only way to get on or off the island. During the summer months, there is only a once-daily ferry service between the Isles of Scilly and the mainland.[26]

In addition, our conversations with industry stakeholders indicate that some airlines regard having precision approaches to be an important criteria for operating at an airport. For example, we were told that Flybe (prior to it going into administration) decided not to serve Oxford as there was no approach with vertical guidance at the airport.[27]

We estimate that if EGNOS were to be reinstated, approximately 105,000 passengers every year would be able to avoid delays or cancellations. Our methodology for calculating this figure and the associated monetised benefits is set out in section 3.

Restoring a comprehensive and competitive flight training school sector

The loss of EGNOS has meant that the UK can no longer offer complete flight training programmes for pilots. This is because without EGNOS, UK airports

[23] NHS (2018), 'NHS to trial tech to cut missed appointments and save up to £20 million'.
[24] Department of Health and Social Care (2015), 'NHS Hospital Stay', 27 May, http://web.archive.org/web/20161022193653/https://data.gov.uk/data-request/nhs-hospital-stay, accessed 12 May 2022.
[25] An ACP is designed to align airports with the government's policy on managing airspace.
[26] Isles of Scilly Travel (2022), 'Timetables', https://www.islesofscilly-travel.co.uk/timetables/, accessed 26 May 2022.
[27] Similarly, a private jet company told us that they normally serve the closest airport with an ILS, due to the uncertainty of operating into a closer airport with only visual or non-precision approaches.

are now unable to provide the full range of approaches that an examiner might wish to see demonstrated by a candidate for test.

Due to the loss of EGNOS, UK flight training schools are now at a disadvantage compared to EU training schools, leading to the relocation of UK training schools to the EU. An airport told us that it has lost significant revenues as a result of a flight training school relocating since it is no longer competitive compared to EU schools.

This was supported by Angus MacNeil MP, who has received comments from a major commercial airline that UK flight training is no longer comprehensive due to the loss of EGNOS.

EGNOS will lead to cost savings for some airports

A major international airport operating international flights has told us that the ILS on one of its runways has reached the end of its life, and that it needs to be replaced. This replacement would cost £500k–£600k; however, the runway accounts for only 5–10% of the airport's arrivals. This is a significant expense given that the runway accounts for a small proportion of its operations. The airport's long-term plan was to use EGNOS at the runway, which would have provided equivalent performance for a significantly lower cost.

Similarly, Bournemouth Airport were planning on utilising EGNOS to avoid a costly replacement of their ageing ILS system. However, they now have to go through a process of tendering for a replacement ILS, at an estimated cost of £0.5m, which they noted was particularly challenging given the current aviation market. Furthermore, they had already designed and submitted their EGNOS procedures to the CAA for approval in 2020. These design costs have already been incurred, and the airport would now not be able to earn a return on its investment.

Greater resilience for airports that have ILS

EGNOS provides benefits for airports that already have an ILS. ILS and EGNOS complement one another—in the event of ILS unserviceability, EGNOS provides an alternative for safe and precise landings.

Newcastle Airport is a major international hub and a prime port of entry for the North East. While Newcastle is ILS-equipped, it has significantly invested in EGNOS to improve the precision of its Required Navigation Performance (RNP) procedures.[28] Newcastle Airport told us that it has maintained EGNOS as a contingency, should it lose its ILS for a significant period of time. Currently, without EGNOS, if it was lose its ILS for a few days during poor weather, there would be significant disruption to the air transport network. This would affect not only Newcastle Airport, but also other airports, airlines and passengers.

- The diversion of flights to other airports would cause disruption to these airports.
- Many airlines aim to operate their aircraft with a high degree of utilisation. The diversion of flights to different airports would significantly affect their schedules, leading to further disruption.

[28] RNP procedures permit the operation of aircraft along a precise flight path with a high level of accuracy and provide the ability to determine aircraft position with both accuracy and integrity.

- Passengers would be affected as they would not arrive at their intended destination.

Similarly, Exeter Airport, despite having access to ILS, invested in EGNOS, one of the first airports in the UK to do so. It noted that 'the main benefits of LPV are as an improvement to safety and to provide a suitable back up procedure in case of ILS unserviceability, without the need for extra ground-based navigation aid infrastructure'.[29]

Biggin Hill Airport was looking to implement EGNOS as part of its Airspace Change Process (ACP). An ACP is designed to align airports with the government's policy on managing airspace.[30] The aim of this ACP was to introduce precision-based navigation (PBN) approaches to one of its runways. This is because its older, currently used ground-based navigation facilities (DVOR) are due to be removed by NATS in December 2022.[31] It also aligns with the CAA's current Airspace Modernisation Strategy regarding the introduction of PBN approaches.

Biggin Hill Airport told us that while it currently has an ILS in place on Runway 21, EGNOS would provide an approach in the reciprocal direction to Runway 03 and resilience to the airfield during ILS outages due to maintenance or unserviceability.[32]

EGNOS leads to safer and more reliable medical and emergency helicopter services

EGNOS enables new precision helicopter procedures known as 'Point in Space down to LPV' (PinS LPV). These allow access to heliports in poor weather, without the need for costly ground infrastructure.[33]

In the CAA's Onshore Helicopter Review Report, they state:

> All onshore operations, and in particular, HEMS [Helicopter Emergency Medical Service] and SAR [Search and Rescue], can theoretically take place under IFR [Instrument Flight Rules], but there are a number of operating conditions in the Air Ops Regulation that do not make IFR a completely practical solution.
>
> A number of the reported incidents and accidents in this report occurred in a DVE [Degraded Visual Environment] where the option of an Instrument Approach/Departure Procedure established at the off aerodrome operating site may have been of significant safety benefit. **In recognition of the needs of onshore helicopter IFR operations the use of Point in Space (PinS) approaches and departures to an initial departure fix (IDF) is therefore required.** [emphasis added, and abbreviations spelt out in parentheses]

In other words, the CAA acknowledged that alternative technological solutions for helicopters (i.e. IFR) is not always a practical solution. They state that a number of accidents have occurred because these of poor visibility, and the use of PINS technology is required.

[29] Exeter Airport (2014), 'Airport leads with new aviation navigation system. GPS instrument approaches to be introduced at Exeter', 18 July, https://www.exeter-airport.co.uk/airport-leads-with-new-aviation-navigation-system/, accessed 12 May 2022.
[30] Civil Aviation Authority, 'Airspace change process. Guidance on changes to the use or classification of airspace in the UK', https://www.caa.co.uk/Commercial-industry/Airspace/Airspace-change/Airspace-Change/, accessed 26 May 2022.
[31] Doppler VHF Omni Directional Range (DVOR) is an older navigation aid used by aircraft.
[32] We understand that having greater operability in two directions provides an airport with more flexibility, e.g. selecting a direction that is most aligned with the wind.
[33] European Union Agency for the Space Programme, 'Helicopter industry goes for the EGNOS advantage', https://www.gsc-europa.eu/news/helicopter-industry-goes-for-the-egnos-advantage-3, accessed 26 May 2022.

One industry stakeholder told us that the CAA had announced support for 'Blue Light Services" helicopter PINS which will see the introduction of patient transfers to hospital helicopter landing sites in poor weather. However, without EGNOS the full benefits would not be available, meaning there is a risk of some avoidable deaths in casualties who may have survived had a landing been possible from the lowest decision height.

Cornwall Air Ambulance Trust told us that while it has an ILS at its base, Penzance, Tresco and Land's End, which do not have an ILS in place, all offered PinS approaches. The Trust also told us that Penzance, Tresco and Land's End had offered EGNOS approaches, and hence they provided a range of diversion options in poor weather emergency situations. However, with the loss of EGNOS, these diversion options are no longer available in poor weather, which may impact safety and patient access to air ambulance services. The Trust noted that this was particularly important given the ever-changing weather in Cornwall.

The Trust also told us that EGNOS provided an opportunity to operate helicopter emergency medical services (HEMS) in poor weather. These advancements have now been paused due to the loss of EGNOS, and they must now wait for an alternative long-term solution.

Another industry stakeholder provided similar views, stating that the loss of EGNOS is likely to affect the Outer Hebrides in addition to the Isles of Scilly.

Furthermore, we were told that the loss of EGNOS, and therefore PinS operations, would affect emergency response and search and rescue (SAR) operations involving drones.

In addition, as EGNOS does not depend on local ground navigation infrastructure, it is an affordable solution for small heliports, hospital helipads, and sea-based helipads used by oil rigs, for whom ground infrastructure is impossible.[34]

2.3 The benefits of EGNOS in other sectors

EGNOS delivers safety benefits and cost savings in the maritime sector

The maritime sector is likely to see EGNOS become increasingly important in the coming years. The General Lighthouse Authorities (GLA) told us that the maritime sector is in a period of transition when it came to EGNOS.

Shipping today relies on differential GNSS (DGNSS),[35] which depend on a network of fixed, ground-based reference stations. However, the cost of maintaining this aging infrastructure is high. The European Commission is developing an EGNOS maritime service that is due to launch in 2023 (known as 'EGNOS v2'). The European Union Agency for the Space Programme stated that this would 'complement and serve as an alternative to DGNSS approaches'.[36]

The use of EGNOS today is limited to non-SOLAS vessels (Non Safety of Life At Sea, i.e. those that do not have to conform to the International Convention for the Safety of Life at Sea), which mainly include leisure users and smaller

[34] European Union Agency for the Space Programme, 'Helicopter industry goes for the EGNOS advantage', https://www.gsc-europa.eu/news/helicopter-industry-goes-for-the-egnos-advantage-3.
[35] Global navigation satellite systems provide satellite-based navigation, e.g. GPS services.
[36] Inside GNSS (2022), 'Europe initiates ambitious SBAS expansions: dual-frequency multi-constellation signals coming to EGNOS', March 30, https://insidegnss.com/europe-initiates-ambitious-sbas-expansions-dual-frequency-multi-constellation-signals-coming-to-egnos/.

craft. However, EGNOS v2 will be available to SOLAS vessels, e.g. cargo and passenger ships. We understand that this means that EGNOS could provide an alternative to aging, ground-based systems starting from next year, leading to cost savings.

In addition, the European Commission is planning to offer an improved service, known as 'EGNOS v3', starting from 2026.[37] The European Commission carried out a cost–benefit analysis of EGNOS v3 and found that it delivered significant safety benefits. In particular, it notes that where there is very dense traffic of vessels (e.g. at ports, where there is little space to manoeuvre and many obstacles), the precise navigational capabilities delivered by EGNOS v3 would considerably improve safety.

Given that the cost of an individual maritime accident is large, at €15m, the Commission's analysis concluded that EGNOS v3 is likely to generate a net present value of €83.9m over a period of 22 years.[38]

The GLA stated that as sea spaces around the UK become increasingly complex, the 'need for integrity is fundamental' and 'the EGNOS system is one of the components that helped provide integrity for positioning'. It noted that 'with seaborne trade set to double by 2030, the precision of position and timing data will become even more pivotal to the speed and efficiency of trade flows and help avoid widespread slowdown and disruption to our trade'.[39]

Furthermore, we understand that the maritime sector is already well equipped to adopt EGNOS, with 93% of navigation devices used in SOLAS vessels being EGNOS-capable.[40] This would help to reduce the costs of adopting EGNOS in the maritime sector.

Therefore, in the event that a UK SBAS is not available for a number of years, the UK maritime sector would be able to benefit from the EGNOS services described above while a UK alternative is installed. This enables to UK maritime sector to remain as safe and as competitive as possible.

EGNOS delivers operational improvements in agriculture

GNSS is used extensively within the UK agriculture sector. A report by London Economics, commissioned by Innovate UK, the UK Space Agency and the Royal Institute of Navigation studied the benefits of GNSS use in agriculture[41].

They note that the agriculture sector relies on sophisticated navigation equipment, many including EGNOS (amongst other technologies) for improved accuracy. There are two key areas in which EGNOS may play a role.

- The first is in tractor navigation, either via a tractor guidance system, where the driver is constantly told whether to steer right or left, or by using an automatic steering system that autonomously steers the tractor. These

[37] Inside GNSS (2022), 'Europe initiates ambitious SBAS expansions: dual-frequency multi-constellation signals coming to EGNOS', March 30, https://insidegnss.com/europe-initiates-ambitious-sbas-expansions-dual-frequency-multi-constellation-signals-coming-to-egnos/.
[38] GMV (2018), 'SEASOLAS final report', 5 October, https://www.euspa.europa.eu/sites/default/files/project/resources/files/seasolas_gmv_d030_v1.2.pdf.
[39] Ship Technology (2021), 'EGNOS and the post-Brexit loss of shipping positioning systems alerts', April 9, https://www.ship-technology.com/analysis/egnos-post-brexit-loss-shipping-positioning-systems-alerts/, accessed 27 May 2022.
[40] Inside GNSS (2022), 'Europe initiates ambitious SBAS expansions: dual-frequency multi-constellation signals coming to EGNOS', March 30, https://insidegnss.com/europe-initiates-ambitious-sbas-expansions-dual-frequency-multi-constellation-signals-coming-to-egnos/.
[41] London Economics (2017), 'The economic impact on the UK of a disruption to GNSS', April, https://londoneconomics.co.uk/wp-content/uploads/2017/10/LE-IUK-Economic-impact-to-UK-of-a-disruption-to-GNSS-FULLredacted-PUBLISH-S2C190517.pdf.

technologies improve the efficiency of farm operations as the working of the field can be completed faster and using fewer inputs, including less labour, fuel and other products used.

- The second is in variable rate technology (VRT). This technology allows the use of fertiliser and pesticides to be optimised. Crops that are too small can receive a fertiliser boost, while crops that are too large and are at risk of falling over can be prescribed a reduced amount of fertiliser. Similarly, pesticides can be more targeted at particular areas that require them. This leads to increased crop yields. One industry stakeholder told us that better targeting of fertiliser and pesticide use helps avoid the contamination of water courses and environment pollution.

EGNOS can benefit the agriculture sector in other ways. For example, it is used to monitor the movement of livestock, and to monitor the health of animals by tracking their movement.

By improving the precision of GNSS services, EGNOS leads to improved productivity and reduced costs in the agriculture sector.[42]

[42] EUSPA, 'Agriculture', https://egnos-user-support.essp-sas.eu/new_egnos_ops/segments/agriculture, accessed 27 May 2022.

3 Methodology summary

Our methodology is based on that adopted by the European Commission to quantify the benefits of EGNOS.[43] We update the Commission's approach using information that we have gathered from our discussions with stakeholders, as well as UK data sources, such as the CAA and the DfT.

We quantify a number of benefits of EGNOS where there is sufficient information to do so. These are:

- time savings to passengers from fewer delays;
- cost savings to airlines from fewer delays and cancellations;
- benefits to patient health and cost savings to the NHS resulting from fewer missed medical appointments;
- improved safety to passengers and cost savings to airlines from lower risk of controlled flight into terrain (CFIT).

These are each discussed briefly below. We set out a more detailed discussion of the methodology in Appendix A1, along with the calculations for each of the benefits to arrive at a monetary value.

Time savings to passengers from fewer delays

When a passenger experiences a delay or cancellation, they suffer welfare losses due to lost leisure or work time.

We estimate the value of time savings to passengers by multiplying the number of passengers who would be able to avoid delays or cancellations by the time lost from a delay or cancellation and the value of time savings.

We estimate the number of passengers who would be able to avoid delays or cancellations by considering only those at airports that have installed EGNOS, but do not have an ILS in place. We estimate the proportion of passengers who would benefit from EGNOS based on data from Land's End Airport on the use of EGNOS over 2020. Land's End provided us with two estimates of the impact of EGNOS.

- Based on data on the use of EGNOS for the year 2020 (which is the only full year for which data on the use of EGNOS is available), EGNOS has been used for flights accounting for around 22% of passengers. Land's End told us that it is unlikely these flights would have been possible without EGNOS.
- Based on METAR data (which are weather reports used by pilots) for the year 2021, Land's End estimated that of the 310 days of operation (excluding weekends and bank holidays), around 62.5 days of operation are lost due to poor weather. They excluded instances where EGNOS would not have been allowed flights to operate, e.g. where there were strong winds and where visibility would have been too poor even with EGNOS. Based on this, they estimate that EGNOS would have enabled around 11% more passengers to travel.

We use the first estimate of 22% as our central estimate given that it is based on actual EGNOS usage. However, we use figures based on the second

[43] L.E.K. (2009), 'EGNOS Cost Benefit Analysis in Aviation', 27 July.

approach as a sensitivity, given the difference in the two estimates we received.

To assess monetised benefits, we consider airports that have already invested in EGNOS.[44] We assume that EGNOS would have enabled a similar proportion of passengers at these airports to Land's End. While different airports operate under different circumstances and Land's End experiences may not be representative of all airports, we have received consistent qualitative evidence from a range of airports that the loss of EGNOS has led to a significant worsening of services.

Furthermore, we consider that this is a conservative approach because it excludes airports that had already made concrete plans to install EGNOS prior to EGNOS being made unavailable, such as London Biggin Hill Airport.[45] One industry stakeholder told us that there were around 20 airfields that were in the process of implementing EGNOS procedures prior to EGNOS being made unavailable.

We base our estimate of lost time for a delay or cancellation on CAA data. We assume that passengers need to wait four hours when there is a delay. For cancellations, the CAA found that passengers had to wait 13 hours. We make a conservative assumption that passengers would be able to spend some of their time productively and not wait the whole 13 hours. Therefore, we associate four hours of lost time with cancellations, the same as delays.

We convert the lost time to a monetary value by applying a passenger value of time. We base our estimate of the passenger value of time from a survey of relevant literature, obtaining a value of £23.60 per hour. However, we also carry out a sensitivity to this value using the DfT's time value for leisure passengers—which is lower, at £11.64 per hour.

Cost savings to airlines from fewer delays and cancellations

When airlines experience a delay or cancellation, they experience increased crew and maintenance costs, as well as costs associated with passenger care and flights rebooking.[46] Additionally, airlines also experience disruption to their network, where an initial primary delay leads to knock-on delays in their future operations.

Our main source of information for these costs is a study by the University of Westminster, updating previous work by the European Commission.[47] It presents the cost of delays for different types of aircraft. We choose an aircraft type that most closely reflects those that will be affected by EGNOS, i.e. smaller turboprop aircraft. This leads to a value of £1,429 per hour of delay.

The benefits of lower risk of CFIT

The benefits of reducing the risk of CFIT are difficult to quantify. While they CFITs are unlikely events, they lead to very high costs when they do occur.

[44] See appendix A1 for further details.
[45] Based on our conversations with the airport.
[46] Under UK law, airlines must provide passengers with care and assistance if flights are significantly delayed. See CAA, 'Delays: your rights when a flight is delayed', https://www.caa.co.uk/passengers/resolving-travel-problems/delays-and-cancellations/delays/, accessed 01/06/2022.
[47] University of Westminster (2015), 'European airline delay cost reference values. Updated and extended values. Version 3.2', https://www.eurocontrol.int/sites/default/files/publication/files/european-airline-delay-cost-reference-values-final-report-4-1.pdf, pp. 6–7.

This includes the potential for loss of life, damage to expensive aircraft and loss of trust in the safety of UK aviation.

We base our estimate of the benefits of reducing CFIT on the European Commission's previous cost–benefit analysis of EGNOS. We adjust their figures for inflation to reflect 2021 prices. We pro-rate the EU-wide benefits in proportion to UK traffic to obtain the benefits for the UK.

Cost savings to the NHS from fewer missed appointments

Flight delays and cancellations lead to missed NHS appointments. Delays for patients seeking treatment could lead to adverse health outcomes, while missed appointments waste NHS resources that could have been used for other patients.

Land's End provided us with data on how many patients arrive using NHS Transport services. We note that these only include bookings made by the NHS on Skybus, and do not include emergency medical services (e.g. helicopter emergency medical services).

Based on the information above, publicly available surveys and information from the European Commission, we estimate how many fewer missed appointments there would be as a result of EGNOS being available. Using survey evidence, we estimate that patients would have to wait around a month to rearrange their appointments. We convert this into a monetary value based on research from the National Institute for Health and Care Research.

To calculate UK-wide benefits, we extrapolate Land's End experience to the other UK airports considered within our monetised analysis (see appendix A1 for a list of these airports).[48]

Our assessment of monetised health benefits to patients and costs savings for the NHS is detailed further in Appendix A1.

[48] We note that Land's End experience may not be representative of other airports. While St. Mary's has a hospital (ten beds total), Sumburgh has a larger hospital on the island (56 beds). As such, the need for emergency hospital services may not be as large on some of the communities served by other airports. However, due to a lack of data on the use of NHS air transport services for these other airports, we make a simplifying assumption of extrapolating Land's End experience to these other airports and the communities they serve.

4 Results and conclusion

This section sets out the results of our assessment of monetised benefits and costs and tests whether the results are sensitive to a range of assumptions. We then summarise the non-monetised benefits of EGNOS.

Our analysis of benefits to the aviation sector, based on readily available data, shows that a temporary reinstatement of EGNOS has a benefit–cost ratio of 2.6. This represents 'high' value for money under the DfT's value-for-money framework. When further taking into account the non-monetised benefits of EGNOS, there is a strong economic case for re-instating EGNOS.

Monetised assessment of costs and benefits

As set out in Table 4.1 below, the overall annual benefits of reinstating EGNOS amount to £57.7m. As these benefits represent those that can be readily quantified based on the available information, there are a number of non-monetised benefits, which we discuss further below. Therefore, we consider that this is a conservative estimate of the benefits of reinstating EGNOS.

Compared to an annual cost of £27.9m, the net benefits of reinstating EGNOS amount to £29.8m per year. The benefit–cost ratio is 2.1, meaning that the reinstatement of EGNOS is likely to deliver high value for money under the DfT's framework.

Table 4.1 Annual monetised benefits, costs, net benefits and the benefit-cost ratio

Passenger time savings	**9.9**
Savings for airlines	43.2
Reduced risk of CFIT	4.1
Benefits to patients and cost savings to the NHS	16.3
Total benefits	**73.6**
Total costs	**27.9**
Net benefits	**45.7**
BCR	**2.6**

Source: Oxera analysis.

Sensitivities

We carry out a number of sensitivities to test whether the results vary depending on the assumptions we have made. We calculate the benefit–cost ratio for each sensitivity in Table 4.2 below.

Table 4.2 Benefit–cost ratio of reinstating EGNOS under different sensitivities

Sensitivity	BCR
Assuming that EGNOS enables only around 11% more passengers per annum to travel rather than 22% more passengers	1.6
Considering only arriving passengers at the ten airports to benefit from the reinstatement of EGNOS[1]	1.4
Cancellations lead to 13 hours of lost time rather than just four hours	4.8
Assuming that Sumburgh Airport is adequately served by the ILS on its single runway, and therefore reinstating EGNOS does not significantly improve delays and cancellations	1.9
Lower passenger value of time	2.5

Note: [1] we have assumed in our main analysis that both departing and arriving passengers at a given airport will benefit from EGNOS. This is because we understand a number of airports were intending to install EGNOS, e.g. St. Mary's, which would mean that departing flights from Lands End to St. Mary's would benefit from EGNOS. However, we carry out a sensitivity whereby this does not materialise, and so only arriving passengers at the tend airports would benefit from a temporary reinstatement of EGNOS.

Source: Oxera.

While some of the sensitivities reduce the BCR, they remain well above 1 in all sensitivities. This means that the finding that the benefits of EGNOS exceed its costs is robust across a range of different assumptions.

While some combinations of the sensitivities above may lead to a BCR of less than one, this has to be balanced against the fact that other sensitivities tend to increase the BCR. In addition, as discussed below, there are a number of other, non-monetised benefits that would improve EGNOS' value for money.

Non-monetised benefits

In addition to the monetised benefits above, there are a number of non-monetised benefits, including:

- benefits for some airports that were intending to adopt EGNOS, such as London Biggin Hill Airport, but have been unable to—one industry stakeholder told us that there were around 20 airfields that were in the process of implementing EGNOS procedures;
- improved resilience for airports in case of their ILS being out of service, such as Newcastle Airport;
- ensuring that UK flight schools are able to offer a competitive and comprehensive training programme (we are already aware that some flight training schools have downsized or closed as they are unable to offer EGNOS);

- enabling precision GNSS services for helicopters (Point in Space, or PinS, technology), which allows for access to heliports in adverse weather conditions without the need for costly ground infrastructure);
- loss of other essential services, e.g. mail and cargo;

Therefore, if non-monetised benefits are included in the economic assessment, the business case of EGNOS is strengthened even further.

There are also benefits to other sectors, including maritime and agriculture, that would be realised if EGNOS were reinstated—at no additional cost to government. These include safety benefits in the maritime sector and increased yields and crop savings in the agricultural sector.

A1 Detailed methodology and results

In this section, we set out the details behind our methodology and the calculations that underlie our results.

Our methodology is based on that adopted by the European Commission in quantifying the benefits of EGNOS in 2009. We update the Commission's approach using with information we have gathered from our discussions with stakeholders, as well as UK data sources, such as the CAA and the DfT.

We quantify a number of benefits of EGNOS where there is sufficient information to do so. These are:

- time savings to passengers from fewer delays;
- cost savings to airlines from fewer delays and cancellations;
- benefits to patient health and cost savings to the NHS resulting from fewer missed medical appointments;
- the benefits of lower risk of controlled flight into terrain (CFIT).

These are discussed further in turn below. Section A1.1 sets out our approach to quantifying monetised benefits and costs. Section A1.2 describes the sensitivities that we have carried out to test the robustness of our results.

A1.1 Monetised assessment of costs and benefits

This section sets out how we have quantified the four benefits as listed above. A summary of the methodology and calculations that we have undertaken to arrive at the monetary value of benefits is set out in Table A1.1 below. These are discussed in turn below.

Table A1.1 Summary of calculations underlying our estimated monetised benefits of EGNOS

Passenger time savings

	Airport	2019 passengers	% pax avoiding DCs due to EGNOS	Pax avoiding DCs due to EGNOS
	Barra	14,599	22%	3,234
	Campbelltown	8,086	22%	1,791
	Dundee	20,917	22%	4,633
	Islay	34,992	22%	7,751
	Kirkwall	172,625	22%	38,236
	Lands-End	64,056	22%	14,188
	Sumburgh	267,456	11%	29,620
	Tiree	12,178	22%	2,697
	Wick	13,149	22%	2,912
[A]	Total pax avoiding DCs due to EGNOS	608,058		105,063
	* Delays and cancellations (DCs)			
[B]	Lost time due to a delay or cancellation (hours)	4		
[C]	Passenger value of time (£/hour)	23.61		
[D=A*B*C]	**Passenger time savings (£)**	**9,923,513**		

Savings for airlines

[E]	Average load factor	15
[F=A/E]	Number of flights avoiding DCs due to EGNOS	7,004
[G]	Cost to airlines for each hour of delay	1,543
[H=F*G*B]	**Savings for airlines**	**43,216,623**

Benefits from reduced risk of CFIT		
[I]	Value of CFIT in 2016 across the EU (EURm, 2009 prices)	21.8
[J]	Growth in air travel between 2016 and 2019	1.07
[K]	CPI Inflation from 2009 to 2019	1.29
[L]	EUR/GBP exchange rate	0.86
[M]	UK landings as a proportion of EU landings	16%
[N=I*J*K*L*M*10^6]	**CFIT benefits for the UK in 2019 (GBP, 2021 prices)**	**4,148,249**
Health benefits to patients and cost savings to the NHS		
[O]	Total number of missed appointments in 2021 involving delayed or cancelled flights at Lands End airport	277
[P]	Proportion of delays and cancellations that can be avoided due to EGNOS	48.5%
[Q=O*P]	Fewer missed appointments due to EGNOS in 2021	135
[R]	Total passengers at Lands End in 2021	53,211
[S=Q/R*1000]	Number of fewer missed appointments at Lands End in 2021	2.5
[T]	Number of passengers at affected airports in 2019	608,058
[U=T*S/1000, accounting for Sumburgh]	Number of fewer missed appointments, assuming 2019 passenger traffic levels	1199
[V]	Cost to a patient of a one month wait	13,464
[W=U*V]	Benefit to patients of fewer missed appointments (£)	16,149,406
[X]	Cost to the NHS of a missed appointment (£)	133
[Y=U*X]	Total cost to NHS	159,514
[Z=W+Y]	**Total benefits to patients and cost to NHS**	**16,308,920**

Source: Oxera analysis.

Time savings to passengers from fewer delays

We estimate the value of time savings to passengers by multiplying the number of passengers who would be able to avoid delays or cancellations if EGNOS were reinstated by the time lost due a delay or cancellation and the value of time savings.

We estimate the number of passengers who would be able to avoid delays and cancellations by multiplying: (i) the total number of passengers at airports who would be able to readily benefit from EGNOS if it were reinstated; and (ii) the proportion of passengers who would be able to avoid delays or cancellations. These two elements are discussed further below.

- We estimate the number of passengers who would be able to readily EGNOS based on a list of 18 airports that already had EGNOS infrastructure installed prior to EGNOS being unavailable. Of these, we excluded airports that already have instrument landing systems (ILS) installed as they would have an alternative system to EGNOS available, mitigating the impact on delays and cancellations. These airports are shown in Table A1.2 below.

Table A1.2 Airports that have EGNOS infrastructure in place, with and without instrument landing systems (ILS)

#	Airport	Has ILS?	#	Airport	Has ILS?
1	Barra	No	10	Kirkwall	No
2	Barrow	No	11	Land's End	No
3	Bristol	Yes	12	Newcastle	Yes
4	Campbelltown	No	13	Prestwick	Yes
5	Cardiff	Yes	14	Southampton	Yes
6	Doncaster	Yes	15	Sumburgh	No*
7	Dundee	No	16	Tiree	No
8	Exeter	Yes	17	Wick	No
9	Islay	No	18	Yeovil	No

Note: * Sumburgh Airport has ILS enabled on one runway but not on another runway. Therefore, it is still likely to partially benefit from a reinstatement of EGNOS. We account for this by halving the efficacy of EGNOS for passengers at this airport. We carry out a sensitivity to test the impact of this assumption, as described further in section A1.2.

Source: Department for Transport written question – answered on 11th March 2022; NATS (2022), 'United Kingdom Aeronautical Information publication', 19 May, pp. 30–33.

Approaches to airports without an ILS would become more reliable if EGNOS were available. However, it is also likely that flights *departing* from these airports would become more reliable. For example, St. Mary's Airport at the Isles of Scilly is well advanced in seeking approval for the use of EGNOS. Therefore, flights departing from Land's End Airport to St. Mary's would also become more reliable. Furthermore, based on discussions with industry stakeholders, we understand some larger airports have invested in EGNOS to cater for EGNOS-enabled aircraft from other smaller islands. For example, an airport in mainland Scotland would invest in EGNOS in order to support EGNOS-enabled flights from the Scottish islands. Therefore, we estimate the number of passengers who may benefit from reinstating EGNOS to be the sum of departing and arrival passengers at the ten airports without an ILS.[49] We use passenger figures in 2019 as it is the latest year of data that is unaffected by the pandemic, given that air passenger demand is returning to pre-pandemic levels. The ten airports account for a total of 608,058 passengers in 2019.

- We estimate the proportion of passengers who would be able to avoid delays and cancellations due to the use of EGNOS when they would otherwise would have experienced them based our on data from Land's End Airport. The airport had fully enabled EGNOS in July 2019, meaning that it was able to collect a full year of data of using EGNOS in 2020 (although COVID has had a significant impact on passenger volumes in 2020). Land's End Airport provided a report showing that in 2020 it used EGNOS a total of 256 times during arrivals, excluding flights for training purposes.

  Based on further conversations with Land's End Airport, we understand that these are flights that would have either experienced delays or cancellations had EGNOS been unavailable. In addition, Land's End Airport told us that this is likely a conservative estimate. This is because the airport was in the process of seeking approval from the CAA to further lower the operating minima, which would have allowed it to operate in even more bad weather days than indicated.

[49] We carry out a sensitivity to this assumption, described in section A1.2 below.

Land's End Airport told us that the average load factor on its flights was 15 passengers. This implies that 3,840 passengers would have been affected. Based on data from the CAA, Land's End Airport saw around 34,673 departing and arrival passengers in 2020. Assuming that half of these were arrivals, there are 17,377 total arriving passengers. This means around 22% of all arriving passengers would have experienced delays if EGNOS were not available to them.

Based on the analysis above, around 105,000 passengers per year would be able to avoid delays or cancellations (see row [A] of Table A1.1 above)

The next step is to estimate how much time would be saved by each passenger as a result of an avoided delay or cancellation. In 2014, the CAA carried out a passenger survey to understand consumers' experiences of disruption to their journeys. It found that the average wait for delayed flights was four hours. For cancelled flights, passengers waited 13 hours on average. The significant duration of delays is consistent with data that we have received from Land's End Airport, showing that bad weather affects a significant proportion of each day.

While a cancellation lasts 13 hours on average according to (CAA data), it may be possible for passengers to return home upon learning of their cancellation (81% of passengers only learn that their flights are cancelled after reaching the airport). This may mean that the disbenefits suffered by the passenger may not be equivalent to the full 13 hours of lost time due to a cancellation. Conversely, if a passenger has travelled from further away and may have to book accommodation while waiting for their next flight, 13 hours or more of lost time may be a reasonable estimate. In our main analysis, we assume that the lost time due to a cancellation is the same as that of delays, at four hours (see row [B] of Table A1.1 above). We present analysis using the 13-hour estimate as a sensitivity, as described further in section A1.2.

To convert the saved time into a monetary benefit, we multiply the saved time by the passenger value of time. Based on a number of different studies, we use a passenger value of time of £23.60 per hour (see row [C] of Table A1.1 above).[50] This value has been used to study passenger choice in other contexts. We carry out a sensitivity with an alternative passenger value of time, as detailed further in section A1.2.

Based on the above, we estimate the passenger time savings from reinstating EGNOS to be around £9.9m (see row [D] of Table A1.1 above).

Cost savings to airlines from fewer delays and cancellations

The calculation of the cost savings to airlines is similar to that of benefits. We estimate the number of affected flights by dividing the total number of passengers who would have avoided delays or cancellations by the average load factor, which is 15 passengers per aircraft, based on data from Land's

[50] Merkert, R., and Beck, M. (2017), 'Value of travel time savings and willingness to pay for regional aviation', Transportation Research Part A: Policy and Practice, 96, 29–42; FAA Office of Aviation Policy and Plans (2021), 'Economic Values for FAA Investment and Regulatory Decisions, a Guide: 2021 Update', section 1, https://www.faa.gov/regulations_policies/policy_guidance/benefit_cost; Ennen, D., Allroggen, F., and Malina, R. (2019), 'Non-stop versus connecting air services: Airfares, costs, and consumers' willingness to pay', MIT International Center for Air Transportation; National Academies of Sciences, Engineering, and Medicine (2015), 'Passenger Value of Time, Benefit-Cost Analysis and Airport Capital Investment Decisions, Volume 1: Guidebook for Valuing User Time Savings in Airport Capital Investment Decision Analysis', Washington, DC: The National Academies Press. https://doi.org/10.17226/22162. These studies have been cited in research understanding how travel times affect passenger choice. For example, see Transport and Environment (2022), 'Assessment of carbon leakage potential for European aviation', January.

End Airport (see row [E] of Table A1.1 above). Based on this, an estimated 7,004 flights per year would be able to avoid delays or cancellations if EGNOS were reinstated (see row [F] of Table A1.1 above).

There are a range of estimates available as to what the cost of delays and cancellation would be for airlines.

- In a study commissioned by the European Commission that carried out a cost–benefit analysis of EGNOS, the authors considered fuel, crew, maintenance and aircraft ownership costs. They found that the cost of a delay or cancellation would be around £3,190 per hour, based on data from the Air Transport Association (ATA).[51] However, this may be an overestimate for the purposes of this study, as the costs may be based on larger jet aircraft, whereas the main flights affected in the UK context are smaller turboprop aircraft.
- A study by the University of Westminster, updating previous work by the European Commission, provides costs for tactical delays, i.e. those incurred on the day of operations and not accounted for in schedules. It finds that for an ATR42-300 aircraft (a small turboprop aircraft comparable to those which will be affected by the loss of EGNOS), the cost to an airline of a 60-minute delay is £1,420.[52] We note that these exclude 'reactionary costs', i.e. the knock-on impacts of an initial primary delay on the rest of an airline's operation. When taking these into account, the costs are £2,503 for a 60-minute delay.

  With a longer delay of 240 minutes, the study finds significantly higher costs of £13,171 and £25,287 with and without reactionary costs respectively. This reflects the costs to airlines of dealing with dissatisfied passengers, who need to be provided with compensation, care and potentially rebooking services the longer the delay is. These are in addition to passengers' value of time.[53] These costs are summarised in Table A1.3 below.

Table A1.3 Costs of a delay for an airline operating an ATR42 aircraft, £ per hour

Length of delay	Without reactionary costs	With reactionary costs
60 minutes	1,429	2,503
240 minutes	13,171	25,287

Source: University of Westminster (2015), 'European airline delay cost reference values. Updated and extended values. Version 4.1', table 22.

We note that Loganair's fleet, which serves the Scottish Islands, includes the ATR42. However, it also includes smaller aircraft, such as the Twin Otter, which is also used by Skybus when serving Land's End and the Isles of Scilly. The Twin Otter is a smaller aircraft relative to the ATR 42 (with 19 seats vs 42 seats).

[51] L.E.K. (2009), 'EGNOS Cost Benefit Analysis in Aviation', 27 July, slide 33.
[52] These figures have been adjusted for inflation to reflect 2021 prices and converted from Euros to GBP.
[53] University of Westminster (2015), 'European airline delay cost reference values. Updated and extended values. Version 3.2', https://www.eurocontrol.int/sites/default/files/publication/files/european-airline-delay-cost-reference-values-final-report-4-1.pdf, pp. 6–7 .

As we do not have delay costs for the average aircraft for airports affected by EGNOS, we use the lower end of the range of values available above, i.e. we assume that the cost of delay per hour for an airline is £1,429 (see row [G] of Table A1.1 above). This assumes a 60-minute delay (where the length of the delay is on average significantly longer at four hours, according to a report by the CAA) and excludes reactionary costs.[54]

We calculate the savings for airlines if EGNOS were reinstated as the costs of delay per hour multiplied by the duration of a delay and the average number of flights. We estimate the savings of airlines to be around £43m per year (see row [H] of Table A1.1 above).

The benefits of lower risk of CFIT

The benefits of reducing the risk of CFIT are difficult to quantify. While CFITs are unlikely events, they lead to very high costs when they do occur. This includes the potential for loss of life, damage to expensive aircraft, and loss of trust in the safety of UK aviation.

We base our estimate of the benefits of CFIT on the European Commission's previous cost–benefit analysis of EGNOS. The study estimated the benefits of reduced risk of CFIT to be €21.8m with 2016 traffic levels, in 2009 prices (see row [I] of Table A1.1 above). We adjust the Commission's figures for inflation to reflect 2021 prices, and we uprate traffic levels to reflect 2019 traffic. We pro-rate the EU-wide benefits in proportion to UK traffic to obtain the benefits for the UK (see rows [J] to [N] of Table A1.1 above).[55]

Cost savings to the NHS from fewer missed appointments

Flight delays and cancellations lead to missed NHS appointments. Delays for patients seeking treatment could lead to adverse health outcomes, while missed appointments waste NHS resources that could otherwise have been used for other patients.

Land's End Airport provided us with data on the number of NHS bookings Skybus carried in 2021, amounting to 3,154 passengers per year. As each medical appointment would require one departure and one arrival at Land's End, Skybus supported 1,577 medical appointments in 2021. These represent trips that were successfully carried out by Skybus, and do not include those that have been delayed or cancelled.

To determine how many medical appointments would otherwise have been missed without EGNOS due to a flight delay or cancellation, we use results from a survey carried out by Healthwatch on medical travel from the Isles of Scilly in 2016; 81% of respondents were able to attend on the day of their appointment, while 19% were unable to attend. Assuming that the 1,577 medical appointments successfully attended above is associated with 81% of all medical appointments,[56] this suggests that there were around 300 missed appointments in 2021. Of these, flight delays and cancellations account for 75% of all missed appointments, representing 277 missed appointments (see row [O] of Table A1.1 above).

[54] Civil Aviation Authority (2014), 'Passenger experiences during flight disruption. Consumer research report. CAP 1258', https://publicapps.caa.co.uk/docs/33/CAP1258_Disruption_research.pdf.
[55] The traffic growth rate and UK traffic figures as a proportion of EU traffic can also be found in the Commission's study. See L.E.K. (2009), 'EGNOS Cost Benefit Analysis in Aviation', 27 July.
[56] Ideally, the 1,577 figure would represent the number of successfully carried medical appointments if EGNOS were not available. However, we note that EGNOS was available for half of 2021. In the absence of further information, we use the 1,577 figure.

The previous European Commission study suggested that 48.5% of all delays and cancellations could be avoided with the use of EGNOS, based on Eurocontrol data (see row [P] of Table A1.1 above). Therefore, this suggests that if EGNOS were reinstated, 135 fewer appointments would be missed (see row [Q] of Table A1.1 above).

If we extrapolate the experience above to all ten affected airports, indicating that 1,199 fewer medical appointments would be missed overall if EGNOS were to be reinstated (see rows [R]-[U] of Table A1.1 above).

The Healthwatch survey suggests that if patients were delayed, they had to wait just under one month on average[57] to rearrange their appointments. According to a study by the National Institute for Health and Care Research (NIHR), patients value a one-month reduction in waiting times to be the same as 0.68x of a quality-adjusted life year (QALY). A value of £20,000 for a QALY has been used to evaluate the cost effectiveness of NHS treatments, implying that the value of a one-month wait time is £13,600.[58] As each missed appointment takes just under a month to rearrange, the cost to a patient of a missed appointment is £13,464 (see row [V] of Table A1.1 above).

Multiplying the cost per missed appointment with the number of missed appointments yields benefits to patients of around £16.1m per year (see row [W] of Table A1.1 above)

In addition, each NHS appointment leads to wasted NHS resources. We proxy the cost of the each missed NHS appointment using outpatient appointments, at approximately £133 in 2021 prices see row [X] of Table A1.1 above).[59] Applying this figure to the number of missed appointments suggests that the cost to the NHS is around £159k per year (see row [Y] of Table A1.1 above).

The total benefits to patients and cost savings to the NHS are therefore £16.3m per year (see row [Z] of Table A1.1 above).

Costs

The costs of UK participation in EGNOS are around €30m–€35m per year.[60] This equates to around £25.8m–£30.1m per year. For the purposes of our analysis, we take the cost of EGNOS to be the midpoint of this range, at £27.9m per year.[61]

There could be additional costs that airports and airlines need to incur to reinstate EGNOS. However, for the purposes of our analysis of monetised benefits, we have only considered airports that have already invested into EGNOS. As a result, there may not be significant additional costs to reinstate EGNOS.

For example, Land's End Airport told us that all the survey work and safety case to introduce EGNOS-assisted procedures has already been done. They highlighted that the EGNOS signal is still currently available to pilots to use, but pilots are unable to legally use it as the UK has stopped participating in EGNOS. Land's End also told us that they do not believe an Airspace Change

[57] 0.99x a month.
[58] NIHR, 'Appendix C: access, equity and cost-effectiveness, and the trade-offs between them', https://njl-admin.nihr.ac.uk/document/download/2026834.
[59] NHS (2018), 'NHS to trial tech to cut missed appointments and save up to £20 million', https://www.england.nhs.uk/2018/10/nhs-to-trial-tech-to-cut-missed-appointments-and-save-up-to-20-million/, accessed 20 May 2022.
[60] Question for Department for Business, Energy and Industrial Strategy, UIN HL5379, 13 January 2022.
[61] As the airports listed in Table A1.1 have already invested into EGNOS, we do not expect there to be costs additional to the £27.9m to deploy EGNOS.

Process (ACP) would be needed as EGNOS would just be an overlay to improve existing approaches.

A1.2 Sensitivities

We have made a number of assumptions to quantify the benefits of EGNOS. To test whether our results are sensitive to these assumptions, we carry out a number of sensitivities.

- **Assuming that EGNOS enables only around 11% more passengers per annum to travel rather than 22% more passengers**. Based on METAR data (which are weather reports used by pilots) for the year 2021, Land's End estimated that of the 310 days of operation (excluding weekends and bank holidays), around 62.5 days of operation are lost due to poor weather. They excluded instances where even with EGNOS, the poor weather would still have not allowed flights to operate, e.g. where there were strong winds and where visibility would have been too poor even with EGNOS. These account for 36.5 days in total. For the remaining days (26 days), EGNOS would have enabled flights to operate when they otherwise would not have been able to.

  Based on this, they estimate that EGNOS would have enabled around 11% more passengers to travel.[62]

- **Considering only arriving passengers at the ten airports.** We have assumed that both arriving and departing passengers at the ten airports will benefit from EGNOS. However, it may be the case that the departing passengers may not benefit from EGNOS (e.g. some departing passengers from Land's End Airport may not benefit from EGNOS if St. Mary's Airport does not implement EGNOS). Furthermore, considering both departing and arriving passengers at each airport could double-count the number of passengers, for example if there are a significant number of flights between the Scottish Highland airports. Therefore, as a sensitivity, we consider only passengers arriving at the ten airports above.

- **Assuming that cancellations lead to 13 hours of lost time rather than just four hours.** We have assumed above that cancellations cause only four hours of delay. However, data from Land's End Airport suggests that when bad weather occurs, it regularly affects significant portions of a given day. In addition, if passengers at these airports are unable to easily use their time in productive ways or for leisure (e.g. if they have travelled far from their home), the cancellation could lead to significantly more than four hours of lost time. Therefore, we carry out a sensitivity where a cancellation leads to 13 hours of lost time (based on CAA data) instead of four hours.

- **Assuming that Sumburgh Airport is unaffected by the reinstatement of EGNOS.** While Sumburgh's main runway is equipped with an ILS, its second cross runway airport is not.[63] In the methodology set out above, we assumed that if EGNOS were to be reinstated, Sumburgh would still partially benefit as the second runway does not have an ILS. As a sensitivity, we assume that the ILS at the main runway is currently adequate for serving most operations at the airport, and therefore the reinstatement of EGNOS would not lead to a significant improvement in delays and cancellations.

[62] 26 days enabled by EGNOS / (310 total operational days – 62.5 days with weather disruptions) = 10.5%
[63] HIAL, 'Energy services', https://www.hial.co.uk/hial-group/commercial/2, accessed 23 May 2022.

- **Lower passenger value of time.** Our estimate of the passenger value of time above is based on a number of studies in the economics literature. These represent a mix of both leisure and business travellers. However, the composition of passengers on routes affected by EGNOS could differ to those in the studies. Therefore, to test the sensitivity of our results to this assumption, we assume that all passengers on this routes are leisure passengers. We use a value of time for leisure passengers of £11.64 per hour, based on the Department for Transport's aviation modelling framework.[64,65]

[64] Department for Transport (2012), 'Rules and modelling: a user's guide to the DfT aviation modelling framework. Edition 3: DLL26', April, https://www.whatdotheyknow.com/request/111789/response/275794/attach/4/120419%20Rules26a.pdf?cookie_passthrough=1.

[65] Based on available information, the value of time for leisure passengers is £6.98/hour in 1998 and £13.48 in 2030. We linearly interpolate these values to obtain the value of time in 2021 of £11.64.

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