Airspace4All GA Airfield ATS ADS-B Traffic Display Trial

Trial Report

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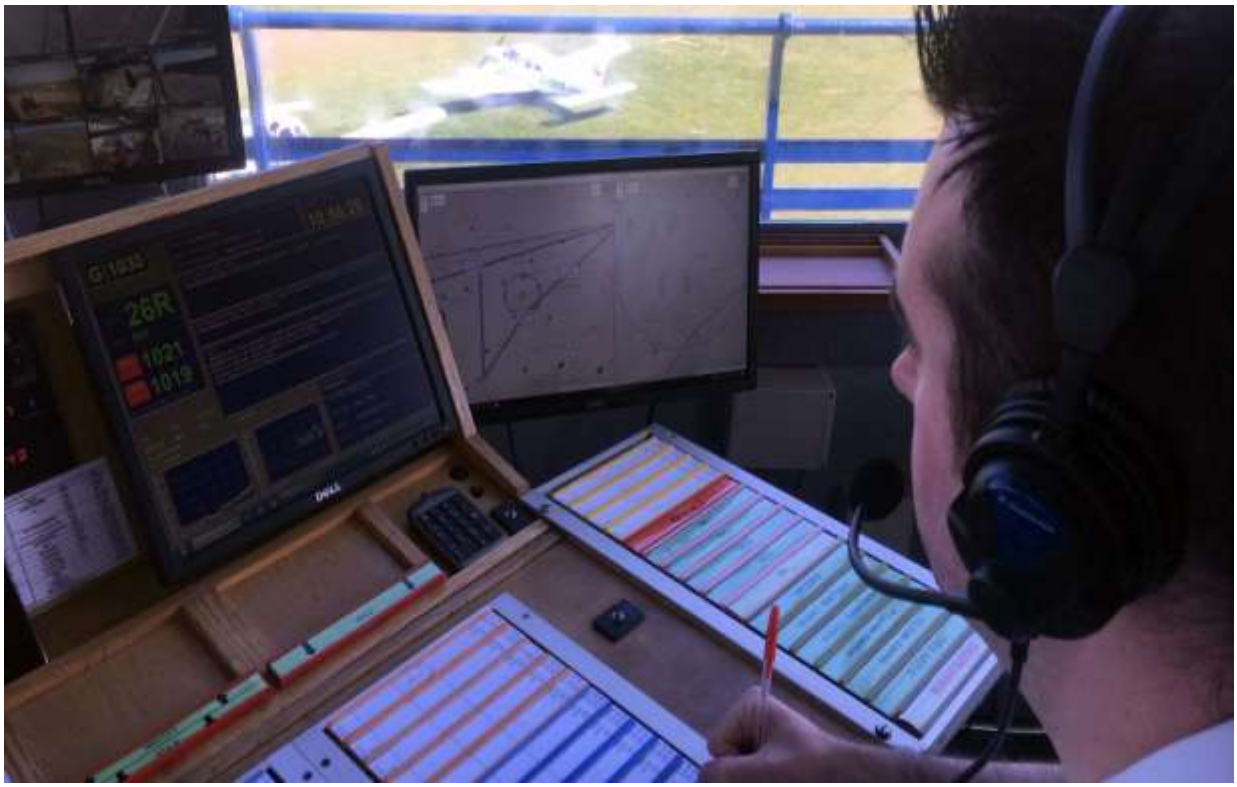

1 Executive Summary

This document reports the findings of the Airspace4All GA airfield ATS ADS-B Traffic Display Trial which sought to test mitigations to the increased risk of mid-air collision that had been identified[1] to occur in airfield traffic circuits and adjacent airspace.

For the 6 month duration of the trial AFIS and AGCS units at three UK GA airfields were equipped with real-time flight tracking equipment that provided a situational awareness tool with the potential to enhance the level of service and thus the safety of aircraft flying in the vicinity of the airfields. The Traffic Display was not used to provide any form of Air Traffic Control service.

The aim of the trial was:

> To gather information to assess the use of ADS-B Traffic Displays at GA airfields with a view to future authorisation and to assess the potential to:
>
> - Reduce the probability of mid-air collisions.
> - Provide increased situational awareness resulting in a reduction in airspace infringements
> - Monitor compliance with local traffic regulations

Additionally, it was expected that this trial would encourage further development and carriage of conspicuity technology to support ATS and AGCS provision at UK GA airfields and to provide aircraft-to-aircraft situational awareness

The trial safety plan and safety case were reviewed and approved by the UK CAA prior to commencement.

ATS and AGCS units provided daily and monthly feedback via online forms. The trial results are based on analysis of this feedback plus direct engagement with the technology and the units concerned.

"Having been a FISO for some 20 years it has been nothing but a positive. It enables me to provide a much better service as a FISO giving me a tool to enhance my own situational awareness. ……

I can now confidently know where aircraft are and identify relevant traffic information and assist pilots in avoiding conflict"

The ADS-B Traffic Display system is relatively low-cost – some 3% of the implementation cost of a multilateration surveillance system formally trialled elsewhere – making it within the means of virtually all UK GA airfields. Setup is reasonably straightforward, only requiring a modicum of IT expertise.

[1] *Mid-Air Collisions: An Evidence-Based Analysis of Risk – 1975 to 2018; Airspace4All, 24th April 2019* https://airspace4all.org/mac-risk-analysis-1975-2018/

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The ADS-B Traffic Display was reported to be reliable, very accurate and did not constitute a distraction hazard; it was safe to use. It was perceived by a large majority of operators to be a valuable enhancement to their existing tools and procedures, improving situational awareness and service and providing a positive safety benefit to aircraft. It also had a positive effect on ATS and AGCS staff's well-being and confidence. However, achieving the benefits required commitment from airfield management and staff to provide the installation, training and supervision, and an openness to change. Its use raised awareness of the benefits of ADS-B carriage which is already leading to increased aircraft fitment and deployment.

The trial concluded that GA safety would be improved by authorising GA airfield ATS and AGCS units to use ADS-B Traffic Displays. That would require amendment to regulations relating to staff licensing, ATS and RTF procedures and surveillance systems. Bringing ADS-B Traffic Display installation and operation within the means of UK GA airfields would require light and proportionate regulation together with simple and inexpensive start-up procedures.

Limitations caused by range and obscuration of portable ADS-B device transmissions were identified but investigating these was outside the scope of the trial. These need to be understood; this could be done by further work using the existing Airspace4All trial equipment and locations.

Clutter caused by ADS-B devices left on in parked aircraft needs to be resolved by procedures and that and other configuration control measures need to be developed to provide a robust system for further deployment.

Overall, the ADS-B Traffic Display was found to be an effective and economic means of providing accurate and timely traffic information to aircraft at and around a GA airfield. Its installation was welcomed by ATS and AGCS operators.

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3 Introduction

This document is a report of the findings of the Airspace4All GA Airfield ATS ADS-B Traffic Display Trial during the 6-month period 1st March 2019 to 31st August 2019.

3.1 Note on Terminology – 'ATS' and 'AGCS'

'ATS' is an acronym of 'Air Traffic Service'. The glossary in the Manual of Air Traffic Services - Part 1 (MATS Part 1) defines '*Air Traffic Service (ATS)*' as:

> *"A generic term meaning variously, flight information service, alerting service, air traffic advisory service, air traffic control service (area control service, approach control service or aerodrome control service). ((EU) 923/2012)"*

This MATS Part 1 definition excludes 'Air Ground Communication Service' (AGCS). However, for brevity, throughout this document where the term 'ATS' is used its meaning is intended to include 'Air Ground Communication Service' (AGCS). In some instances, for emphasis or specificity, the terms 'Air Ground Communication Service' or 'AGCS' and 'Aerodrome Flight Information Service' or 'AFIS' are also used.

3.2 Why have a Trial?

When flying in an area close to an airfield or in the circuit general aviation (GA) pilots are often in receipt of an ATS provided by the airfield's ATS unit. Yet analysis of past UK GA mid-air collisions has shown that this environment remains the highest risk area for mid-air collisions.

Previous studies have identified limitations to the 'see and avoid' principle by which pilots flying Visual Flight Rules (VFR) should avoid other aircraft and have stated that ***alerted*** see-and-avoid is eight times more effective than unalerted. Further, many of the factors that hinder a pilot's ability to see other aircraft also hinder the ability of ATS staff to visually acquire aircraft in/joining/leaving their airfield's visual circuit. This has a bearing on the safety of the flights in receipt of their service. Better traffic information from ATS could be the alert that enables a pilot to see and avoid other traffic.

Surveillance systems based on radar have been available for many years to Air Traffic Control Officers at airports that can afford them, but this technology is far too expensive for smaller UK GA airfields. However, with the development of electronic conspicuity (EC) solutions for GA aircraft, such as Automatic Dependent Surveillance Broadcast (ADS-B), computer-based traffic displays that can present highly accurate real-time EC surveillance information are now available at a price affordable to GA airfields.

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These systems can provide greater certainty to ATS staff on the position of ADS-B equipped aircraft, yet current licensing regulations[2] covering non-radar GA ATS units do not allow their use.

3.3 What did the Trial entail?

With permission from the UK CAA, Airspace4All has undertaken a trial of low-cost ADS-B traffic display technology used in support of traditional methods by ATS units at three UK GA airfields. Known as the ***Airspace4All GA Airfield ATS ADS-B Traffic Display Trial***, it sought to evaluate the potential for small UK GA airfields to improve situational awareness for ATS staff and pilots, and thus improve safety.

Timeline to commencement of Trial at First Airfield	
June 2017	Proposal for funding to run Trial submitted (by FASVIG, name of Airspace4All prior to 1st September 2018)
July 2017	Funding for Trial granted by Future Airspace Strategy Facilitation Fund Investment Board. Order placed for purchase of equipment. Awaiting CAA CONOPS (deemed a prerequisite by CAA before work on trial Safety Case & Safety Plan could commence).
August 2017	Public announcement of intention to run trial.
November 2017	CAA published Electronic Surveillance Roadmap Project: Concept of Operations (CONOPS) Issue 1.
January 2018	CAA published Electronic Surveillance Roadmap Project: Concept of Operations (CONOPS) Issue 2.
February 2018	First Draft of Trial Safety Case submitted to CAA.
March 2018	First Draft of Trial Safety Plan submitted to CAA.
June 2018	Second Draft of Trial Safety Case & Safety Plan submitted to CAA.
July 2018	Third Draft of Trial Safety Case & Safety Plan submitted to CAA.
September 2018	Fourth Draft of Trial Safety Case & Safety Plan submitted to CAA.
October 2018	Trial Safety Case & Safety Plan Approved by CAA. Barton prepared first draft of their Airport Supplementary Instructions (ASI) and Training Plan for the Trial. CAA site visit to Barton to review ASI and other preparations.
March 2019	CAA approved ASI, etc, granting permission for trial at Barton. Trial commenced at Barton (first of three trial airfields).

The aim of the trial was to gather evidence to enable the CAA to assess this capability and give consideration to policy change that would authorise the use of ADS-B real-time traffic displays by GA airfields. Additionally, it was expected the trial

[2] E.g. CAP 774 UK Flight Information Services 2.2, page 23, CAA May 2017
"A FISO shall not utilise surveillance-derived data to provide traffic information when providing a Basic Service. The use of surveillance equipment by FISOs for other specific tasks is subject to regulatory approval."

would encourage further development of technology to support ATS provision at UK GA airfields. Without a policy that permits use of such systems there can be no market to encourage innovation and development.

For the duration of the trial the ATS units at the participating GA airfields were equipped with real-time flight tracking equipment based on ADS-B that provides a situational awareness tool. It was not used to provide any form of Air Traffic Control service. ADS-B is the UK CAA's publicly stated preferred EC solution[3]. It is an international standard that is used under existing international regulations on a radio frequency that is protected worldwide for use solely by aviation.

The Trial Airfields were:

- City Airport Manchester Barton (Barton)
- Chichester/Goodwood Aerodrome (Goodwood)
- North Weald Airfield

Additionally, to complement those aircraft already equipped with ADS-B Out (portable or fixed airframe installations), a number of GA aircraft based at the Trial Airfields were equipped with loaned CAP1391-compliant portable ADS-B Out devices. Airborne usage and air-to-air ADS-B In capabilities of the CAP1391 compliant devices were outside the scope of the trial except where they had a bearing on the ATS provision.

Further information about the trial is available on the Airspace4All website[4].

3.4 Planning for the Trial

3.4.1 Safety Plan & Safety Case

A Safety Plan[5] and Safety Case[6] were developed for the trial and approved by the CAA. These documents are available on the Airspace4All website.

3.4.2 ADS-B Trial Objectives

The objectives of the trial were as follows:

1. Gather information to assess the use of ADS-B Traffic Displays at GA airfields with a view to their future authorisation at other GA airfields[7].
2. Reduce the probability of mid-air collisions.
3. Provide increased situational awareness resulting in a reduction in airspace infringements
4. Monitor compliance with local traffic regulations

[3] https://www.caa.co.uk/News/ADS-B-can-help-reduce-airspace-infringements-and-mid-air-collisions,-says-CAA/

[4] https://airspace4all.org/projects/ec/ec-detail/

[5] https://airspace4all.org/wp-content/docs/20181012-Airspace4All-GA-Airfields-ATS-ADS-B-Traffic-Display-Trial-Safety-Plan-V1.0.pdf

[6] https://airspace4all.org/wp-content/docs/20181012-Airspace4All-GA-Airfields-ATS-ADS-B-Traffic-Display-Trial-Safety-Case-V1.0.pdf

[7] On 17th September 2018 the CAA published a consultation on FISO Licensing that outlines a suggested licensing change that might permit use of surveillance tools by FISOs. CAP1669 Review of CAA Policy on the Training, Qualification and Licensing of Flight Information Service Officers (https://consultations.caa.co.uk/future-safety/fiso-training-qualification-licensing-review/)

3.5 Scope of Trial

The scope of the Trial was:

Within Scope

- Aircraft operations in the vicinity of the trial airfields only.
- ATS operational aspects resulting from using the ADS-B Traffic Display system.
- Safe use of ADS-B Traffic Display (including position plots with no integrity).

Outside of Scope

- Any third-party devices that are connected to the airborne ADS-B unit (e.g. iPad with moving map).
- Air-to-air links, as these require additional airborne equipment (i.e. cockpit display device).
- Integrity of internet/cloud based data.
- Equipment assurance for airborne and ground based equipment, meaning:
    - Equipment integrity.
    - Software assurance.
    - Electro Magnetic Interference (EMI) and interference with other systems and equipment.
    - Health and Safety at Work aspects, or project and financial risks.

3.6 Amendments to the Original Plan

3.6.1 The Trial Airfields

Originally, the agreed Trial airfields were Barton, Goodwood and Gloucester; however, Gloucester later notified that they were unable to commit to participate and were replaced by North Weald. As well as a change of airfield, this also allowed for an adjustment to the mix of types of air traffic services. Gloucester operates an Air Traffic Control Service. North Weald operates an Air Ground Communication Service (AGCS). Barton and Goodwood both operate Aerodrome Flight Information Service (AFIS).

The trial at each airfield was scheduled to run for a period of six months. Barton's trial period commenced on 1st March 2019, North Weald commenced 1st May 2019 and Goodwood commenced 16th May 2019. Barton's trial completed on 31st August 2019. Because of the delay in commencing the trial at Goodwood and North Weald, those elements of the trial are ongoing. Sufficient data has been collected to support this report and any later findings will be published as an addendum.

In the last week of August 2019 the CAA granted permission for a Phase 2 trial which enables Barton to continue using the ADS-B Traffic Display until 30th April 2020. Phase 2 is outside the scope of this report.

3.6.2 Feedback

Two amendments were made to the collection of feedback.

a) As suggested in the original plan, the use of hardcopy paper-based feedback forms was replaced by web-based online feedback forms. This was simpler and more efficient from both the input and analysis perspective and the process worked well.
b) A request was made to change the Duty Period Feedback (typically 2 hours) to once per day. This was accepted and applied to all three Trial airfields. Each airfield was requested to submit one Daily online feedback form at the end of each day covering the experiences and views of all staff on duty on that day.

4 Literature Review

The following documents with extracts provide context to the trial and its objectives

Limitations of the See-and-Avoid Principle; ATSB Research Report, April 1991,
http://www.atsb.gov.au/publications/1991/limit_see_avoid.aspx

> This study identified limitations to the 'see and avoid' principle by which pilots flying Visual Flight Rules (VFR) are meant to avoid collision with other aircraft.
>
> *"On the 20th May 1988 at approximately 1609 hours, a Cessna 172 collided with a Piper Tomahawk in the circuit area at Coolangatta, Queensland. The accident, in which four people died, occurred in conditions of good visibility.*
>
> *This collision and others which occurred in the late 1980s drew attention to the deficiencies of the see-and-avoid concept.*
>
> *The Coolangatta accident report stated that: 'As a result of this accident, the Bureau of Air Safety Investigation has undertaken to conduct an evaluation and prepare a report on the practicability of the see and be seen (see-and-avoid) principle in controlled and non-controlled airspace.' (BASI report 881/1042).*
>
> *This report, prepared in response to that undertaking, summarises the research relevant to unalerted see-and-avoid and is intended as a reference document for Civil Aviation Authority (CAA), Industry, and BASI personnel as well as a source of recommendations. The report does not analyse the Australian accident experience."*

Unalerted Air to Air Visual Acquisition, J W Andrews, November 1991, Massachusetts Institute of Technology.
https://apps.dtic.mil/dtic/tr/fulltext/u2/a243806.pdf

> This study found that alerted see-and-avoid is eight times more effective than unalerted. I.e. one second of alerted search is as effective as eight seconds of unalerted search.

Mid-Air Collisions: An Evidence-Based Analysis of Risk – 1975 to 2018; Airspace4All, 24th April 2019
https://airspace4all.org/mac-risk-analysis-1975-2018/

> This report states "85% of risk to powered aircraft is from other powered aircraft. 43% of that risk occurs in the cruise and **57% in or close to the airfield or circuit making the latter the greatest risk area**."

Report on Mid-Air Collision between G-RVGC and G-CEZR in the Visual Circuit at Shoreham on 4th July 2011, Air Accident Investigation Branch, 10th December 2014
https://www.gov.uk/aaib-reports/vans-rv-6a-g-rvgc-and-da-40d-diamond-star-g-cezr-4-july-2011
https://assets.publishing.service.gov.uk/media/5422ec3340f0b613460000e3/Vans_RV-6A_G-RVGC_and_DA_40D_Diamond_Star_G-CEZR_06-12.pdf

G-RVGC (downwind in the circuit) and G-CEZR (joining the circuit crosswind) collided in mid-air at Shoreham despite both aircraft being in receipt of an air traffic control service from Shoreham. There was one fatality. Shoreham was providing a combined Aerodrome (ADC) and Approach Procedural (APP) service at the time without the aid of surveillance equipment.

The report states the following with regard to the fact that the ATCO did not see the aircraft joining the circuit:

> *"The sun's position and angle, to the south-west and about 55° above the horizon, meant that it was unlikely to have affected the pilots' lookout. However, it may have affected the ATCO's who would have been looking generally towards the sun when looking for aircraft joining crosswind. The CAA acknowledges that composite aircraft can be difficult to see and, while the ATCO does not specifically recall the sun being a particular issue, the combination of factors may explain why ZR was not seen before it joined the circuit. The remainder of the approach to the collision occurred behind and at a high angle to the ATCO, making visual sighting unlikely."*

Airprox Report No 2019075, Airprox Board, Airprox Date: 18 Apr 2019
https://www.airproxboard.org.uk/uploadedFiles/Content/Standard_content/Airprox_report_files/2019/Airprox%20Report%202019075.pdf

This report analyses an airprox at Sibson Aerodrome involving two aircraft that ended up on short final to land at the same time. Circuit radio calls failed to provide the pilots with sufficient situational awareness and neither pilot sighted the other aircraft. As the first aircraft touched down the second aircraft was 50ft directly above. At this point the ACGS radio operator instructed the higher aircraft to "Go around". The Airprox Board commended the AGCS radio operator for his actions and estimated that, had there been no go around instruction, a collision would have occurred after about 5 seconds.

GPS *General Aviation: ADS-B / GPS Trial Results, NATS, December 2015*
https://nats.aero/blog/wp-content/uploads/2016/03/GA-ADS-B-GPS-Trial-report.pdf

This report found the reliability and accuracy of ADS-B based on non-certified GPS to be comparable to ADS-B based on certified GPS. This is pertinent because of 'Safe use of ADS-B Traffic Display (including position plots with no integrity)' being within the scope of the trial plus the loaned CAP1391 devices which were configured to indicate a position integrity of 'unknown (SIL=0)'.

Among its conclusions, the NATS report stated:

"Based on the results of this trial, it can be seen that the quality of non-certified GPS is sufficient for use in enhancing visual acquisition / electronic conspicuity between participating general aviation aircraft outside controlled airspace."

"It was interesting to note how closely the non-certified data matched the performance of the certified 'white-list' fleet."

"Therefore, General Aviation should be encouraged to enable ADS-B from capable transponders to create an ADS-B based Electronic Conspicuity environment to support the introduction of dedicated ADS-B IN Electronic Conspicuity devices"

CAP1669 Review of CAA Policy on the Training, Qualification and Licensing of Flight Information Service Officers, CAA, September 2018
https://consultations.caa.co.uk/future-safety/fiso-training-qualification-licensing-review/

A CAA consultation on FISO Licensing that outlines a suggested licensing change that might permit use of surveillance tools by FISOs.

Display and use of surveillance data from unapproved systems - Guidance for air navigation service providers, CAA, April 2018
https://www.caa.co.uk/Commercial-industry/Airspace/Communication-navigation-and-surveillance/Display-and-use-of-surveillance-data-from-unapproved-systems/

"The CAA is aware that various electronic means are available to access live aircraft surveillance data in the public domain, with programmes and 'Apps' developed by a number of organisations. Aircraft surveillance data can be displayed on downloaded programmes; on internet web pages; and on various Apps that can be viewed on smart phones, tablets and laptops or other display equipment.

The CAA is mindful that some airfields in the UK that do not currently have access to assured surveillance data may wish to use these programmes and 'Apps' (both henceforth to be described as applications) in the provision of an air traffic service without obtaining the necessary approvals and authorisations associated with a conventional surveillance system.

.....”

5 Methodology

5.1 Engagement with ATS

The Trial Manager engaged with the Airfield ATS units, usually with the primary contact established with each unit. Engagement (via email, telephone or site visits) was greater at the outset of the trial while the technology was being set up, bedding in and optimised through early lessons learned. These lessons were shared by the Trial Manager across all three ATS units and implemented where required and practical. Key learning points are documented in the Results section.

5.1.1 Informal Data Feedback Loop

The instantaneous online delivery of the formal feedback, together with regular personal communications between the Airspace4All Trial Manager and the primary contact at each trial airfield, facilitated a feedback loop where suggestions and ideas for enhancements to the Traffic Display were discussed and, where possible, implemented.

5.1.2 Mode S/CAP1391 Simultaneous Transmission

Airfield ATS loaned out a number of CAP1391 portable ADS-B devices provided by Airspace4All and some of these went into aircraft which already had Mode S non-ADS-B transponders. Airspace4All facilitated a process whereby operators of these aircraft applied for and were granted special permission by the CAA for 'Simultaneous Transmission'. Without this permission, under CAP1391, this simultaneous transmission would not have been permitted.

5.2 Formal Data

5.2.1 ATS Staff Feedback and Reporting

During the trial period ATS staff members were requested to record details of pertinent events/situations (positive, neutral or negative) relevant to the trial. Online feedback forms hosted on the Airspace4All website were created for this purpose, one for Daily Feedback and another for Monthly Feedback.

At the end of each day one member of ATS Staff was requested to complete the Daily Feedback Form describing the ATS unit experience of using the ADS-B Traffic Display on that day.

After the end of each calendar month each member of ATS Staff was requested to complete a Monthly Feedback Form describing their personal experience of using the ADS-B Traffic Display during the previous calendar month.

The content of the submitted online forms was stored in tables on the Airspace4All website (enabling simple extraction of data in CSV format) and emailed to the Airspace4All Trial Manager plus nominated personnel at the submitting airfield.

5.2.2 ATS Staff Daily Feedback Form

The Daily Online Feedback Form requested the date for which feedback was being submitted and the name of the submitter plus other ATS staff on duty that day, in addition to 12 quantitative inputs and two free-form qualitative inputs.

Quantitative Feedback

This requested input based on a five-point Lickert scale plus 'Not Applicable' to indicate the degree of agreement with each of 12 statements:

strongly agree | *agree* | *neutral* | *disagree* | *strongly disagree* | *N/A*

The statements were:

The Traffic Display was fully operational for the entire day.

The Traffic Display distracted me from my core tasks.

The Traffic Display alerted me to inaccurate position reports.

The Traffic Display provided improved situational awareness of aircraft ground movements.

The Traffic Display provided improved situational awareness of aircraft in/joining/leaving the circuit.

The Traffic Display provided info on some relevant traffic that was not on my frequency.

The Traffic Display provided info that helped to address aircraft infringing CAS or about to do so.

The Traffic Display provided info that assisted in confirming aircraft complied with local traffic regulations.

An aircraft was observed on the Traffic Display to appear, disappear then re-appear while remaining within typical operational range.

The Traffic Display provided me with situational awareness that enabled a safer service.

Traffic Display information prevented a safety related incident.

The absence of non-ADS-B traffic negated any benefits of the Traffic Display.

The Traffic Display enhanced situational awareness of aircraft approaching high ground (helping to avoid CFIT).

Qualitative Feedback

Responses to the following two requested inputs were analysed thematically:

Situation - Please provide a brief description of any traffic situations that arose during the day upon which the Traffic Display had a positive or negative bearing. Please include the time of any incident.

Comment - Please provide further comment below, if required. Please elaborate on any of the answers above or add further comment on the operation of the Traffic Display during the day.

5.2.3 ATS Staff Monthly Feedback Form

The Monthly Online Feedback Form requested the date and the name of the submitter plus free-form inputs in response to eight questions.

How effective was the range and reception of Traffic Display system?

How did the absence of non-ADS-B traffic from the Traffic Display affect your use of the system?

How would you assess the contribution made by the Traffic Display to your suite of support tools?

How would you assess the Traffic Display screen presentation (maps, background, traffic, supporting data)?

Overall, do you feel the Traffic Display is enhancing your situational awareness? Please give rationale:

Would you support the retention of the Traffic Display after the end of trial period?

Are there any system enhancements you would like to see?

Do you have any further comments regarding the trial and the Traffic Display system?

The responses to the Monthly Feedback were analysed using qualitative inductive analysis.

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6 Trial Results

6.1 Equipment

6.1.1 ADS-B Traffic Display Technology used in the Trial

6.1.1.1 Acquisition

The equipment and software used in the trial is readily available and well within the financial means of all UK GA airfields. The Virtual Radar Server (VRS) software is available at no cost and runs as a local webserver on a standard Microsoft Windows PC accessed by a conventional web browser (Google Chrome worked well). A reasonable sized low reflection PC monitor is most suitable (Barton's 21 inch monitor upgrade cost £72). The video recording software license cost £36. The main cost is the uAvionix PingStation all-weather ADS-B ground receiver which is available for £1499 [8] in the UK or US$1750 [9].

6.1.1.2 Deployment

Deployment was relatively straightforward. Manufacturer installation guides are available and bespoke setup and usage guides were created during the trial. A modicum of IT expertise is beneficial, particularly for network configuration, but most airfields that do not already possess these skills ought to be able to readily access such expertise at affordable cost. A high mounting location is required for the ADS-B ground receiver which affords a clear view of the sky. Some mounting infrastructure (a pole or fixture) is required plus Ethernet cabling between ground receiver and PC or network switch (supporting Power-over-Ethernet – a PoE Power Injector or PoE network switch may be used).

Correct placement of the screen is important to ensure it is easy to see at a glance. Care must be taken to avoid reflections in high ambient light conditions. Note that, if the VRS server is accessible via a network, then additional web browsers can present the ADS-B Traffic Display. Barton utilised this capability to provide a secondary Traffic Display for the Assistant's position and also to present the Traffic Display on a screen in their Pilot Briefing Room.

8 https://www.unmannedtechshop.co.uk/product/pingstation-all-weather-ads-b-receiver/

9 https://uavionix.com/products/pingstation/

6.1.1.3 Operation

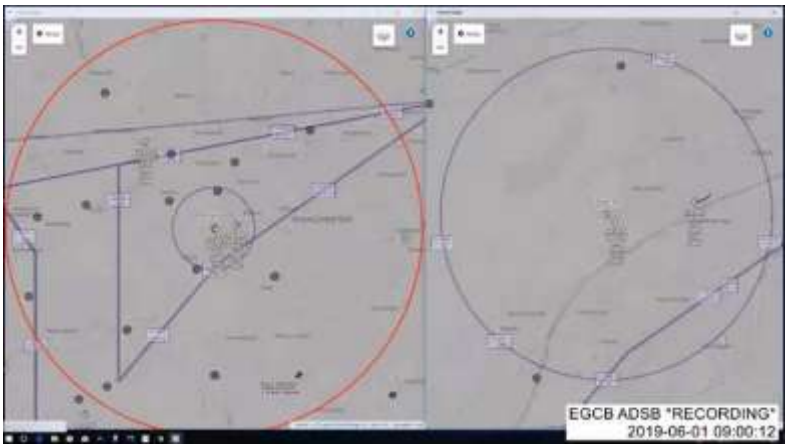
Operation of the Traffic Display was shown to be simple, intuitive and reliable. Start-up was fully automated, meaning that in the event of a technical issue a straightforward restart of the PC would bring the Traffic Display function back up. Care must be taken to ensure that scheduling of native PC operating system functions, such as long running software updates, is managed (to avoid unexpected loss of Traffic Display serviceability during airfield operating hours).

6.1.1.4 VRS Configuration

VRS display configuration is relatively straightforward and easy to learn. Once use of a new system has settled down there is usually little reason to change configurations.

6.1.1.5 Mapping, Airspace Overlay and VRPs

VRS offers multiple styles of mapping but none match typical aviation charts. The preferred option adopted during the trial was a low contrast grey-scale map that worked well as a background against which traffic symbols showed up.



The Airspace Overlay worked well in use but the source mechanism (an add-on to the basic VRS) leaves a few things to be desired. It covers the whole UK FIR but offers no control options (take it or leave it) and contained a few unexpected demarcated areas (which were believed to be temporary restricted airspace).

The VRPs implemented at Barton worked well. They were a bespoke hand-crafted add-on that was not part of the basic VRS or airspace overlay.

The implementation method for the Airspace Overlay and VRPs was documented in a guide developed during the trial.

6.1.1.6 Screen Video recording

The ability to review past events as presented on the ADS-B Traffic Display was an important addition. It was cost effective and simple to setup so as to be fully automated, requiring no manual intervention except in the case where a specific period of recording needed to be saved for archiving.

6.1.1.7 System Performance Criteria Assessment

The table below lists the systems performance criteria which were suggested prior to the trial as appropriate benchmarks for assessing the performance of the ADS-B Traffic Display together with the assessed performance.

Criteria	Benchmark	Assessed Performance	Notes
Update period	5 seconds or less	2 seconds or less	When reception is lost from a specific aircraft the symbol continues to display in the last position for a period which is configurable in the VRS application.
Accuracy / precision	200 metres	Typically <10 metres	As evidenced by ground movements on narrow taxiways. This is dependent on accuracy of position data in received ADS-B broadcasts.
Reliability	MTBF 30 days	MTBF 19.7 days (21 / 414)	21 reports (Disagree/Strongly Disagree in quantitative feedback) of ADS-B Traffic Display not being operational for the entire day out of 414 days of trial across 3 airfields. Some of these could have been due to user error due lack of familiarity with a new system. Also, lack of configuration of operating system function unrelated to the Traffic display service such as uncoordinated scheduling of Windows system updates – a lesson learned.
Availability	98% uptime	393 of the 414 trial days (94.9%) had no reports of outages.	Duration of outages was not recorded on the 21 days where the system was reported in quantitative feedback as not available for the entire day. But there is no indication that the systems were down all day on these days, hence availability on these days was greater than zero meaning total availability was greater than the calculated 94.9% to the left. If availability was 11 out of 12 hours on these 21 days then total availability becomes **99.5%.**
Latency	5 seconds or less	Under 2 seconds	ADS-B broadcasts from aircraft are roughly every 1 second and reception is direct air-to-ground. System processing time is negligible.
System/Data integrity (Incidences of position reports outside of Accuracy / Precision Metric)	Once in 30 days or better	Once in 414 days (for GA) (across all three airfields)	This is dependent on accuracy of position data in received ADS-B broadcasts. Only one instances of a transient (2 second duration) 'bad' position for GA traffic reported in feedback. Two instances of permanent bad position reported for CAT traffic inbound to MAN showing half mile north of MAN runway centreline. Investigation led to determination of Jet2 B757's broadcasting ADS-B data based on Inertial Navigation System position that had 'wandered'.
Coverage	Range of at least 10NM	>10NM	Dependent on the quality of the aircraft transmission. Low-level GA Mode S ES ADS-B range has been seen at over 17NM. Low-level GA airframe shielded lower-power portable ADS-B range can be as low as 5NM. Coverage of the ATZ is very good. High-level CAT ADS-B reception range is well in excess of 100NM but is filtered out of the display.

6.1.2 Mode S/CAP1391 Simultaneous Transmission

No safety related adverse effects were identified by the trial concerning those aircraft that used a CAP1391 portable ADS-B device alongside a Mode S non-ADS-B transponder. No advice was received from CAA or NATS that they identified any issues either.

It was discovered that some Mode S ES capable transponders do still output limited ADS-B data, e.g. registration, ICAO hex code, altitude and squawk even when the transponder has no GPS connected. This was noticeable on the ADS-B Traffic Display for these aircraft when the squawk code was set other than to 7000 on the transponder. In this circumstance the Traffic Display would show the squawk on the traffic symbol label flip-flop between 7000 received from the portable ADS-B device and the non-7000 squawk received from the Mode S ES transponder. The common ICAO hex code used by both devices enables the ADS-B Traffic Display to combine the two data streams together and present the transponder supplied data at the geographical position provided by the portable device's GPS. There was no perceived safety concern raised by ATS regarding this matter.

6.1.3 ADS-B (General)

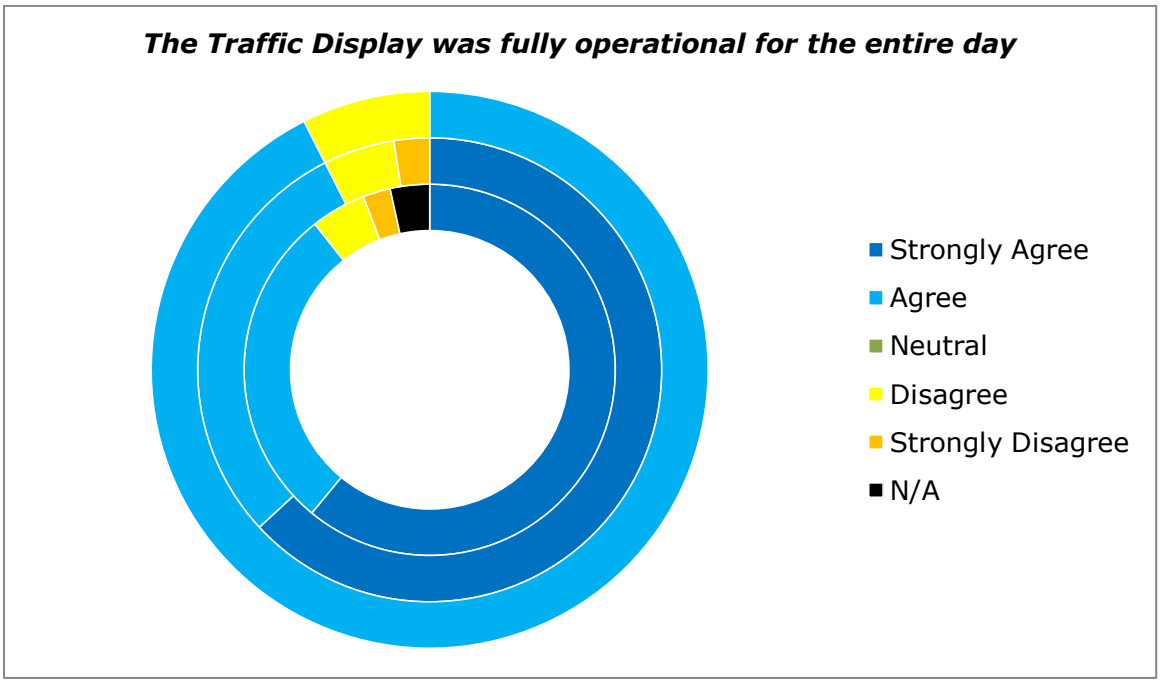
The trial has raised the general awareness of ADS-B in the GA pilot community, especially at Barton. Since the trial began Barton ATS has noticed an increase in independently funded installations of ADS-B into aircraft based at Barton.

6.2 Daily Feedback Data Quantitative Analysis

Quantitative feedback was provided via the ATS Daily Feedback submissions. In the tables below, the highest percentage response in each row is highlighted. The percentages are then presented in the associated 'Doughnut' chart, as follows:

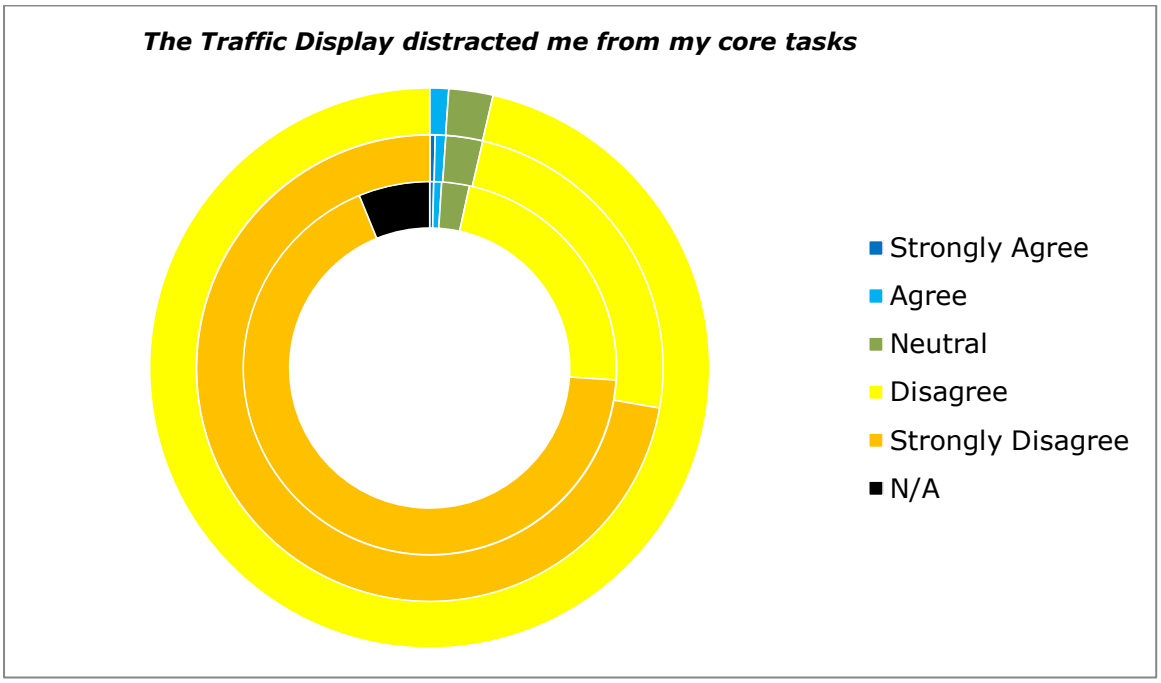
- Inner Ring: All data, including 'Not Applicable' (N/A).
- Middle Ring: Likert scale data only, discounting 'Not Applicable'.
- Outer Ring: Likert scale data only combining Strongly Agree/Agree and Disagree/Strongly Disagree.

The Traffic Display was fully operational for the entire day						
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	N/A	Total
178	83	0	14	7	10	292
60.96%	28.42%	0%	4.79%	2.40%	3.42%	100%
63.12%	29.43%	0%	4.96%	2.48%	Discounting N/A	
92.55%		0%	7.45%		Agree/Neutral/Disagree	



Availability of the Traffic Display was generally good and certainly good enough, although there were a few interruptions. However, this capability was only intended to be an additional support tool, therefore overall ATS provision was unaffected by the interruptions (though was missed).

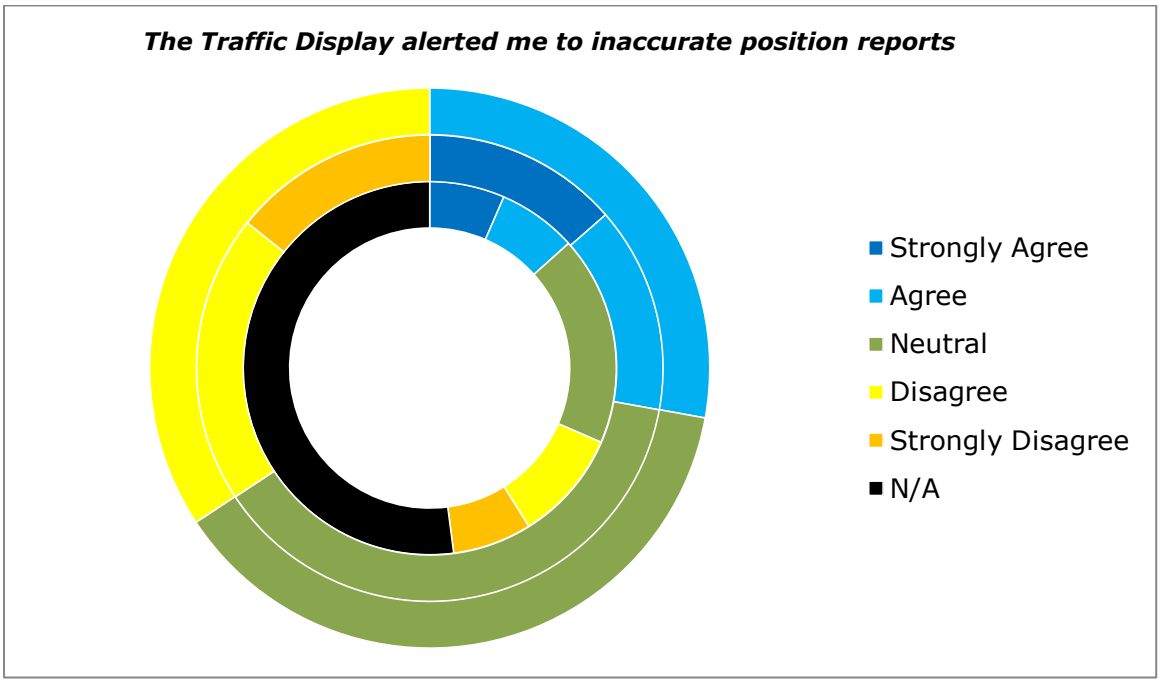
The Traffic Display distracted me from my core tasks						
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	N/A	Total
1	2	7	66	198	18	292
0.34%	0.68%	2.40%	22.60%	67.81%	6.16%	100%
0.36%	0.73%	2.55%	24.09%	72.26%	Discounting N/A	
1.09%		2.55%	96.35%		Agree/Neutral/Disagree	



This feedback indicates that ATS staff overwhelmingly reported that the Traffic Display did not cause a distraction hazard.

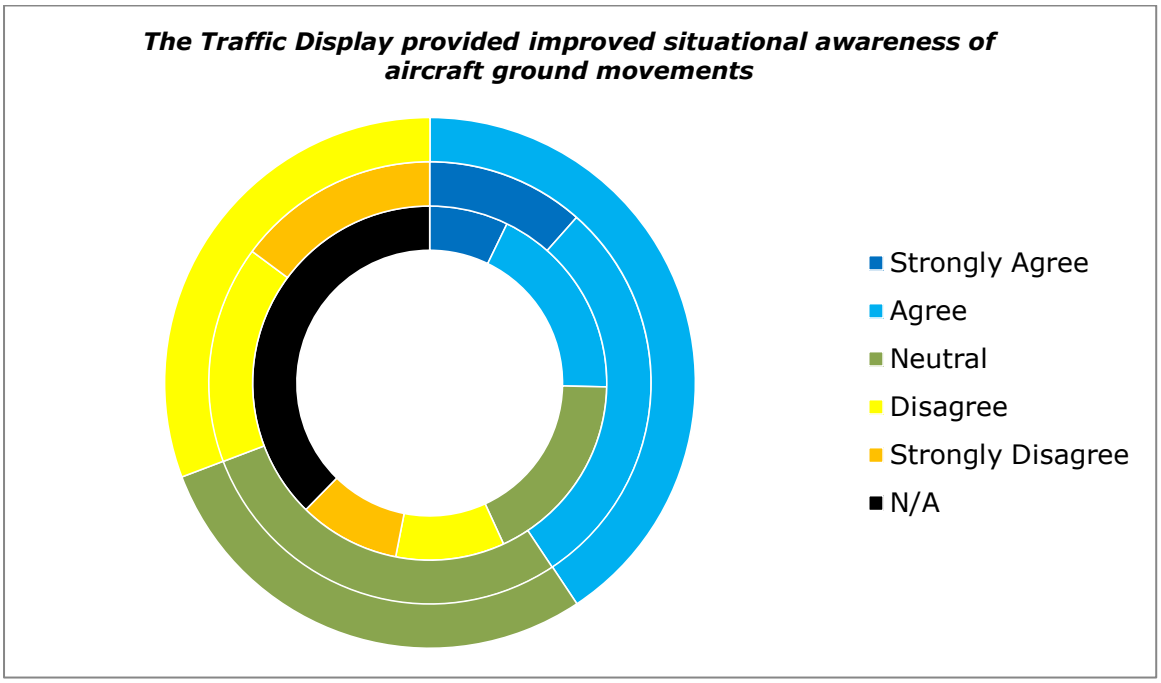
Airspace4All Ltd, 31 Walker Avenue, Wolverton Mill East, Milton Keynes, MK12 5TW

The Traffic Display alerted me to inaccurate position reports						
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	N/A	Total
19	20	53	28	20	152	292
6.51%	6.85%	18.15%	9.59%	6.85%	52.05%	100%
13.57%	14.29%	37.86%	20.00%	14.29%	Discounting N/A	
27.86%		37.86%	34.29%		Agree/Neutral/Disagree	



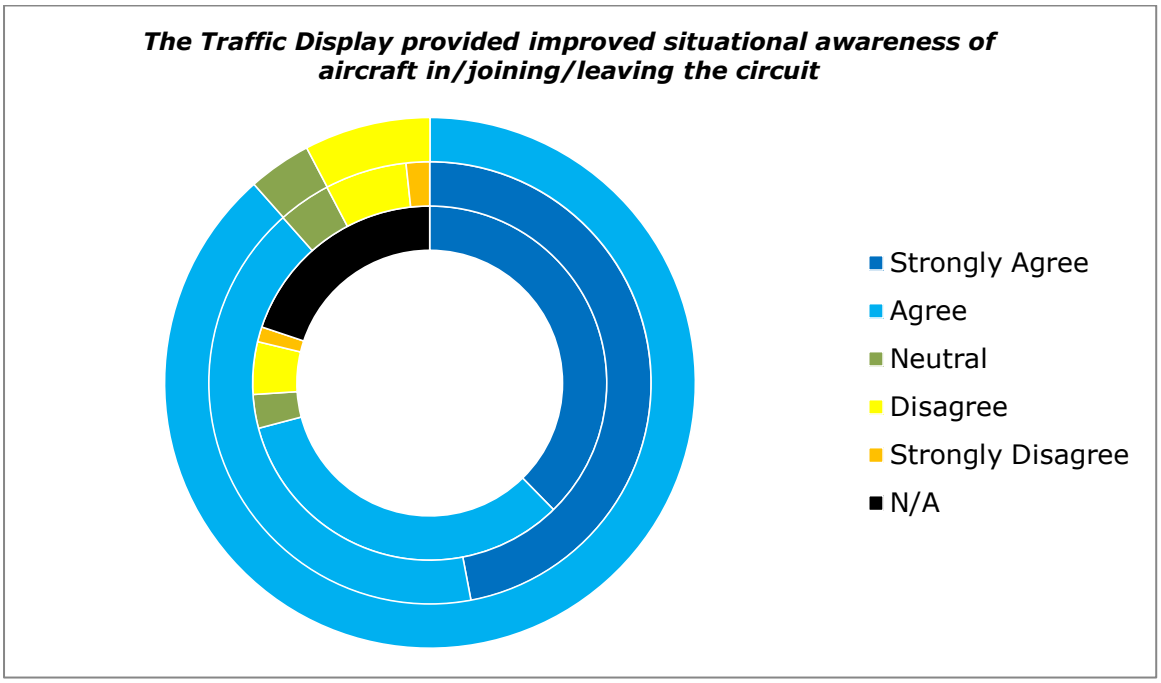
This feedback indicates mixed views on whether the Traffic Display alerted ATS staff to inaccurate pilot position reports. However, it is pertinent to note that without an ADS-B reference position it is unlikely that ATS would discover whether a pilot position report was inaccurate, unless the aircraft was very close by and clearly visible. Hence, an interpretation of 'Neutral/Disagree/Strongly Disagree' responses meaning 'there were no occurrences of inaccurate pilot position reports' would seem sound. Thus the 'Strongly Agree/Agree' response count is material, and is supported by the qualitative feedback describing actual situations where inaccurate pilot position reports were identified.

The Traffic Display provided improved situational awareness of aircraft ground movements						
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	N/A	Total
21	53	52	29	27	110	292
7.19%	18.15%	17.81%	9.93%	9.25%	37.67%	100%
11.54%	29.12%	28.57%	15.93%	14.84%	Discounting N/A	
40.66%		28.57%	30.77%		Agree/Neutral/Disagree	



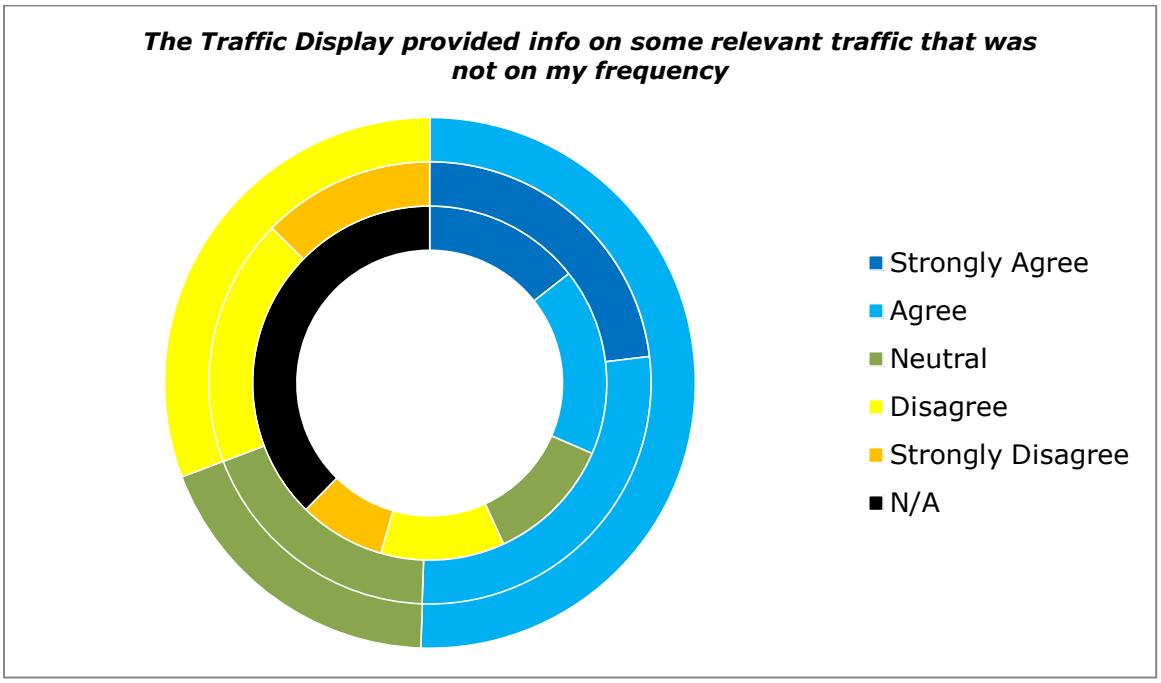
On balance, this feedback does support a view that in some circumstances the Traffic Display aids ATS situational awareness of aircraft ground movements. However, on small GA airfields having numerous stationary or taxiing aircraft in close proximity broadcasting ADS-B simultaneously can clutter the Traffic Display. To avoid this clutter, advice to pilots has been developed asking that devices be set to activate ADS-B Out at speeds of 30+kt so that aircraft only show on the Traffic Display while airborne or during take-off or landing. (This advice does not apply to rotary wing aircraft.)

The Traffic Display provided improved situational awareness of aircraft in/joining/leaving the circuit						
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	N/A	Total
110	97	9	14	4	58	292
37.67%	33.22%	3.08%	4.79%	1.37%	19.86	100%
47.01%	41.45%	3.85%	5.98%	1.71%	Discounting N/A	
88.46%		3.85%	7.69%		Agree/Neutral/Disagree	



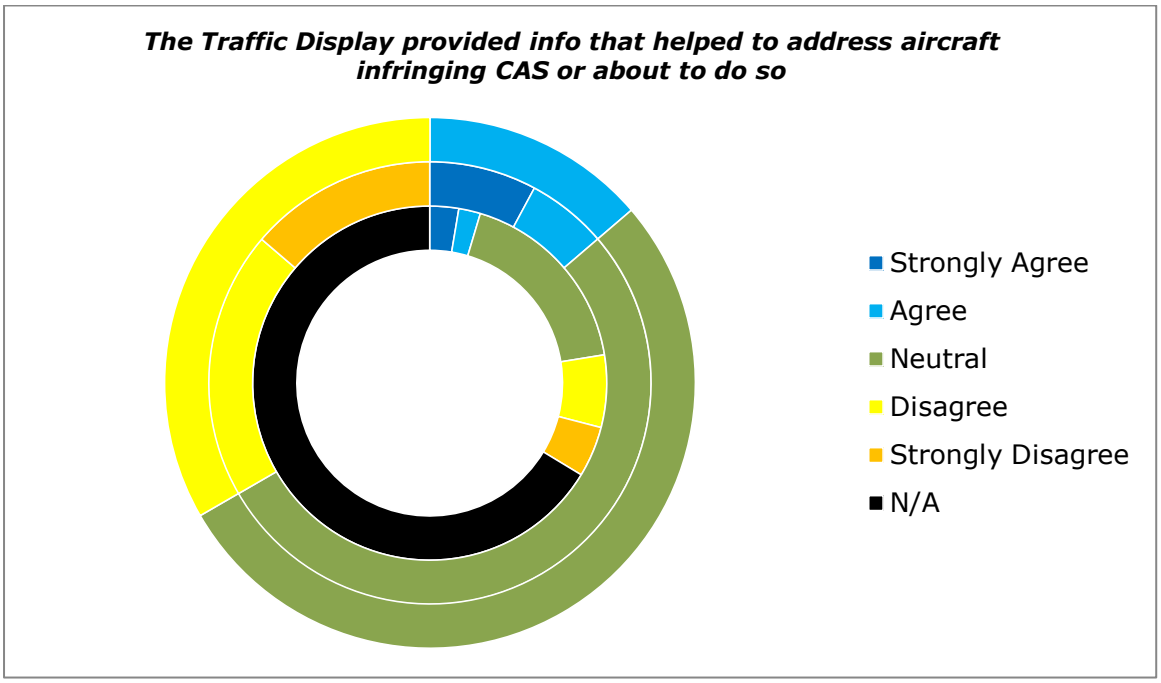
This feedback strongly supports the view that the Traffic Display improves ATS situational awareness of aircraft in the airfield circuit and of aircraft joining/leaving the airfield circuit. This is a key finding as the area in the vicinity of airfields is one in which there is higher risk of GA aircraft mid-air collision.

The Traffic Display provided info on some relevant traffic that was not on my frequency						
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	N/A	Total
42	50	34	33	23	110	292
14.38%	17.12%	11.64%	11.30%	7.88%	36.67%	100%
23.08%	27.47%	18.68%	18.13%	12.64%	Discounting N/A	
50.55%		18.68%	30.77%		Agree/Neutral/Disagree	



Although not an everyday occurrence, this feedback supports a view that the Traffic Display does aid ATS situational awareness of aircraft in the vicinity of the airfield that are not in radio contact with the airfield ATS unit but which are operating in locations affecting airfield traffic.

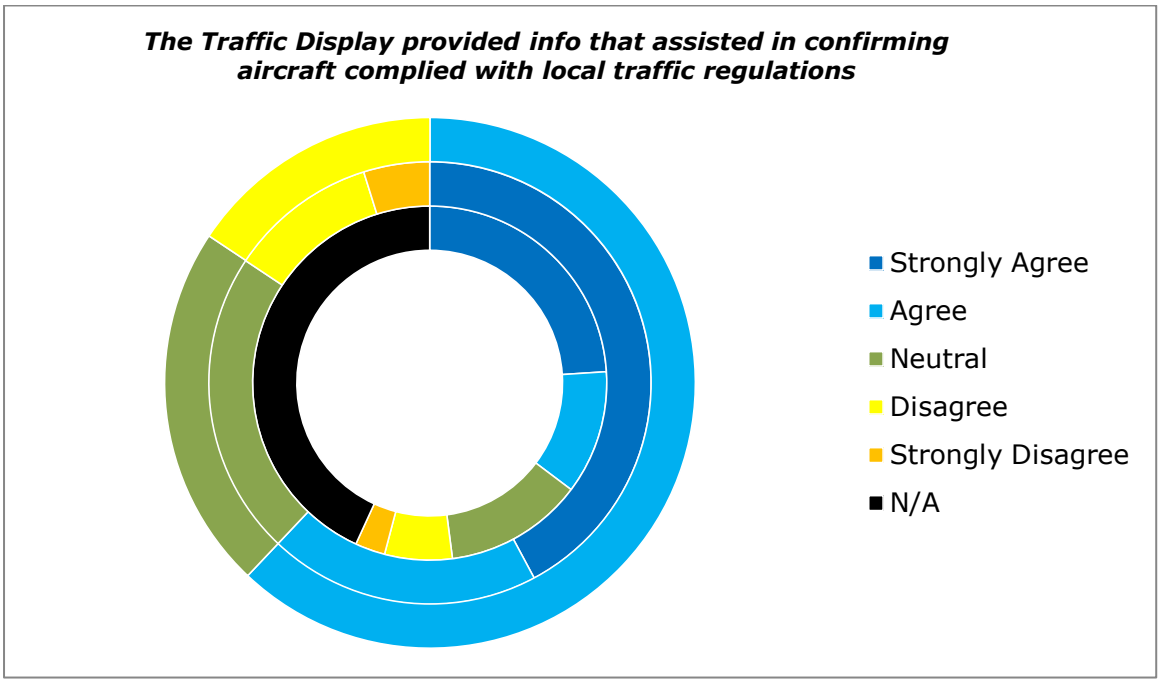
The Traffic Display provided info that helped to address aircraft infringing CAS or about to do so						
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	N/A	Total
8	6	54	20	14	190	292
2.74%	2.05%	18.49%	6.85%	4.79%	65.07%	100%
7.84%	5.88%	52.94%	19.61%	13.73%	Discounting N/A	
13.72%		52.94%	33.34%		Agree/Neutral/Disagree	



The high 'N/A' and Neutral response count in this feedback suggests, thankfully, that CAS infringement, or near infringement, is not a regular occurrence in the vicinity of the trial airfields (Goodwood has no CAS immediately nearby that affects operations). The relatively low count for 'Strongly Agree/Agree' implies that only on a limited number of occasions did the Traffic Display help address potential CAS infringement.

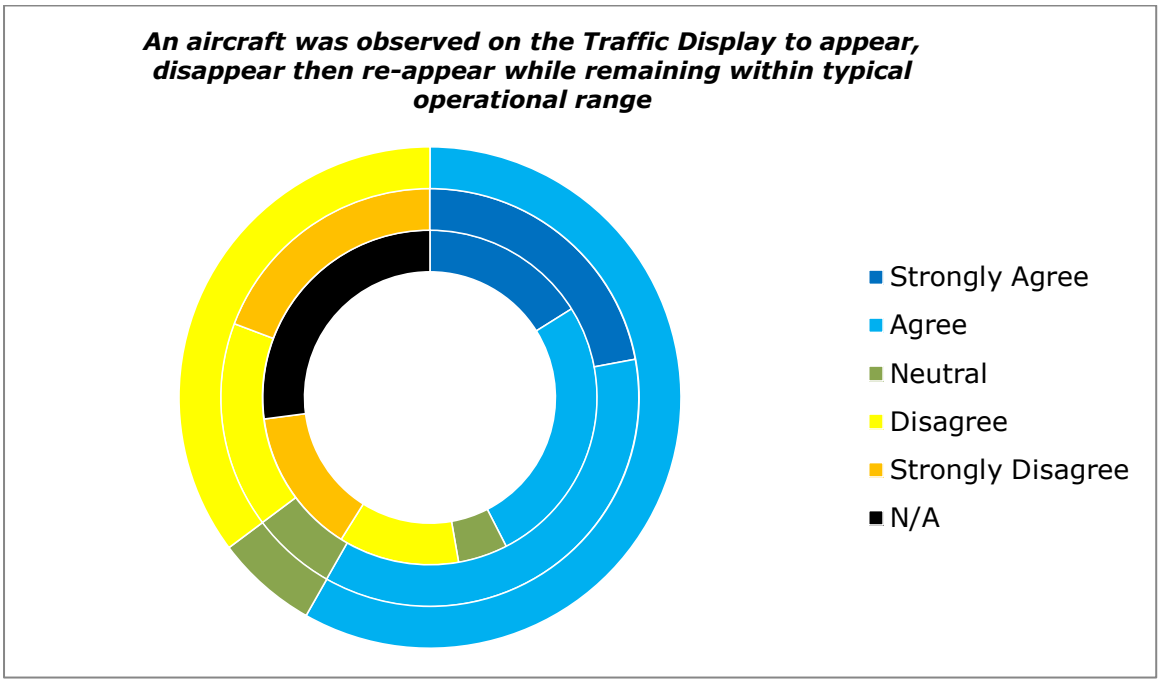
Note that CAS Infringement is separate from ATZ Infringement (aircraft entering an airfield ATZ without first gaining joining information). There have been instances during the Trial where the Traffic Display has enabled ATS to proactively contact an inbound aircraft that has not made radio contact to confirm their intentions and pass joining information, thus helping to avoid an ATZ infringement.

The Traffic Display provided info that assisted in confirming aircraft complied with local traffic regulations						
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	N/A	Total
70	33	37	18	8	126	292
23.97%	11.30%	12.67%	6.16%	2.74%	43.15%	100%
42.17%	19.88%	22.29%	10.84%	4.82%	Discounting N/A	
62.05%		22.29%	15.66%		Agree/Neutral/Disagree	



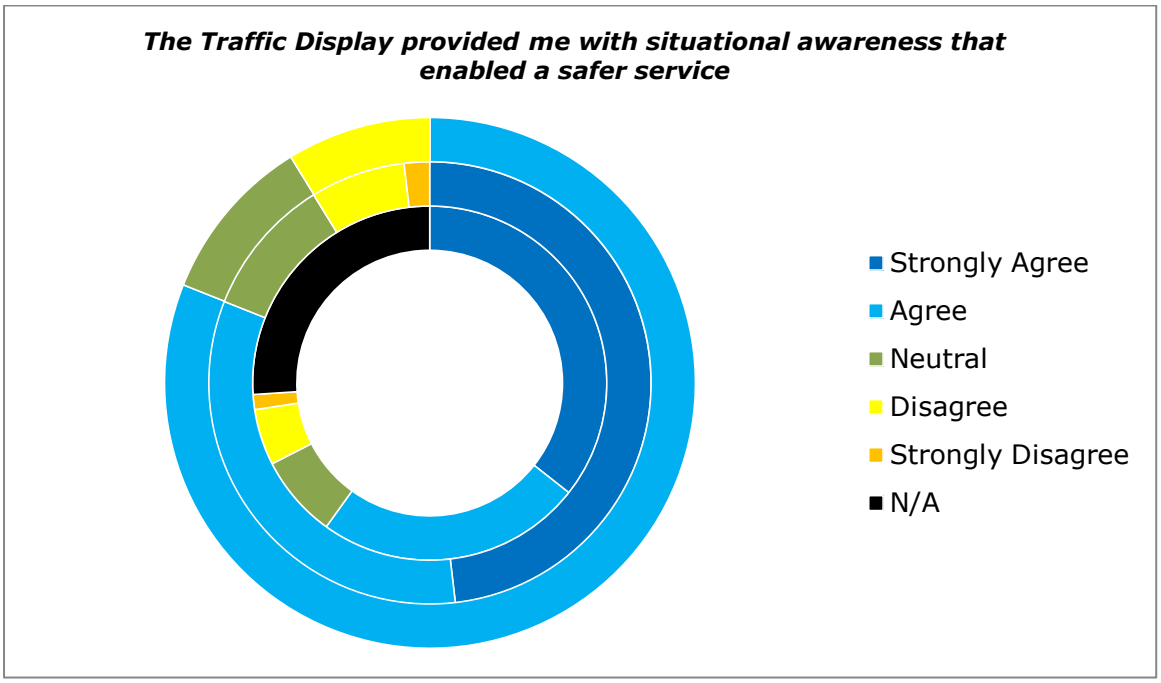
This feedback supports the view that, when there was a need to confirm aircraft were complying with local traffic regulations, the Traffic Display does provide helpful assistance.

An aircraft was observed on the Traffic Display to appear, disappear then re-appear while remaining within typical operational range						
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	N/A	Total
47	77	14	34	41	79	292
16.10%	26.37%	4.79%	11.64%	14.04%	27.05%	100%
22.07%	36.15%	6.57%	15.96%	19.25%	Discounting N/A	
58.22%		6.57%	35.21%		Agree/Neutral/Disagree	



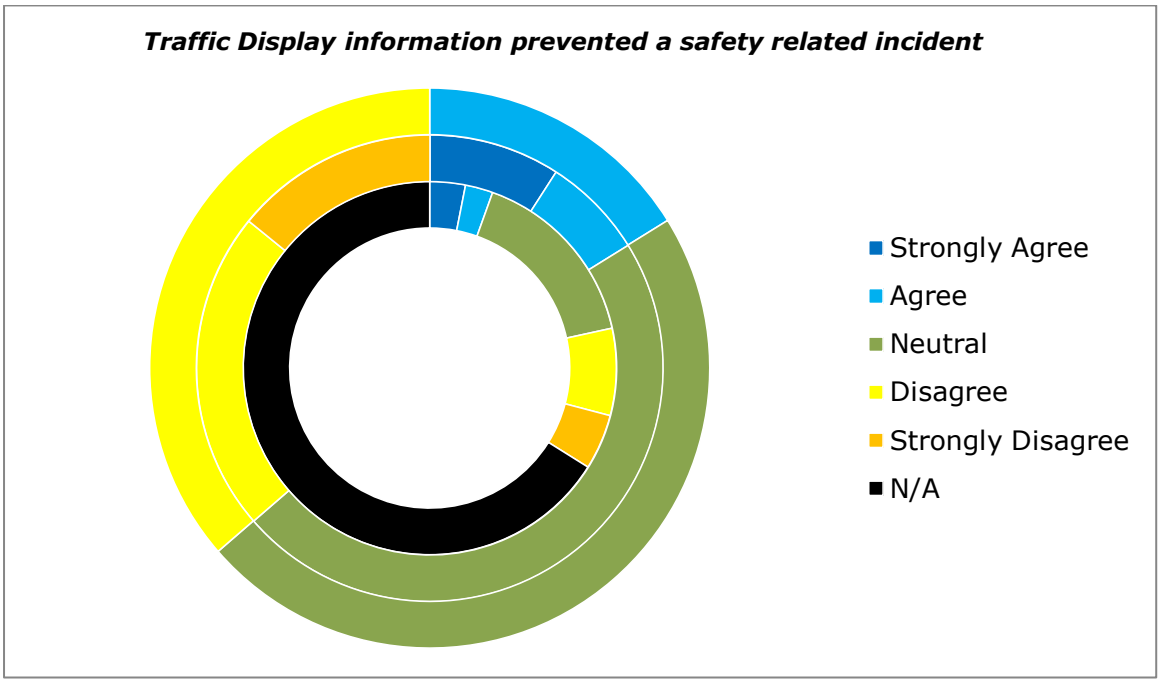
This feedback indicates another relatively mixed view. Ratio of 'Strongly Agree/Agree' to 'Disagree/Strongly Disagree/N/A' is 124:154. The qualitative situation feedback highlights intermittent loss of signal from aircraft with portable ADS-B devices at typically 5+nm range means this feedback is noteworthy and merits further investigation during follow-on trials.

The Traffic Display provided me with situational awareness that enabled a safer service						
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	N/A	Total
104	71	22	15	4	76	292
35.62%	24.32%	7.53%	5.14%	1.37%	26.03%	100%
48.15%	32.87%	10.19%	6.94%	1.85%	Discounting N/A	
81.02%		10.19%	8.79%		Agree/Neutral/Disagree	



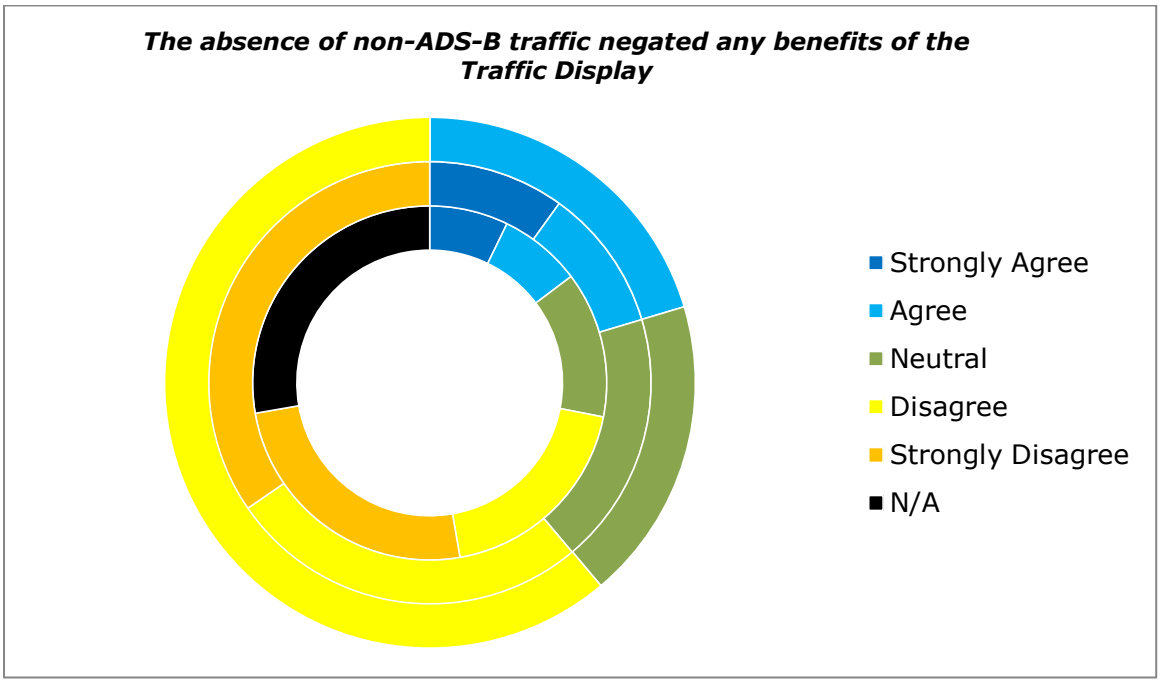
This feedback confirms that the Traffic Display was viewed by ATS as an enhancement to the level of safety of the service they were able to provide.

Traffic Display information prevented a safety related incident						
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	N/A	Total
9	7	47	22	14	193	292
3.08%	2.40%	16.10%	7.53%	4.79%	66.10%	100%
9.09%	7.07%	47.47%	22.22%	14.14%	Discounting N/A	
16.16%		47.47%	36.36%		Agree/Neutral/Disagree	



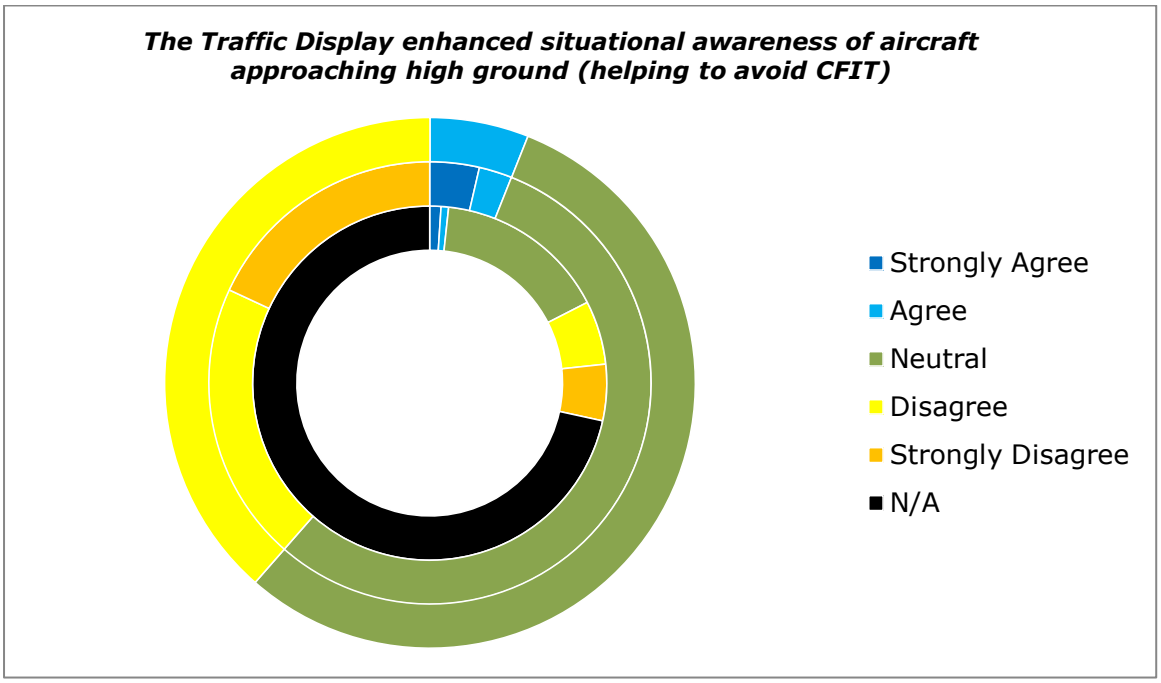
The high 'N/A' response count in this feedback is reassuring in that it highlights the rarity of safety related incidents. Nevertheless, the small number of 'Strongly Agree/Agree' responses do tie in with the reports of safety related incidents (e.g. aircraft loss of communications, aircraft electrical power failure) where the Traffic Display did contribute to improved management of the situation.

The absence of non-ADS-B traffic negated any benefits of the Traffic Display						
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	N/A	Total
21	22	39	56	73	81	292
7.19%	7.53%	13.36%	19.18%	25.00%	27.74%	100%
9.95%	10.43%	18.48%	26.54%	34.60%	Discounting N/A	
20.38%		18.48%	61.14%		Agree/Neutral/Disagree	



The high support shown in this feedback for the view that the absence of non-ADS-B equipped aircraft from the Traffic Display does **not** negate the benefit is a key finding. One major reason for undertaking this long-term trial was to investigate use of such systems in today's real world environment where most GA aircraft are not equipped with ADS-B Out.

The Traffic Display enhanced situational awareness of aircraft approaching high ground (helping to avoid CFIT)						
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	N/A	Total
3	2	46	17	15	209	292
1.03%	0.68%	15.75%	5.82%	5.14%	71.58%	100%
3.61%	2.41%	55.42%	20.48%	18.07%	Discounting N/A	
6.02%		55.42%	38.55%		Agree/Neutral/Disagree	



The low 'Strongly Agree/Agree' response count in this feedback is probably a indication of high ground not being a major factor affecting operations at the trial airfields.

6.3 Daily Feedback Data Qualitative Analysis

Two questions on the daily feedback form provided opportunity for ATS staff to provide free form text comments on specific situations or other issues which had occurred during their shift in relation to the Traffic Display. Not all provided further data; 263 comments were received in response to the question relating to specific situations; 147 comments were received in response to the additional comments question. Some text included in the "Comments" related to scenarios described in the "Situation" questions; similar issues were raised in both questions. For these reasons both questions were analysed together.

In total 263 comments were received in response to the "Situation" question. Of these 148 comments were very brief stating information such as shift duration, weather conditions, no activity, local events such as fly-ins, or descriptive comments such as "*quiet day*", "*busy day*" or "*steady day*" with no additional explanation. Due to the limited information provided these were excluded from the analysis resulting in 115 comments remaining for analysis.

In total 147 comments were received in response to the "Comments" question; 28 of which were "no comment" or similar. A further eight simply reported "a quiet day"; and four in which "poor weather conditions" resulting in little airfield activity. Nine other comments relating to administration issues were also recorded. As a result 95 comments remained for analysis.

In total 200 comments were included in the final analysis and were analysed thematically, whereby comments were examined to identify key themes which facilitated the development of distinct categories. These are explained below with illustrative quotations selected and extracted verbatim from the feedback forms. Some comments were deemed to fit into multiple categories. Where specific aircraft, registrations and locations have been used these have been changed to maintain confidentiality.

6.3.1 Theme 1: Positive Experiences of ATS Staff

The first theme identified describes the positive experiences of ATS staff in relation to key aspects of their role; these comprised one theme which was divided into two sub-categories – situational awareness and provision of traffic information. They were retained under the same theme as comments frequently referred to these mutual aspects of the ATS staff role.

6.3.1.1 Situational Awareness

"A grey day when it was easier to spot aircraft in the circuit with the aid of the TD"

"We were able to see a returning helicopter prior to it being on frequency"

"The TD allowed me to visually acquire the aircraft from the VCR. G-ABCD reported overhead B (town centre) inbound however the TD showed him over F (location). Duty FISO at the time asked for a position report to which they

confirmed "2 miles East of H VRP". This then matched what we were seeing on the TD"*

"During the morning I recall at one point that I had 4 in the circuit, all on the display plus another two either in or outbound, and I recall thinking how useful the display was as it helped me with keeping track of aircraft positions around the circuit when busy, allowing me to more quickly re-assess positions by a glance at the display then knowing where to look out of the window. Much like a pilot has a 'scan' around the cockpit and out of the window, I find that I've developed a FISO 'scan' which incorporates the strip board, the display, wind instruments and out of the window as an efficient way of maintaining situational awareness. I've not found this to be any form of detriment at all, indeed it's wholly positive in its assistance with the situational awareness"

6.3.1.2 Traffic Information

"The display continues to be useful, giving enhanced situational awareness. Very useful when aircraft join long final as I can more easily see their progress in relation to determining appropriate traffic information to circuit traffic"

"One other useful note was an aircraft observed passing the airfield from a nearby strip, around 3-4 miles west tracking north. Although not talking to us, the display allowed us to view the aircraft and (although wasn't necessary this time) would allow information to be passed to other aircraft that may be in or outbound where it would be relevant to them."

"TI was provided on several occasions - notably to an Ikarus that was leaving the ATZ North West against a Cessna that was operating in the local area under a Basic Service. Both aircraft reported visual with each other based on ADS-B derived TI"

"HAB12 was outbound to the NE visible on the TD and G-EFGH was inbound from the NE visible on TD. On G-EFGHs initial call I prioritised the traffic information on H-AB12 leaving the ATZ to the NE, G-EFGH responded immediately saying the traffic was in sight. I then gave airfield information and the G-EFGH made a safe join being able to avoid HAB12 with ease"

6.3.2 Theme 2: Accuracy

A further area noted related to the accuracy of the position display.

"The TD is proving extremely accurate. Today I was given position reports and altitudes from a based instructor and asked to cross check these on the display... all were spot on and the altitudes were correct and altered with the correct QNH"

"GABCD Transponder was giving very accurate positions, useful to also see the SQK, Aircraft Type and Height."

6.3.3 Theme 3: Incidents & Safety Issues

A third theme described issues related to incidents and safety issues. These included reference to the benefits the system was perceived to offer in relation to the provision of accurate and appropriate traffic information to aircraft:

"*The display allowed improved situational awareness helping monitor a situation and providing confidence that it wouldn't become a safety conflict by the improved awareness and ability to pass suitable traffic information*"

"*Helped with inbound traffic needing to make a non-standard join, slotting in to the circuit in a safe manner, at the time I had no visual of the inbound but I had accurate position due to the ADS-B screen*"

"*The equipment has proved to be useful in helping to avoid airprox with equipped aircraft, unsure of location for student pilots and keeping training aircraft flying iaw local noise abatement regulations*"

Comments also described specific potential situations which had been averted as a result of using the TD:

"*G-WXYZ Cessna ** inbd AD 1,200ft not visual with G-ABCD Cessna ** Dep'd AD 1,200ft both not visual. Advised of conflict, G-ABCD took avoiding action. Pilot was well impressed!*"

"*The loss of N12345 on the TD and loss of RTF led us to believe the aircraft was in difficulty. The time this gave us to plan for the arrival was useful as we were able to decide that with a wet runway and no headwind component there was a chance the aircraft could overrun the runway on landing due to a flapless landing. This meant we could pass this information to RFFS and place them on standby for the arrival*"

"*ADS-B helped deconflict two ground incidents out of visual range and prevented one incursion into controlled airspace (vertical).*"

Comments also referred to the valuable role that the system may have on the ground:

"*Used for ground movement on a taxiway that is only partially visible from the tower, preventing a conflict between aircraft incoming and outgoing from the runway*"

A group of comments in this category also explained the role that the system had had in the prevention of infringements by ADS-B equipped aircraft:

"*Infringement of EG** ATZ prevented by warning ADS-B equipped aircraft (G-EFGH), that it was approaching ATZ. This aircraft had transited the CTR,*

*exiting the CTR in the vicinity of *town, and began tracking towards the ATZ with no comms established. As the aircraft reached * I proactively called G-EFGH, advised that it was about to enter the ATZ and asked if he was inbound. G-EFGH entered an orbit whilst aerodrome information and TI was passed. Had this aircraft not had ADS-B then it would have likely entered the ATZ without aerodrome information"*

"*We had an aircraft infringe the * CTR inbound to us however it was not ADS-B equipped. If it was I may have been able to see it approaching CAS*"

"*A noise complaint from *town was supported by FLIGHTRADAR24 radar traces. We did not see the aircraft on our system because * flying school did not have their device switched on*"

6.3.4 Theme 4: Inaccurate Pilot Position Reports & Incorrect Squawks

This theme was identified which related to inaccurate position reports (locations, altitude etc) made by pilots and incorrect squawk settings which the TD assisted in identifying and correcting. The ADS-B data is more reliable than pilot position reports:

"*G-IJKL report 6 miles west when in fact he was showing as 3 miles southwest. One minute later aircraft was downwind so the pilot position report was definitely wrong and the ADS-B data was proved correct and accurate*"

"*A joining a/c called downwind right-hand for runway nn. It could not be seen through the window. However, it did appear on the virtual radar over *town (downwind for the reciprocal). The pilot would not accept this at first and continued to fly in a north-westerly direction. Shortly afterwards he admitted that he had got runways mm and nn mixed up, a surprisingly common error. The Traffic Display allowed us to pick this problem up quickly and early on, thus preventing a situation from developing*"

"*Two wrong squawks seen on taxiing aircraft. Corrected*"

"GWXYZ seen to be squawking 7361 advised "Check squawk 7365" Pilot apologized and changed to correct squawk."

6.3.5 Theme 5: Signal Reception

Another theme identified related to the issue of signal reception when aircraft appeared intermittently on the TD. Some of these may have been due to misuse of the portable devices by pilots which, as a matter relating to airborne device usage, is outside the scope of this report. However, learning points on such matters are discussed in Appendix A. Some comments included reflection by the ATS staff on what may have caused the issue:

"Individual aircraft disappeared from display on several occasions where the aircraft's airframe would have shielded the transmission from the device.

Generally this occurred when the aircraft were outside the ATZ, but within the 10nm area of responsibility."

"G-ABCD displayed on the display in the ATZ, however disappeared from the display shortly after leaving, reappeared just outside the ATZ when inbound."

"*A few aircraft disappeared towards the end of the day - might this be a charging issue?*"

"*Multiple aircraft called stating ADS-B equipped however they did not show on the TD. EG** IFR traffic showed on the TD so it was operational however it would appear some of the portable devices were not. One aircraft only showed on the TD as he was final to land after a local flight*"

Whilst others provided clear description of what they had observed:

"*G-IJKL was inbound and reported 10NM North West of the airfield inbound. The aircraft, that has a permanent ADS-B install, did not show on the display. When asked to confirm his transponder was on the student pilot confirmed it was. A few minutes later G-IJKL appeared on the display approx 12nm NW of the airfield*"

Other comments detailed what action the ATS staff member had taken as a result:

"*G-MNOP appeared on the TD until travelling off the edge of the TD. When it reported inbound at * he was advised that he no longer appeared on the TD*"

Several described brief disruptions; whilst others were for longer periods:

"*A couple of aircraft disappeared for the odd few seconds but otherwise they showed up well on the TD*"

"*G-UVWX based at a PLS just outside the ATZ usually shows up on the TD. Last night the aircraft disappeared off the display while still airborne, today it did not show up at all*"

6.3.6 Summary

In summary the themes identified from the free-text comments provided on the trial daily feedback forms were the positive ATS staff experience as a result of the enhanced situational awareness and subsequent ability to provide accurate, appropriate and timely traffic information; accuracy of traffic position data; good reception from aircraft in the ATZ and from Mode S ES ADS-B transponder equipped aircraft at much longer range but some reception issues with the portable devices typically beyond 5nm range; pilot usage (see Appendix A); incidents and safety issues; and ability to identify and correct inaccurate location/altitude reports and incorrect squawk settings. Together these demonstrate both the positive contribution the system was felt to make to ATS staff across a wide range of their

work responsibilities; and highlight issues where possible further developments may be indicated; ultimately enhancing the safety of pilots.

6.4 Monthly Feedback Data Qualitative Analysis

Qualitative data gathered in the monthly feedback forms was analysed using qualitative inductive analysis (Thomas, 2006[10]); wherein data is analysed to permit the creation, and refinement, of categories which reflect the overarching material. The analysis was undertaken by an independent analyst not connected to the trial in order to enhance the trustworthiness of the analysis by reducing the likelihood of introducing bias (Lincoln and Guba, 1985[11]; Thomas, 2006). The report below reflects the categories identified from the data collected from feedback forms completed during the trial; and which appear most relevant to the trial objectives. The specific questions included on the feedback forms can be found in the methodology section. The analysis of the data is organised under three categories rather than by each question; this attempts to provide clarity and coherence to the data by bringing together overlapping material across responses. Each category contains multiple sub-categories which serve to elucidate the category. Direct quotations taken from the feedback forms are integrated to provide further illustration of the meanings and experiences reported by the ATS staff participating in the trial.

6.4.1 Category 1: The System

Within this category ATS staff identified issues they experienced in learning to use and integrate the device into their work. The opportunities offered in relation to enhanced visibility of aircraft were viewed positively; whilst the issue of aircraft with portable devices disappearing from the screen at shorter range than transponder fixed installations due to problems with signal masking was disappointing. The positioning of both the Traffic Display and the individual ATS staff member was also found to be important. Three sub-categories were highlighted:

6.4.1.1 Visibility

The Traffic Display system was reported to enhance situational awareness of aircraft beyond the visual line of sight; and in poor and hazy conditions. In addition the system facilitated speedier visual identification of aircraft as the Traffic Display indicated the area to be scanned and reduced the need for scanning of a wide area:

> "*The TD is extremely helpful in aiding both circuit traffic and traffic joining from the south visually. This can be difficult in hazy / overcast conditions and the TD helps by showing which area an aircraft is expected to be in allowing me to quickly spot the aircraft rather than scanning a large area of sky*"

[10] Thomas D (2006) A General Inductive Approach for Analyzing Qualitative Evaluation Data. American Journal of Evaluation: 27(2), 237-246

[11] Lincoln Y & Guba E (1985) Naturalistic inquiry. Beverly Hills, CA: Sage

"It's very useful for situational awareness and I am starting to use it more to obtain traffic in the circuit when it's hazy / misty. This allows me to pass traffic information to traffic much more quickly"

"When aircraft are joining the circuit directly I can more easily know their range of joining and whether they will be in conflict with established circuit traffic. It also helps to acquire aircraft visually out of the window as I know which direction to look, reducing uncertainty"

"I have been able to monitor aircraft inbound which are approaching from the South / South West and which are usually behind us as our VCR faces North"

6.4.1.2 Signal Reception

The issue of signal shielding was identified and indicated the importance of fitting and appropriately positioning portable devices in aircraft to best avoid the risk of "drop out" on the Traffic Display screen, thereby reducing visibility. Some reports proposed that where Mode S ES transponders were used, their reliability of reception was enhanced:

"The TD range works well within the distance of the ATZ, less so further out when portable devices are used. If the ADS-B output is from a "fixed device" then it works better"

"TD system is perfectly adequate for circuit traffic however the range of the all-in-one portable devices is limited due to airframe shielding"

"Traffic will often drop off the display due to shielding whilst within the operational range – this is only with aircraft with portable devices"

"Some contacts appear / disappear at times, usually when further away from the airfield and likely due to positioning of the portable devices in the cockpit"

"Range was fine and is often showing aircraft outside of our DOC however I have noticed quite a few aircraft that disappear and then reappear numerous times. Having spoken with the instructors they believe that it is positioning of the portable devices inside the aircraft (back seat). They are unable to mount them elsewhere as it blocks their field of view or interferes with the compass / DI"

6.4.1.3 Positioning in the Visual Control Room

Positioning of the Traffic Display was identified as relevant to its usage if its position created glare which reduced its value. Whilst this was only noted where there were 360 degree windows; it might be anticipated that without remedial action the Traffic Display would gradually be used less:

"In a 360 windowed environment this can be problematic due to glare and reflection"

In contrast the position of the staff member was noted as it was suggested that the Traffic Display facilitated more reliable tracking of aircraft in visual blind spots:

> "*There have been times when it has been useful such as tracking in my blind spots which I have never had before, often relying on a second person to be present within the VCR who can spot / track the traffic*"

6.4.2 Category 2: Using the System

In *using the system*, ATS staff highlighted issues which were relevant to their personal usage of the system. Some of these related to information displayed on the Traffic Display and it should be acknowledged that it was possible to address some of these during the trial to positive effect. Experienced ATS staff who engaged with the new system appeared to integrate it into their work more easily. Recognition of coping with the impact of change in an already potentially stressful and demanding role should also be considered. Overall it was recognised that increased uptake and usage of the system by both pilots and ATS staff would enhance the positive outcomes identified. Three sub-categories were identified.

6.4.2.1 Balancing Act

Integrating the system into the workload required the ability to recognise the potential benefits; and was perhaps more straightforward for experienced ATS staff:

> "*Any system that helps keep track of aircraft in a busy and sometimes complex traffic situation is worth having. I do not find it distracting*"

Whilst the ability to move seamlessly between the system and the act of looking out of the window is perhaps a skill to be developed and should be considered in the training of new staff.

> "*We need to look at initial FISO training, whilst the TD is being used. During the validation of our most recent FISO and my first time watching over this FISO, it was obvious they were relying on it too much and were "heads down" looking at the stripboard and TD, more than looking out of the window*"

Further, there was some indication that unless staff were engaged in using the new equipment, there may be a reluctance to use it and its presence may be deemed negatively. This was surmised by the gradual increase in positive comments received as the trial continued, and familiarity and benefits were experienced; whilst negative comments declined. Initially the system was identified as adding an additional task to the role rather than supporting the work; as one user commented:

> "*Given the number of movements here is on the up at a constant rate there are times that having the available time to look at the display can be impossible. We are looking to instigate a 2 person shift on days where traffic and staffing permits*"

6.4.2.2 Managing the Risks

ATS staff acknowledged the reassurance offered by the system in being able to provide a reliable and safe service, particularly during periods of poor weather and reduced visibility. This facilitated enhanced ability to plan ahead and the avoidance of conflict.

> "*Having been a FISO for some 20 years it has been nothing but a positive. It enables me to provide a much better service as a FISO giving me a tool to enhance my own situational awareness. Rather than relying solely on (often inaccurate and woolly) position reports, I can now confidently know where aircraft are and identify relevant traffic information and assist pilots in avoiding conflict*"

It was also noted that the system was an aid to the prevention of ATZ infringements.

> "*It is a positive step forward and enhances the ability of the FISO to provide the service. It can help avoid ATZ/Airspace infringements and allows improved and more appropriate traffic information. I feel it enhances safety and the benefits will continue to be realised further with increased levels of aircraft which are able to be displayed*."

> "*Retention of the equipment would be beneficial to helping reduce the number of infringements*"

6.4.2.3 Visual Preferences

Whilst the Traffic Display was viewed as a positive enhancement to service provision, it was clear that there were individual preferences for what information was shown on the screen. The wide-ranging nature of these preferences suggests that, within reason, options for managing how and what information is displayed would be a well-received enhancement to the system. Options identified included the use of symbols with a trail to indicate the direction of the last few seconds of travel; weather overlays; a list of the aircraft on the screen; a scale; ability to move to a smaller scale for the ground view as this can appear cluttered when viewed in the "zoomed out" aerial perspective:

> "*Due to the display being so "zoomed out" I find it not as useful for ground traffic and the display becomes cluttered. It is much easier to watch the ground movements out of the window*"

> "*Sometimes if there are multiple aircraft on the ground with ADS-B it can clutter the screen and we cannot see if the ADS-B in the aircraft is working. It may be worth inhibiting it at lower levels to avoid clutter at the airfield*"

> "*The addition of the split screen with one side focusing on the ATZ has made a big difference as it allows us to readily identify which aircraft are which in the visual circuit*"

"*The ability to reduce label data with a click (to an agreed standard) would assist in reducing label clutter*"

6.4.3 Category 3: The User

This category explains the experience of the ATS staff using the system during the trial. The overarching message indicated by ATS staff suggests the alleviation of allostatic load[12] experienced by ATS staff as a result of using the Traffic Display system. Two sub-categories were identified.

6.4.3.1 Improving Health and Wellbeing

Reports from the ATS staff referred to reduction in eye strain; as well as reference to more general issues such as wellbeing were noted. In what is recognised to be a stressful environment in which considerable demand may be placed on staff, the system was strongly noted to be supportive of wellbeing, despite it being a new system which they were being asked to integrate into their workload:

"*If on a poor visibility day whereby I have several aircraft in the circuit, consisting of a mix of ADSB and non-ADSB traffic I feel this is when it's noticed more, as ideally if all the traffic was giving out ADSB it would reduce the strain on my eyes scanning the visual circuit. Often on poor visibility days, the "sky" is bright or white which can make for scanning for traffic hard work. The TD would help me and give me more confidence in knowing where traffic was*"

6.4.3.2 Improving the Service

ATS staff who participated in the trial reported experiencing increased confidence in their situational awareness. In turn this facilitated greater confidence in their role and their ability to provide accurate and appropriate information to pilots:

"*During this last month I also had one particular morning when I was FISO / ADM and it was busy with circuit traffic. During this period 3 out of 4 aircraft had ADSB out which helped keep a better track of them whilst I answered phone calls, updated weather info etc*"

"*The TD has proven to be an extremely useful aid for situational awareness and has allowed me to provide better / more relevant traffic information*"

"*Excellent. It's a huge safety benefit for advanced awareness*"

6.4.4 Further Areas Identified for Future consideration

During the analysis three additional points were noted which, whilst not directly linked to the trial feedback, may prove significant in determining future successful uptake of the system. These are:

[12] Allostatic load is defined as the cost of chronic exposure to elevated or fluctuating endocrine or neural responses resulting from chronic or repeated challenges that the individual experiences as stressful (International Encyclopedia of the Social & Behavioral Sciences, 2001).

- Importance of training ATS staff – this relates both to its usage and to being able to balance this with their use of more traditional tools and approaches to the role.
- Reluctance to accommodate change – as with all changes, the ability to adapt in the workplace is an individual process. Whilst some ATS staff will fall into the category of "*first adopters*", there will be others who fit more comfortably into the "*laggards*" category and will require more support to adapt (Kotter, 1995[13]; Rogers, 2003[14]).
- Education of pilots – there were several comments which referred to incorrect usage of aircraft ADS-B systems by pilots. These referred primarily to the positioning of portable devices in aircraft; remembering to switch the device on/off appropriately; and not charging the battery. See Appendix A.

6.5 Informal Data Feedback Loop

The instantaneous delivery of the online feedback, together with regular personal communications between the Airspace4All Trial Manager and the primary contact at each trial airfield, facilitated a feedback loop whereby suggestions and ideas for enhancements were discussed and, where possible, implemented.

6.5.1 Enhancements During The Trial

The purpose of the trial was to gather information and learn about the use of the ADS-B Traffic Display. The VRS software that drives the presentation of traffic data is highly configurable so ideas were explored to enhance the presentation as the trial progressed.

Altitude filters were applied so as not to display higher level traffic passing overhead which were not pertinent to the airfield or ATS service being provided. Short 'trails' were added to traffic symbols to aid recognition of the direction of travel. A range ring was implemented around the centre of the airfield to simplify traffic range assessment. An overlay was added to the map to present airspace boundaries for nearby controlled airspace. Markers (small grey circles) for local Visual Reference Points (VRPs) were added to the map at Barton to aid correlation of pilot position reports to actual aircraft position.

Barton upgraded from a conventional 17" flat screen pc monitor to a larger 21" flat screen pc monitor, improving visibility. It is noteworthy that both Goodwood and North Weald wanted to upgrade to larger screens but encountered difficulties gaining purchasing approval due to their organisation structure and separate IT departments (also an indication of cost sensitivity).

Barton implemented a split screen display presenting a zoomed-out DOC area on the left and a zoomed-in ATZ area on the right. This proved to be highly effective at addressing the differing resolution requirements for joining/departing/passing traffic

[13] Kotter J (1995) Leading Change: Why Transformation Efforts Fail. Harvard Business Review: March - April, 59-67

[14] Rogers, Everett (2003) Diffusion of Innovations (5th Edition). New York: Simon and Schuster

at greater distance versus closer proximity circuit traffic and was welcomed by ATS staff.

A digital video screen recording system was setup at all trial airfields to capture the display, in 1-hour files. These require a reasonable amount of disk space. A rolling 3-week video recording retention period was found to be viable, with automated deletion of older video. This gave sufficient time to copy off noteworthy periods for permanent retention. Clips from captured video have been used to raise awareness of the trial among the GA community. In permanent use, this capability could be especially useful for investigation of accidents, airprox reports and other safety-related incidents.

7 Discussion

7.1 Limitations of the Trial

There were several limiting factors affecting the trial to greater or lesser extent.

ADS-B was chosen as the base EC technology for this trial as it is the CAA stated preferred EC solution[15]. Other unapproved EC solutions would not have survived the scrutiny of a safety case[16] for use in provision of a live ATS service. A single ADS-B ground antenna system, functioning on direct aircraft-to-ground reception, was selected for simplicity, cost, low latency and reliability reasons. Alternative systems based on internet transmission of traffic data were rejected due to potential for unknown latency thus uncertain position information. Radar and multi-receiver Multilaterated (MLAT) systems were rejected due to complexity and cost – an objective was to assess a system that was economically viable for any small UK GA airfield (an MLAT system trialled in elsewhere in the UK cost over £80,000 to implement).

This trial assessed a concept that is not permitted under the current UK CAA regulations[17] covering ATS provision at small non-radar UK airfields. As such there is currently no commercial market for tools and technology to support this concept. Hence the choice of software solutions for the presentation of the ADS-B Traffic Display was limited and none were designed to meet the specific needs of UK GA ATS.

This was a 'real-world' trial taking place in fully operational UK GA airfield ATS environments with all the necessary safety-related considerations that needed to be respected. Although a limitation, this 'real-world' aspect was vital to ensure that if the ADS-B Traffic Display proved successful in the trial it would truly be possible to make it work in the real-word.

Use of the ADS-B Traffic Display and feedback thereon was wholly dependent on the commitment and diligence of airfield ATS management and staff.

The volume of traffic detectable by the ADS-B Traffic Display was partially dependent on the number of pre-existing ADS-B equipped aircraft operating at the airfields. The other part of this equation was the loaned portable ADS-B devices made available, through the airfield ATS units, to non-ADS-B operators based at their airfield. This in turn created a dependence on the ATS units engaging with operators to loan out the portable ADS-B devices and following up on their use.

15 https://www.caa.co.uk/News/ADS-B-can-help-reduce-airspace-infringements-and-mid-air-collisions,-says-CAA/

16 https://www.caa.co.uk/Commercial-industry/Airspace/Communication-navigation-and-surveillance/Display-and-use-of-surveillance-data-from-unapproved-systems/

17 E.g. CAP 774 UK Flight Information Services 2.2, page 23, CAA May 2017
"A FISO shall not utilise surveillance-derived data to provide traffic information when providing a Basic Service. The use of surveillance equipment by FISOs for other specific tasks is subject to regulatory approval."

Proper usage of the loaned portable ADS-B devices was entirely down to the commitment and diligence of the loanees. Where these were flying schools or aircraft syndicates this further relied on all flying instructors/student and syndicate members. This was partially mitigated where ATS were motivated to spot issues and minded to raise the matter with the operator.

Portable ADS-B devices and Mode S ES ADS-B transponders have different operational characteristics which are reflected in the results of using the ADS-B Traffic Display.

7.2 Literature Review

Trial feedback provides numerous examples evidencing difficulties for ATS staff sighting traffic which are comparable to the difficulties experienced by VFR pilots employing 'see and avoid' as described in the ATSB report entitled *Limitations of the See-and-Avoid Principle.* This is of no surprise as many of the difficulties are due to physiological limitations of the human eye. The working environment in an aircraft cockpit and a ATS visual control room share similar challenges, e.g. glare, haze, blind spots, window bars, lack of contrast between traffic and background, small angular size of traffic at distance. The following quotes from feedback illustrate.

> *"Very wet day. Poor visibility meant that the TD proved very helpful in following the progress of aircraft on frequency."*

> *"GABCD carrying out a number Practice EFAT on climb out in poor visibility, I was able to monitor the aircraft on ADSB."*

Trial feedback reports the effectiveness of the Traffic Display as an enhancement to ATS situational awareness. This is analogous to the increased effectiveness of 'alerted see and avoid' for VFR pilots over 'see and avoid' (as reported in MIT's report entitled *Unalerted Air to Air Visual Acquisition*). If ADS-B In traffic awareness tools are deemed appropriate for pilots then it follows that the same should be true for ATS. This example from the feedback is an illustration.

> *"I recall at one point that I had 4 in the circuit, all on the display plus another two either in or outbound, and I recall thinking how useful the display was as it helped me with keeping track of aircraft positions around the circuit when busy, allowing me to more quickly re-assess positions by a glance at the display then knowing where to look out of the window."*

The Airspace4All report *'Mid-Air Collisions: An Evidence-Based Analysis of Risk – 1975 to 2018'* states *"85% of risk to powered aircraft is from other powered aircraft. 43% of that risk occurs in the cruise and 57% in or close to the airfield or circuit making the latter the greatest risk area."* It goes on to say that few GA airfield ATS units have radar and thus suggests that the nature or existence of an ATS is not an obvious risk mitigation. However, this suggestion does not take into account the potential safety benefit of enhanced traffic information being provided by ATS made

possible by a CAA policy change that would allow use of new GA airfield ATS ADS-B Traffic Displays.

In the Air Accident Investigation Branch *'Report on Mid-Air Collision between G-RVGC and G-CEZR in the Visual Circuit at Shoreham on 4th July 2011'* it is reported that the ATCO, unaided by a surveillance system, did not see the aircraft joining the circuit and the report surmises that the ATCO's reduced situational awareness was due to a combination of factors, including the difficulty of seeing a composite aircraft coming from the direction of the sun which then flew at a high angle behind the ATCO making sighting unlikely. For ADS-B equipped aircraft, the ADS-B Traffic Display directly addresses this reduced situational awareness scenario. The following quotes from feedback illustrate.

> *"I have been able to monitor aircraft inbound which are approaching from the South / South West and which are usually behind us as our VCR faces North."*
>
> *"Runway NN in use most of the day. Traffic approaching from behind the AFISO so TD was used to aid situational awareness."*
>
> *"G-ABCD Cessna 152 inbd AD 1,200ft not visual with G-WXYZ Cessna 152 Dep'd AD 1,200ft both not visual. Advised of conflict, G-WXYZ took avoiding action. Pilot was well impressed!"*

The Airprox Board report on the airprox at Sibson Aerodrome raises a number of questions relevant to this trial. The Airprox Board commended the AGCS operator for exceeding his privileges when issuing the "Go around" instruction but pointed out the criticality of calling the correct a/c reg in the "Go around" instruction at the very late stage in the airprox. Had the AGCS operator been armed with better situational awareness from an ADS-B Traffic Display, the AGCS operator could have given better traffic info much earlier avoiding the aircraft getting as close as they did and avoiding the need to exceed his privileges. Clearly this would also require both aircraft to be equipped with ADS-B Out. If so, one or both aircraft could also have had an ADS-B In traffic awareness system, another possible barrier to the airprox, able to enhance the pilot's situational awareness.

It is of note that the Airprox Board mistakenly said that AGCS operators "*were not empowered to give Traffic Information*". CAP413[18] explicitly states AGCS operators can give traffic information "*based primarily on reports by other pilots*". Likewise, CAP452[19] states "*AGCS radio station operators provide traffic and weather information to pilots operating on and in the vicinity of the aerodrome. Such traffic information is based primarily on reports made by other pilots*". Greater clarity is

[18] CAP413 Radiotelephony Manual, Chapter 4, page 60 twenty-second edition, CAA, 26th May 2016 https://publicapps.caa.co.uk/docs/33/CAP413%20MAY16.2.pdf

[19] CAP452 Aeronautical Radio Station Operator's Guide. Chapter 4 Air ground communication service, page 24, fifteenth edition, CAA, 30th September 2016 https://publicapps.caa.co.uk/docs/33/CAP452_Edition15_OCT2016.pdf

needed on provision of traffic information by AGCS. ADS-B data from an aircraft should be treated the same as a pilot position report (except ADS-B is much more accurate). As this airprox showed, AGCS operators can have a vital role in safety which should not be understated or diminished.

The NATS report entitled *"General Aviation: ADS-B / GPS Trial Results"* stated that the quality of ADS-B data using a non-certified GPS position source closely matched the performance of ADS-B data based on a certified GPS position source. The ADS-B Traffic Display used in the trial received and displayed ADS-B data with certified and non-certified GPS position source. Trial feedback supported the view that position information presented on the Traffic Display was highly accurate and presented no issues regardless of the certification status of ADS-B equipped aircraft GPS.

The CAA consultation document *'CAP1669 Review of CAA Policy on the Training, Qualification and Licensing of Flight Information Service Officers'* outlines a suggested licensing change that might permit use of surveillance systems by FISOs. From CAP1669:

Proposed licensing structure for FISOs

The revised FISO licence may contain:

- **Flight information ratings.**
  - **Aerodrome Flight Information – Visual (AFV) rating.** Would entitle the holder to provide aerodrome flight information service in Class G airspace to transiting, arriving or departing aircraft at an aerodrome that has no associated published instrument approach or departure procedures.
  - **Aerodrome Flight Information – Instrument (AFI) rating.** In addition to the privileges of the AFV rating, the holder of an AFI rating would be entitled to provide aerodrome flight information service at an aerodrome in Class G airspace that has associated published instrument approach or departure procedures.
  - **FIR Flight Information Service (FIS) rating.** Would entitle the holder to provide flight information service within a FIR, or part thereof, to aircraft flying in accordance with the Instrument Flight Rules or Visual Flight Rules in Class G airspace, or the Visual Flight Rules alone in Class E airspace.
- **Flight information rating endorsements.**
  - **Surveillance (SUR) endorsement.** The Surveillance (SUR) endorsement may be held with the AFI or FIS rating and would entitle the holder to utilise an ATS surveillance system to supplement the provision of a flight information service.

The change suggested in CAP1669 to permit use of surveillance systems is very limited in scope. So much so that, were it to be in force today, it would not permit use of the ADS-B Traffic Display by any of the AFIS airfields that participated in this trial. The *Surveillance (SUR) endorsement* would not be able to be held with an *Aerodrome Flight Information – Visual (AFV) rating*. Therefore, as the AFV rating would be the most prevalent rating at small UK GA AFIS airfields, these suggested changes in CAP1669 would prevent the majority of small UK GA AFIS airfields using an ADS-B Traffic Display and deprive them of the enhanced situational awareness and safety benefits found in this trial. Although not covered by the same regulations, UK GA AGCS airfields would most likely be similarly deprived.

CAA published guidance in April 2018 entitled *'Display and use of surveillance data from unapproved systems - Guidance for air navigation service providers'.*
The guidance includes:

> "Regulatory approval
>
> *While the CAA understands that in some circumstances, having improved situational awareness using an application that displays aircraft position information may be useful, there are safety implications in the use of such data that must be carefully considered. The introduction of such systems will need to be assessed in accordance with an ANSP's Safety Management System and evidence of compliance with regulatory requirements for ATS equipment must be demonstrated.* ***In the absence of information from application developers of the capabilities of their applications, it is unlikely that a case for use in a tactical air traffic service environment can be made, other than for tasks assessed as not safety-related.***
> *The CAA reminds ANSPs that the use of any surveillance data to support the provision of an air traffic service with any of the surveillance services described in the MATS Part 1, or for the acquiring of traffic information in an ATC or Aerodrome FISO environment will only be permitted following the submission of safety assurance documentation and with approval by the relevant ATM Regional Office; and that unapproved surveillance systems can only be used for tasks that are not safety-related."*

The component-based ADS-B Traffic Display, including the Virtual Radar Server (VRS) software (a free to download/use, open-source application) which was used in this trial, would fall foul of the section of the above CAA guidance highlighted in bold blue text. Yet in this trial ATS feedback has reported the ADS-B Traffic Display, incorporating this VRS software, has made the service they provide safer. The commercial market in the UK for approved surveillance systems built specifically to meet the needs of the small GA airfield ATS sector is tiny and highly cost sensitive. No solutions targeting this specific market exist, hence why this trial has had to rely on open source software. It is imperative that the CAA do not set the regulatory bar so high that it stifles this nascent market before it is born and prevents the use of new surveillance technology that can deliver safety enhancement to GA and help save lives.

7.3 Equipment

This trial proves that ADS-B Traffic Display technology is manageable within the financial, expertise, staffing and operational constraints of UK GA airfields. Keeping down the cost of the system to levels that are affordable to UK GA airfields is perhaps the most important lesson. If systems are unaffordable then, no matter how much they might contribute to safety, they will never be adopted.

The simplicity of making changes to the display settings of Virtual Radar Server software (e.g. choice of background map, number and choice of traffic data labels,

etc) data can be both a blessing and a curse. The temptation to 'play' must be resisted in case one person's attempts at improvement are viewed as detrimental by others. It is recommended that relatively formal change procedures and change management are applied.

The larger 21" screen and split screen DOC vs ATZ presentation implemented at Barton was one of the most effective developments during the trial. Further study should be undertaken to research, identify and document standards for the optimum presentation of information on the Traffic Display, covering the many configurable setting in Virtual Radar Server.

The screen video recording is another important development introduced early in the trial that will be of great future value.

System performance assessed against the criteria suggested at the outset of the trial is reasonable. Some aspects can undoubtedly be improved by applying some of the lessons learned concerning optimal configuration and operating procedures.

The absence of any adverse effect from Mode S/CAP1391 simultaneous transmission is further contribution to analysis of this subject.

7.4 ATS Feedback

The ATS staff quantitative and qualitative feedback both reported positive experience using the Traffic Display and supported retention of the Traffic Display post-trial. It was reported to be reliable and highly accurate, to enhance ATS situational awareness and not be a distraction safety hazard. As far as the Traffic Display enhancing awareness of aircraft approaching high ground (helping to avoid CFIT), this was not shown in this trial.

Feedback contained numerous instances where the traffic position as reported by ADS-B was shown to be more accurate than the position reported by the pilot via R/T. With ADS-B accuracy of less than 10m it is not surprising that there were no instances where pilot position reporting via R/T was more accurate than ADS-B.

The feedback included a number of reports on enhanced situational awareness of ground movements, especially when movements were out of sight of ATS. Monitoring ground movements provided a strong measure of accuracy of the system, with aircraft taxiing on narrow tarmac taxiways less than 10m wide being presented on the zoomed-in Traffic Display precisely where they were seen to be, in the centre of the taxiway on the screen map. However, ADS-B Out broadcast from traffic on the ground, and especially from inactive parked aircraft, was found to clutter the display, so advice was developed to request operators to set minimum ADS-B Out activation speeds at around 30kt so they only showed when airborne and during take-off and landing (plus operators being encouraged to switch off ADS-B broadcast when parking up). Note that ADS-B activations speed setting greater than zero can sometimes fool pilots into thinking their ADS-B Out is not working – testing can often be performed when stationary on the ground and forgetting/not knowing

about the ADS-B Out activation speed setting cause give rise to false assessment of ADS-B Out being faulty.

A suggested alternative approach to managing screen clutter from traffic on the ground has not been implemented yet but has the advantage of not relying on aircraft deactivating their ADS-B broadcasts at lower speeds. The suggestion involves an extra browser window (and probably extra screen) dedicated to display of ground traffic, with an altitude filter set to only display traffic under, say, 200ft above airfield level. The primary display(s) would be reconfigured with an altitude filter set to only display traffic over 100ft above airfield level.

Feedback did not suggest the Traffic Display had a significant role to play during the trial in preventing infringement of controlled airspace – the highest response by far to the question relating to this matter was 'N/A' indicating that the situation rarely arises. However, there were situations where the Traffic Display helped to prevent an infringement of the airfield ATZ.

A number of situations were reported where the Traffic Display enabled ATS to provide pertinent traffic information to pilots concerning aircraft not on their frequency but visible to ATS on the Traffic Display and the value of this aspect of use was supported in the quantitative feedback.

Feedback suggests that the Traffic Display can be a useful tool for helping airfields to verify compliance with local traffic regulations, e.g. helping to be 'good neighbours' and better monitor/manage traffic in relation to noise sensitive areas. This monitoring/management may well actually take place at a later stage (reviewing the screen video and offline discussion with aircraft operators)

The reception range for traffic on the Traffic Display was reported as good, especially for aircraft with Mode S ES ADS-B transponder which regularly could be seen on the screen well beyond the 10nm DOC range. Aircraft with CAP1391 portable ADS-B devices have lower power transmitters and in-cabin antenna so their reception range is lower and can vary due to signal masking by the aircraft's own fuselage. Even so reception from these aircraft was typically out to 5nm and easily enough range to cover the ATZ. When operating at the extreme of this reception range, manoeuvring aircraft with CAP1391 portable devices could be seen to 'come and go' on the screen as their broadcasts were intermittently masked during turns. No matter what type of ADS-B device an aircraft has, they all pass out of range eventually when departing the airfield. But coverage of the ATZ and just beyond is what matters in this application of the technology and the trial showed this requirement to be met.

Fortunately there were few examples of safety related incidents during the trial. There were two incidents of note that were reported where the Traffic Display proved its worth - an aircraft losing radio communications (detected by seeing the 7600 squawk code on the Traffic Display) and an aircraft losing electrical power (determined due to broken then lost radio communications and disappearance of the traffic from the screen).

Squawk codes are another area where the characteristics of ADS-B from a Mode S ES transponder differs to that of a CAP1391 portable device. This difference is visible on the ADS-B Traffic Display. Mode S ES transponders include the current squawk code setting, as set by the pilot, in the broadcast ADS-B data stream and this can be presented in data labelling under the traffic symbol on the Traffic Display. CAP1391 portable devices also include a 'Mode A squawk code' in their ADS-B data stream but it is always set to 7000 – a Mode A/C/S non-ADS-B transponder in the same aircraft may have its squawk code set the same or differently but the transponder squawk code will never show on the Traffic Display screen. This behaviour can have an impact in situations where knowledge of the squawk code set by the pilot can make a difference, such as squawking 7600.

Feedback relating to the absence of non-ADS-B equipped aircraft from the Traffic Display largely indicates this is a nuisance but not such that it negates the benefit of the Traffic Display. This is a key finding regarding 'real-world' use of the Traffic Display in an environment where many aircraft are not ADS-B equipped. Even here the Traffic Display does provide worthwhile enhancements to situational awareness.

In general, the more the airfield ATS unit put into the trial and using the ADS-B Traffic Display the more they got back. For future use, beyond technical training there will need to be some focus on helping ATS staff adapt to new ways of working.

Feedback in this trial reports improvements due to the Traffic Display in staff well-being and confidence from the reassurance offered by the system in being able to provide a reliable and safe service. At a time when there is a recognised general shortage of ATS staff this should not be overlooked.

8 Conclusions

The trial period at Barton is complete but the CAA has authorised the continued use of the equipment there. The trials at Goodwood and North Weald started later and are still in progress but the results gathered to date are sufficient to complete this report now. Any additional issues that come to light will be issued in an addendum.

This was a 'real-world' long-term trial taking place in fully operational UK GA airfield environments with all the necessary safety-related considerations respected. Although a limitation, this aspect was vital to ensure that if the ADS-B Traffic Display proved successful in the trial it could be deployed on the basis of this work.

8.1 Aim

The aim of the trial was to gather information to assess the use of ADS-B Traffic Displays at GA airfields with a view to future authorisation. It found that:

8.1.1 Safe to Use

The ADS-B Traffic Display was reliable, safe to use and highly accurate in presenting real-time low latency traffic position information for ADS-B equipped aircraft to enhance both ATS and AGCS situational awareness. It was not a distraction safety hazard. It had a positive effect on ATS and AGCS staff well-being and confidence in doing their job.

8.1.2 Range

Mode S ES transponder ADS-B devices displayed well at range up to and beyond the DOC. Portable ADS-B devices were displayed consistently within the range of the ATZ but inconsistently beyond that.

8.1.3 Viability

ADS-B Traffic Display technology, equipment and deployment was manageable within the financial, expertise, staffing and operational constraints of typical UK GA airfields.

8.1.4 ATS Unit Commitment

The benefit accrued from use of Traffic Displays was affected by the degree of commitment from airfield ATS management and staff. It was not simply about training. Openness to new ways of working was essential.

8.2 MAC and Airspace Infringement

In addition the trial was to assess the potential of ADS-B Traffic Displays to:

8.2.1 Reduce the probability of mid-air collisions.

The ADS-B Traffic Display increased awareness of traffic and enabled accurate information on traffic position and altitude to be passed to other aircraft within the DOC of the airfield.

A side-benefit of the introduction of the ground system was that more aircraft are likely to install ADS-B Out and many of those are likely to also fit ADS-B In which would enable direct aircraft-to-aircraft traffic awareness without necessarily having a ground station in the loop. This would give it utility beyond the coverage of ground systems and where no service is provided.

8.2.2 Provide increased situational awareness resulting in a reduction in airspace infringements:

No event occurred to test the utility of the system in preventing or mitigating an infringement of regulated airspace. However, the system provided valuable awareness of aircraft entering the ATZ without first making contact, enabling safety to be maintained. This suggests that the ADS-B Traffic Display would provide this capability.

8.2.3 Monitor compliance with local traffic regulations:

When there was a need to confirm aircraft were complying with local traffic regulations, the Traffic Display provided helpful assistance.

8.3 Other Relevant Results

The trial identified a number of other results which will be relevant to any future development, authorisation and deployment:

8.3.1 Accuracy

Strong confidence in the accuracy of the system as a whole was achieved by monitoring the accuracy of displayed ground movements on taxiways.

8.3.2 Treat ADS-B Position Data the Same as Pilot Position Reports

Pilot position reports were often less accurate than ADS-B position data. As it is more accurate, ADS-B position data should be treated the same as pilot position reports for the purposes of ATS and ATS giving traffic information.

8.3.3 Separate Displays (Ground/ATZ/DOC)

Separate displays for ground and flight areas (on the same screen) with different scales were very effective and overcame the clutter effect close to the airfield.

Separate displays (on the same screen) with different scales covering the DOC and the ATZ were very effective in separating aircraft symbology close to the airfield whilst maintaining a wider picture of traffic.

8.3.4 Managing Clutter

ADS-B Out from aircraft on the ground, and especially from inactive parked aircraft with portable devices, was found to clutter the display but could be resolved by activating the aircraft transmission only above 30kts or by altitude screening at the ATS display. However, this would need further consideration to determine the optimum arrangement and its consequences.

8.3.5 Raising General Awareness of ADS-B

The trial has raised the general awareness of ADS-B in the UK GA community. Since the trial began there has been an increase in independently funded installations of ADS-B into aircraft based at Barton.

8.3.6 Incentive for Operators to Equip with ADS-B

The knowledge that the airfield ATS/AGCS unit had an ADS-B Traffic Display appears to incentivise operators to equip their aircraft with ADS-B.

8.3.7 Standard Display Configuration

The Traffic Display is highly configurable and whilst this provided flexibility during the trial, there is a risk that operational installations could be reconfigured to different operators' personal wishes which may become confusing. If the system is to be deployed operationally, a standard format configuration could be prepared.

8.3.8 No Safety Issues Found with Simultaneous Mode S/CAP1391 Transmission

Simultaneous transmissions by a Mode S transponder and a CAP1391 portable ADS-B in the same aircraft did not produce any false or confusing data on the Trial Display.

9 Recommendations

At the outset, the object of the trial was to provide the CAA with evidence on which to base a review of potential ADS-B deployment at GA airfields. This report sets out that evidence but makes no recommendation as to the CAA decision. However, if the CAA decides to progress this area of policy the following considerations, which were highlighted during the trial, may be relevant:

9.1 ATS Unit Approval

The work needed to obtain CAA approval to proceed was substantial and most GA airfields are unlikely to be equipped to prepare the necessary documents and procedures. Neither are they likely to be able to afford to pay for such work. If deployment is to be encouraged a standard set of documents would need to be made available and a standard and low-risk approval process set up. Airspace4All Ltd has the expertise and experience to prepare this material.

9.2 Intermittent Loss of Signal from Portable Devices

Intermittent loss of signal from aircraft equipped with portable ADS-B devices has an impact on ground station displays and on other aircraft equipped with ADS-B In. This is likely to be due, in the main, to obscuration by aircraft structure and crew and will vary with aircraft configuration, device position, range and aircraft orientation to ground antenna. This will affect the safety and operational benefits delivered by the system. This issue is expanded further in Appendix A.

If it is decided to deploy ADS-B in any form, this issue needs to be quantified. Airspace4All has the experience and access to the equipment needed to carry out the measurements necessary to understand and mitigate this issue. A follow-on investigation would be required.

9.3 AGCS & Traffic Information

Airspace4All is aware that consideration is being given to limiting what information may be passed to aircraft by an AGCS operator. Currently they can pass traffic "information based primarily on pilot reports", a phrase that does not exclude information from other sources which could include ADS-B Traffic Displays. ADS-B position data has been shown to be highly accurate and often far more accurate than pilot position reports. Most GA airfields operate an AGCS at the most and would not have the resource to change to an AFIS.

It would be unfortunate if in the future they were not able utilise a safety system that is available to them today.

Appendix A

Portable ADS-B Devices

The trial exposed issues regarding pilot use of CAP1391 portable ADS-B devices that had a negative bearing on the ATS use of the Traffic Display. These airborne device usage matters are beyond the scope of this trial but are reported here for completeness. Feedback which illustrate this related to inappropriate usage and positioning:

- poor positioning of the device in the aircraft
  - resulting in 'shielding' or 'masking' of the signal (both in and out) by the airframe and poorer reception on the Traffic Display
- omitting to charge devices before use
  - resulting in no signal or loss of signal during flight
  - occurring on first flight in morning – not charged overnight
  - occurring later in day – poor battery management during the day
- not switching the device off when parked on the ground
  - resulting in 'clutter' on the Traffic Display screen and possibly loss of signal during subsequent flights due to loss of battery power
- not switching the device on
  - even when available for use in the aircraft
  - more prevalent in flying school and syndicate/group owned aircraft
- difficulty seeing the status led lights or accessing the on/off switch
  - this affected older units and resulted in uncertainty about the state of the device and the need to recycle (reboot) them to maintain contact.
- Using a device programmed with information for the 'wrong' aircraft
  - E.g. in flying school/club environments with multiple aircraft and multiple devices where the device taken flying is not the one programmed for the aircraft being flown.

It might be anticipated that these issues may be resolved with informal advice/education, experience and familiarity with using the system. However, it is clear that portable devices can be a poor fit for shared use aircraft such as those operated by flying schools and syndicate/group owned aircraft. These tend to be relatively higher utilisation aircraft where the benefit of ADS-B Out is consequently greater. For such aircraft a permanently installed Mode S ES ADS-B Out transponder/GPS combination is a better option as this would address all the above issues.

> "*The pilot of G-YZAB came up to the tower and we found the cause may be down to the device being mounted upside down on the roof of the aircraft meaning it was struggling to maintain GPS signal. The pilot will reposition the device and see if the issue is resolved*"

"*G-CDEF took the wrong device and showed as G-GHIJ, the pilot was advised and shut down the device before departure*"

"*G-KLMN departed and soon stopped showing on the TD. Unit not fully charged prior to departure. Instructor attended the tower after landing to say the unit had stopped working after departure and believes it wasn't charged properly prior to departure*"

"*G-OPQR (PA28 X Flying School) reported his ADS-B device had not been charged - so non ADS-B equipped*"

"*One helicopter today (not one with the loan devices but a visitor) was observed on the ground for several hours, even though it was parked and unattended, perhaps indicating a device or something was left transmitting. This adds a little clutter to the display*"