Electronic Conspicuity Data Collection at the LAA Rally

30 August to 1 September 2019

Version 10.0

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Index

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

1 Executive Summary

The LAA Rally 2019 was a 3½-day event attended by 743 different light aircraft (some 7.5% of the UK fleet). There were no gliders or balloons. Airspace4All Ltd (A4A) took the opportunity to collect electronic conspicuity (EC) data to obtain a large sample snapshot of EC equipage and operation in GA aircraft. Pre-flight booking data, ATS logs and data from a receiving station in the exhibition area were merged to define the electronic signature of each aircraft.

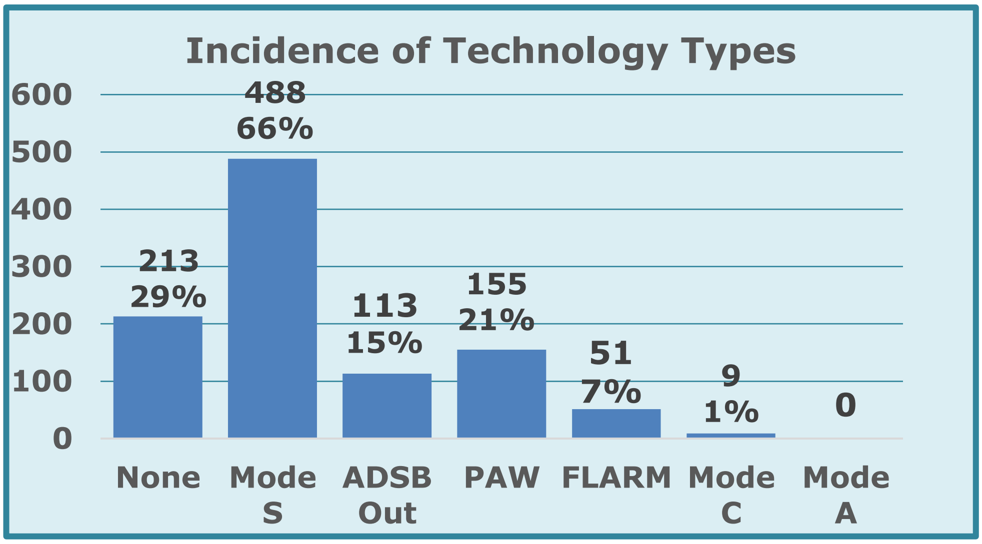

Figure 1 Incidence of Technology Types

Many aircraft had multiple devices: there were more devices than aircraft.

The transponder distribution correlated closely with the UK aircraft register and licensing database suggesting that these results are indicative of EC distribution in the GA sector.

<u>Equipage</u>

Of the 66% of aircraft equipped with Mode S, 59% had Mode S only and 41% were also equipped with another system. Of those:

26% also had ADS-B Out,
21% also had PAW
9% also had FLARM
13% of those were equipped with multiple systems

- There were no Mode A only and just 1% of aircraft had Mode C only.
- Just 4% had unregulated equipment as the sole system (FLARM and/or PAW).
- ADS-B Out was fitted to 15% of aircraft, most commonly with Mode S.
- Only 1% of aircraft were equipped solely with ADS-B.
- PAW was fitted to 21% of aircraft, most commonly in addition to Mode S.
- FLARM was fitted to 7% of aircraft, most commonly in addition to Mode S.
- PAW and PowerFLARM provide an ADS-B In capability

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Interoperability Today

Mode S, as fitted in 66% of GA aircraft, can be seen by ATS radar and CAT aircraft TCAS systems but is not directly interoperable with other GA aircraft except that some EC devices include bearingless detection of Mode C and S.

ADS-B Out/In is fitted in 15% of GA aircraft which can see and be seen by each other and can be seen by a total of 18% of other aircraft with PAW and PowerFLARM which include an ADS-B In capability; a total GA ADS-B interoperability of 33%. In addition, these 33% of aircraft can also see ADS-B Out broadcast by most CAT aeroplanes and commercial helicopters.

GA ADS-B Out is not supported by ATS radars and is only partly interoperable with CAT TCAS systems because of the System Integrity Level (SIL). However, because 94% of GA ADS-B installations are in aircraft with Mode S, this is not a practical limitation today.

PAW is fitted to 21% of GA aircraft, which can see and be seen by each other and because PAW devices provide ADS-B In they can also see the 8% of other GA aircraft with ADS-B Out; a total GA interoperability of 29% plus ADS-B Out broadcast by most CAT aeroplanes and commercial helicopters.

PowerFLARM is fitted to 7% of GA aircraft which can see and be seen by each other and by the majority of cross-country gliders. Because PowerFLARM devices provide ADS-B In they can also see the 12% of other aircraft with ADS-B Out; a total interoperability of 19% plus most gliders and most CAT aeroplanes and commercial helicopters

33% of GA aircraft can see most CAT aeroplanes and large helicopters via ADS-B In either in discrete devices or using the functionality in PAW, PowerFLARM or other devices.

Clearly, two-way "see and be seen" is better than one-way "see" or "be seen" because it provides a more complete air picture to both aircraft in the equation. However, the diversity of the technologies in use provides a remarkable degree of interoperability between the 4 systems and between different categories of aircraft

Key Points and Issues

- GA aircraft equipped with all 4 systems described are interoperable with almost all CAT aeroplanes and large helicopters and most gliders.
- Although ADS-B aircraft interoperability is some 33% achieved through diversity of devices, ADS-B ground stations can only see 15% of GA traffic.
- SIL level zero prevents ADS-B interoperability beyond GA systems.
- Unregulated devices are delivering a large proportion of ADS-B In functionality.
- Screening and range issues of portable ADS-B devices have not been analysed.
- Development of functionality in the regulated but particularly the unregulated sector is rapid and innovative.

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2 Introduction

2.1 With the increasing development and manufacture of electronic conspicuity (EC) devices for light aircraft, the GA community has begun to install them, partly because of an increased awareness of collision risk and partly because of the attraction and interest of having an in-cockpit view of nearby activity. This is leveraged from the popularity of GPS navigation devices which can share displays. Equipment development has been rapid in both the regulated and unregulated sectors resulting in a diversity of systems which have only limited interoperability. Moreover, even within the regulated group of equipment, there is no State or other record of what is installed in which aircraft, so the overall EC environment is unquantified. The radio licence database records which aircraft are licenced to transmit on 1090MHz but the equipment type, which could be Mode S, Mode C, Mode A or ADS-B, is not recorded. This results in there being no evidence-based information on the current distribution in the UK fleet.

2.2 The LAA Rally at Sywell Aerodrome is a 3½-day event attended by a significant number of light aircraft of all types; it is probably the largest gathering of light aircraft in the UK calendar with between 1500 and 2000 movements. During the 2019 event, A4A took the opportunity to collect electronic conspicuity data on those aircraft, including the type of EC technology fitted, to obtain a large sample snapshot of EC equipage and operation in the GA aircraft sector.

2.3 This report sets out the collected data and analyses the EC equipage.

3 Aim

3.1 The aim of this activity and report is to determine the distribution and function of EC devices carried by aircraft attending the LAA Rally 2019 and thence:

- Extrapolate the result to the UK light aircraft fleet.
- Assess the interoperability of the recorded EC fits in air-to-air and air-to-ground situations.
- Highlight key EC Issues.
- Archive the source data against any future analysis requirement.

4 Data Collection Arrangements

4.1 Sywell Aerodrome collect data on aircraft visiting the LAA Rally through an on-line landing slot booking system and a physical booking-in process after landing. The Sywell ATS Unit also maintains movement logs. For this event, Sywell Aerodrome agreed to expand the slot booking system to include a declaration of the basic EC fit of each aircraft. The declaration was completed for every participating aircraft and the resulting data with aircraft EC fits and the ATS traffic logs of aircraft movements was made available to A4A after the event.

4.2 Several exhibitors at the LAA Rally operate ground stations to display the EC air picture around the airfield to potential customers. A4A arranged for one exhibitor to collect and record EC track files of all aircraft flying into the event. After the event this data, collected from ADS-B, PAW, FLARM equipped aircraft and from the multilateration of Mode S transponders, was merged with the Sywell aircraft booking and ATS log data to generate a comprehensive record of EC activity by the 743 different aircraft.

5 Existing UK Electronic Conspicuity Data

5.1 Pre-existing data related to UK GA aircraft and EC can be sourced from the Aircraft Register and the Radio Licensing Database. Table 1 sets out the number of aircraft by class and MTOM in 2011 and 2018 and records the proportion that have 1090 MHz licences and therefore have transponders installed.

Table 1 UK Aircraft Register and Radio Licensing Data

UK Aircraft Register Categories	Aircraft 2011	TXPDR 2011	% Fitted 2011	Aircraft 2018	TXPDR 2018	% Fitted 2018	Delta
BALLOON	1800	15	1%	1503	9	1%	-40%
SMALL AEROPLANES <1500KG	8000	4200	53%	8208	4821	59%	15%
LARGE AEROPLANES >1500KG	2000	1660	83%	2214	1963	89%	18%
GLIDER	2700	46	2%	2269	80	4%	74%
ROTARY WING	1600	1200	75%	1602	1225	76%	2%
MICROLIGHT	4000	212	5%	3957	406	10%	92%
Total	**20100**	**7333**	**36%**	**19753**	**8504**	**43%**	16%
UNREGISTERED (ESTIMATE)	7000			7600			

5.2 It is likely that unregistered aircraft are not fitted with transponders.

6 The Aircraft Sample

6.1 The LAA Rally attracts mainly light single engine aeroplanes below 1500kg MTOM, mostly from the UK but a few from other States. A proportion of aircraft are registered as microlights but most tend to be the heavier 3-axis aircraft, some of which can be registered as either an aeroplane or a microlight. Some helicopters, gyrocopters and motor gliders also attend. Of the 743 aircraft that attended the event, 619 were aeroplanes, 88 microlights, 12 Self Launching Motor Gliders (SLMG) and 24 helicopters or gyrocopters. As the majority of aircraft were from the small aeroplane group the number of aircraft and transponders was compared to the known data in Table 1 to check if the sample is representative of the fleet.

6.2 In 2018 there were 8208 aeroplanes below 1500kg MTOM on the UK register and 4821 (59%) were licenced to operate a transponder. In 2019, 619 such aeroplanes (7.5% of the UK fleet) attended the LAA event and of those, 427 (69%) were fitted with a transponder. We should expect some increase in transponder carriage over the year so the difference of 10% suggests this sample is broadly representative of the UK aeroplane fleet.

6.3 Because of the nature of the event there were no balloons, gliders, hang gliders, paragliders or paramotors at the event. The analysis does not address these types.

6.4 The table of data records is substantial and unsuited for publication in a printed report. The data is held electronically by A4A against any further data analysis requirement.

7 Data Collection and Recording

7.1 Booking Data and ATS logs recorded aircraft and pilot data together with the ATA and ATD of each aircraft movement. 1168 aircraft were booked into landing slots for the 3½ days of the event. A total of 743 unique aircraft arrived during the event and their EC carriage data and signature were recorded once although some aircraft arrived and departed more than once on different days. There were 1580 aircraft movements in total.

7.2 Throughout the 3 main days of the event the electronic signature of the arriving aircraft was recorded. Antennae were erected to collect Mode S, C and A and ADS-B transmissions on 1090MHz, Pilotaware transmissions on 869.525MHz and FLARM transmissions on 868MHz. A fast internet connection was established to enable multilateration of Mode S transmissions to provide location data. This connection also enabled displays of the "local air picture" in the exhibition area and at the booking-in desk which was located on the CAA exhibition stand.

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7.3 Pre-flight data for each aircraft was collected by Sywell against a unique reference number:

Aircraft Details	EC Systems
Date	Mode S
Slot Time	Mode C
Aircraft Registration	Mode A
Pilot name and contact	ADS-B
Flight ID	FLARM
Aircraft Type	PilotAware
Departure Airfield	None

This data was merged with the electronic data collected during the event and processed to remove duplicate entries. A4A holds these original data logs for future reference and analysis.

7.4 Anomalies were found between the declared EC fit and the detected EC signature; ground stations detected fewer ADS-B Out devices and more PAW devices than expected.

7.4.1 ADS-B Numbers. Some attending aircraft which had reported as ADS-B equipped were not detected as ADS-B but were detected as Mode S or PAW or were not detected at all. Although attempts were made to resolve the missing ADS-B signatures by contacting pilots, many did not reply and the matter remains unresolved. However, because PAW and some FLARM devices contain an ADS-B In function it is possible that pilot entries in the booking log may have recorded ADS-B where PAW or FLARM was installed but ADS-B Out was not. It is also possible that the EC questions during the slot booking process some months ahead of the event prompted some pilots to install an EC device increasing the overall EC carriage figure by some 2%.

7.4.2 PAW Numbers. The detected EC signatures identify the systems functioning at the time of arrival and provide aircraft identification so are the reliable indication of the actual EC status; they have been used throughout this report. However, 17 aircraft which were detected with PAW did not display an ICAO Aircraft Address so the aircraft identification could not be determined and these devices could not be assigned to an aircraft EC group or classification in this data analysis. These additional PAW detections are noted in various places in the text but are not able to be included in the analysis.

7.5 A presentation given by A4A to the MACCG [1] on 6 December 2019 was based solely on pre-flight reported data because at that stage the anomalies in the received signatures had not been resolved. The data and analysis presented in this report now use verified received data which results in some differences to the figures presented. Changes are principally in the ADS-B and PAW carriage numbers

[1] CAA Mid-Air Collision Challenge Group

which also have a minor knock on effect on some overall percentage figures. Where there is a difference, the figures presented in this report are the more accurate.

8 Distribution of EC technologies

8.1 Mode S transponders were the dominant EC system carried by the aircraft attending the event and in the light aircraft sector. In addition to the 619 aeroplanes attending the event (69% with transponders), 88 Microlights (53% with transponders), 12 SLMGs (25% with transponders) and 24 helicopters and gyroplanes (83% with transponders) attended. The overall transponder carriage by the 743 aircraft attending the event was 497 (67%).

8.2 Of the 743 aircraft recorded, 213 (29%) had no EC system and 530 (71%) had one or more of the 816 EC technology systems listed in Figure 1. The 17 PAW devices with no ICAO Aircraft Address have been omitted from Figures 1 and 2.

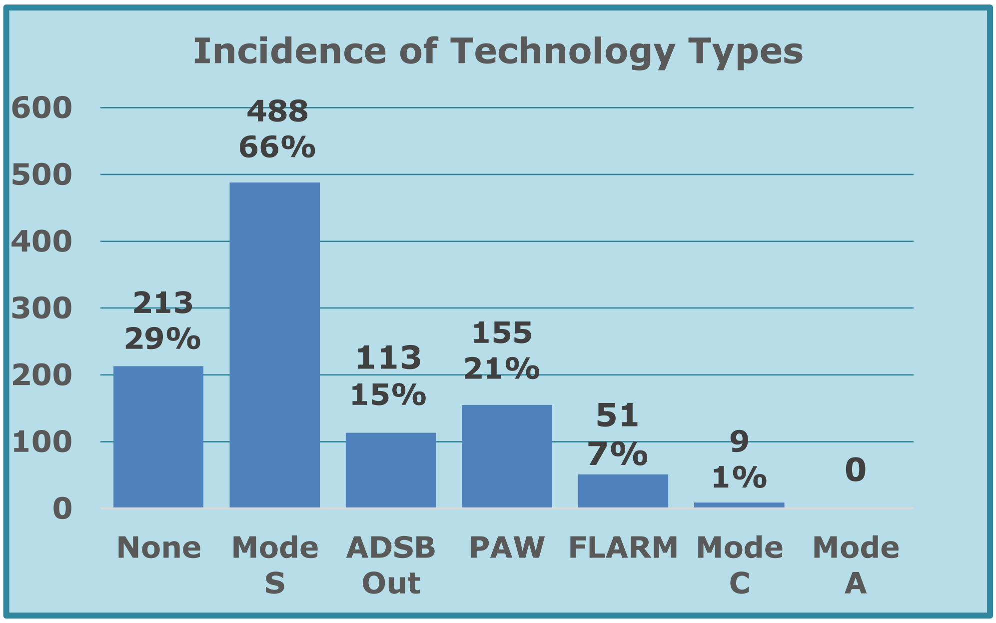


Figure 1 Incidence of Technology Types

8.3 There is considerable overlap within the columns in Figure 1, mainly with aircraft fitted with Mode S having one or more additional systems. This is set out in Figure 2.

	Aircraft
No EC System	213
Single Systems	
Mode A only	0
Mode C only	9
Mode S only	284
ADSB only	3
FLARM only	5
PAW only	22
Total Single	**323**

Multiple Systems	Aircraft
ADSB + FLARM	1
ADSB + PAW	2
Mode C + ADSB	0
Mode-C + PAW	0
Mode-S + ADSB	41
Mode-S + FLARM	16
Mode-S + PAW	75
Mode-S + FLARM +PAW	6
Mode-S + ADSB+FLARM	16
Mode-S + ADSB+PAW	43
Mode-S + ADSB+FLARM+PAW	7
Total Multiple Systems	**207**

Figure 2 – Distribution of EC Systems by Aircraft

8.4 Out of the 530 identified aircraft that had some EC system, only 30 (6%) had an unregulated system (PAW and/or FLARM) as its sole installation and only 3 (<1%) had ADS-B alone. 497 (94%) had Mode S or C. The overwhelming majority of installations included Mode S either:

- As the sole system; 284 (53%)
- With ADS-B either alone or with FLARM and/or PAW in addition; 107 (20%)
- With FLARM and/or PAW; 97 (18%)

8.5 Distribution of EC systems by Aircraft Classification

	Aeroplane	Microlight	SLMG	Rotary	Total
Aircraft Total	619	88	12	24	743
No EC	27%	40%	67%	12%	29%
Some EC	73%	60%	33%	88%	71%
Distribution					
Mode-A	0%	0%	0%	0%	0%
Mode-C	1%	1%	0%	0%	1%
Mode-S	68%	52%	25%	83%	66%
FLARM	6%	9%	25%	4%	7%
ADSB	16%	11%	0%	17%	15%
PilotAware	20%	26%	0%	25%	21%
Total Devices	691	88	6	31	816

Figure 3 – Distribution of EC Systems by Aircraft Classification

The distribution of EC systems between the different classifications of aircraft is set out in Figure 3. This shows what proportion carried EC and what proportion of types were carried:

- Many aircraft carried more than one system.
- There were more EC devices than aircraft.
- An additional 17 aircraft with PAW (2%) were not displaying an ICAO code so could not be included in this table.

8.6 Mode S Distribution

Figure 4 – Mode S Distribution

Mode S only	284	58%
Mode S & ADS-B	107	22%
Mode S & PAW	131	27%
Mode S & FLARM	45	9%

72 of those were in multiple installations of 3 or more systems

Mode S was fitted in 488 (66%) aircraft at the event. The distribution of those 488 systems is shown in Figure 4.

In the aeroplane group, 69% had transponders consistent with the CAA licence records set out in Figure 1. However, 52% of microlights carried transponders compared to the 10% listed in the licence record for 2018. This suggest that the larger 3-axis microlights which predominate at this event have the greater proportion of Mode S installations and the lighter and flex wing microlights a much lower rate of installation. An inspection of the list of microlight types in the event data record supports this.

83% of rotary wing aircraft carried transponders which is again consistent with licensing record of 76% in 2018

8.7 ADS-B Distribution

Figure 5 – ADS-B Distribution

ADS-B (only)	3	3%
ADS-B & Mode S	107	95%
ADS-B & PAW	52	46%
ADS-B & FLARM	24	21%

66 (58%) of those were in multiple installations of 3 or more systems

ADS-B Out was detected in 113 (15%) of aircraft that arrived at the event. It was most commonly installed in conjunction with Mode S. The distribution of those 113 systems is shown in Figure 5.

ADS-B Out was detected in 13% of aeroplanes and 11% of microlights.

8.8 ADS-B System Integrity Level (SIL)

Of the 113 ADS-B systems detected, 54% had a SIL of zero and 46% had a SIL of 1 or greater.

The effect of this is that whilst all aircraft with ADS-B Out would be detectable by other GA ADS-B aircraft and unregulated ground stations, commercial aircraft TCAS systems and ATC radar units would not be interoperable with them.

8.9 PAW Distribution

PAW was fitted in 155 (21%) of aircraft at the event. It was installed most commonly in addition to Mode S. PAW devices also provide an ADS-B In function and are often fitted in aircraft that use Mode S to transmit ADS-B Out, thus completing the functionality.

The distribution of PAW was similar across the aircraft classifications considered. An additional 17 (2%) of PAW devices were detected with no ICAO Aircraft Address so cannot be assigned to an aircraft and are not included here.

Figure 7 – PAW Distribution

PAW alone	22	14%
PAW & Mode S	131	85%
PAW & ADS-B	52	34%
PAW & FLARM	13	8%

56 (36%) of those were in multiple installations of 3 or more systems

8.10 FLARM Distribution

FLARM was fitted in 51 (7%) of aircraft at the event, most commonly in addition to Mode S

PowerFLARM devices also provide an ADS-B In function and is likely to be the majority of equipment fitted to these aircraft. But the distribution of the different FLARM types is unknown. For the purposes of analysis the 51 aircraft are assumed to be fitted with FLARM with ADS-B In but without evidence of the model fitted, that is a maximum figure.

Figure 8 – FLARM Distribution

FLARM (only)	5	10%
FLARM & Mode S	45	88%
FLARM & ADS-B	24	47%
FLARM & PAW	13	25%

29 (57%) were in multiple installations

9 Data Analysis

9.1 The move from Mode A/C transponders in GA aircraft is largely complete with only 1% of aircraft retaining Mode C and few, if any, retaining Mode A only. Mode S transponders are now installed in 60% to 70% of UK light aeroplanes.

9.2 Although the installation of transponders in microlight aircraft is some 10% overall, these seem to be concentrated at the heavier, 3-axis end of the microlight spectrum with 53% of such aircraft equipped at this event. This is similar to the aeroplane figure previously derived. Perhaps the separate classification of microlights and aeroplanes is less relevant when considering EC equipage analysis and policy.

9.3 Newer technologies (ADS-B, PAW and FLARM) are installed mainly in aircraft which already have Mode S suggesting the owners are motivated to embrace additional capabilities and those without Mode S are not. That motivation might come from a desire to become more conspicuous but could also come from a recognition that in the absence of a universal ATS, transponders do not prevent collisions between light aircraft which is their principle collision risk. The interaction between aircraft and systems is explored in paragraph 11.

9.4 The data collected at this event can be used to assess the number of installations of EC equipment in the UK GA Fleet. In particular, the light aircraft (<1500kg MTOM) correlation against the known 1090 MHz licencing data is good. An estimated fleetwide equipage for the 8208 GA aeroplanes <1500Kg MTOM on the UK register is at Figure 9.

Of the 8208 aeroplanes<1500Kg MTOM on the UK register it is estimated that:

- 29% have no EC device
- 71% have at least one EC device
    - 69% have transponders and 68% are Mode S
    - 16% have ADS-B Out/In;
      Of which 54% have SIL=0 and 46% SIL=>1
    - 20% have PilotAware with ADS-B In
    - 6% (maximum) have PowerFLARM with ADS-B In

Figure 9 – Estimated Fleetwide Light Aeroplane EC Equipage

The equipment distribution of microlights is less clear because of the substantial difference across the weight/configuration spectrum.

Within the glider fleet, the majority of cross-country gliders are known to have FLARM for safety and between 5 and 10% have Mode S. Gliders were not present at this event.

Balloons were not present at this event.

In 2018 the rotorcraft fleet had 76% transponder equipage which is consistent with the 83% found at the event. Extrapolation of this to other technologies in the 1602 rotorcraft (1248 helicopters and 354 Gyroplanes) on the UK register is in Figure 10; note the overlap with multiple technologies installed.

Of the 1602 rotorcraft on the UK register (all helicopters and gyros) it is estimated that:

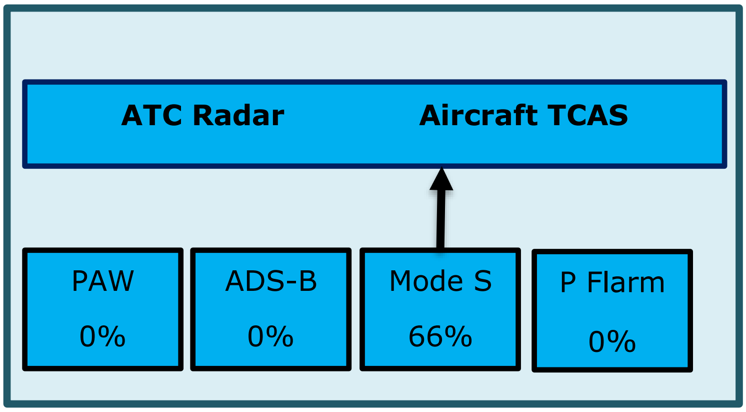
- 12% have no EC device
- 88% have at least one EC device:
  - 66% have transponders, all Mode S.
  - 17% have ADS-B Out/In
  - 25% have PAW with ADS-B In
  - 4% (maximum) have PowerFLARM with ADS-B In

Figure 10 – Estimated Fleetwide Rotorcraft EC Equipage

10 Operational Capability

10.1 The object of this section is to assess the operational effect of the current distribution of EC technologies based on the equipage rates set out above. The interoperability of the technologies and the equipments that provide them is complex. Interoperability can have 3 states; A-B, B-A or both, so variations on the phrase "see and be seen" are used to differentiate the capability. Because many aircraft have multiple systems the aircraft numbers that follow have been adjusted to avoid double counting of capability; in each paragraph below the subject system is counted in full and other systems which are fitted to the same aircraft are discounted.

10.1.1 Mode S. Mode S, carried in 66% of GA aircraft, can be seen by ATS radar and CAT aircraft TCAS systems but not directly by other GA aircraft or airfields. In the absence of a radar-based FIS it provides no indirect interoperability with other GA aircraft.



Some unregulated GA devices offer bearingless detection of transponders which includes an estimate of range and data-sourced altitude difference provided the target aircraft is being interrogated by a secondary radar or TCAS. That function is not included as "can be seen by" for the purposes of this report but it does provide some benefit to the user. Some PAW ground stations offer rebroadcast of MLAT Mode S tracks but that is also not included in this assessment

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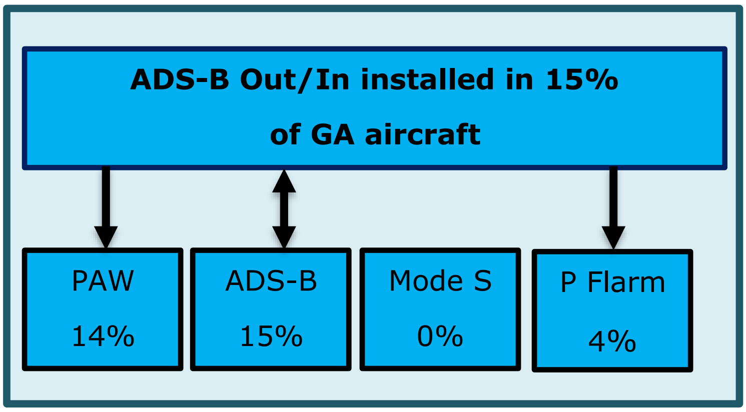
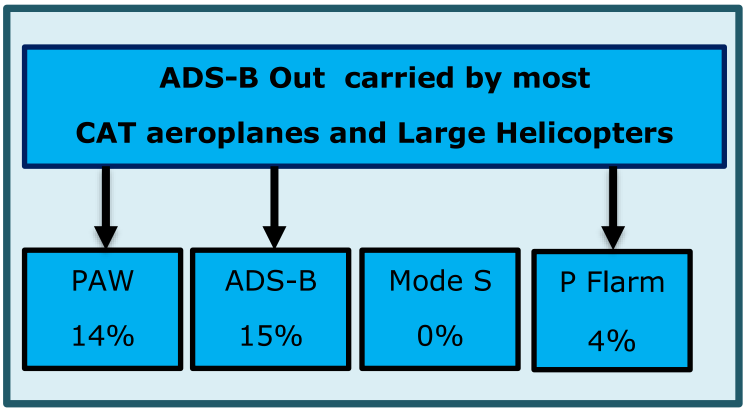
although it can provide some benefit to GA airfields and to PAW equipped aircraft flying in the vicinity.

10.1.2 ADS-B within GA. ADS-B Out/In, carried in 15% of GA aircraft, can see and be seen within that cohort and can be seen by other GA aircraft equipped with PAW, PowerFLARM or other devices that include an ADS-B In function. An additional 18% of aircraft have such devices so an aircraft with ADS-B Out can be seen by a total of some 33% of GA aircraft.



10.1.3 ADS-B beyond GA. GA aircraft implement ADS-B In through a range of devices, mainly discrete ADS-B devices or using the functionality in PAW or PowerFLARM devices. This enables 33% of GA aircraft to see most CAT aeroplanes and large civil helicopters



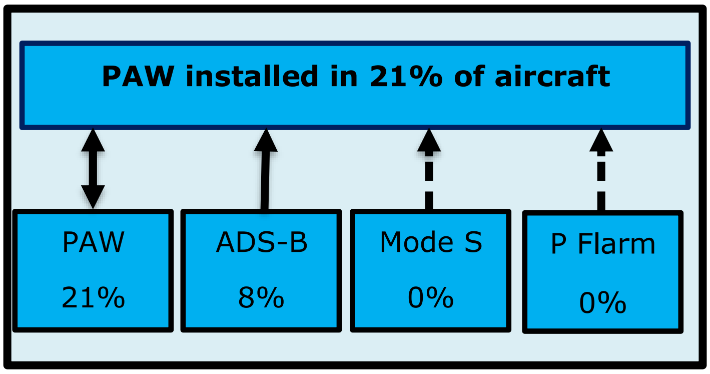
ADS-B Out, carried in 15% of GA aircraft, cannot be seen by ATS radars nor the majority of CAT TCAS systems. ATS radar systems do not normally implement ADS-B In and although some TCAS systems do implement ADS-B In they do not interoperate with systems with a SIL=0. It was possible to record the SIL of 113 (85%) of GA ADS-B aircraft systems at the event but because ADS-B has been taken up more quickly in aircraft with a permit to fly than those with a CofA, the results across those fleets are different:

> 25% of CofA aircraft and 66% of PtF aircraft had a SIL=0
>
> 75% of CofA aircraft and 34% of Ptf Aircraft had SIL>0

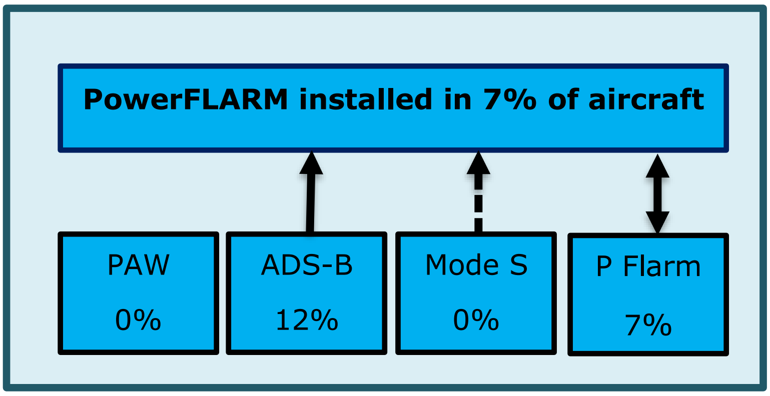
It should be said that the issue of SIL=0 is only relevant to ADS-B implementation through Mode S transponders but not through portable ADS-B devices which are unaffected by the aircraft status and generally have a SIL>0.

Of note, 94% of the current deployment of ADS-B devices today is in aircraft which already have Mode S which itself can be seen by ATS radars and TCAS; the principle advantage from the ADS-B installations accrues to interoperability within GA.

10.1.4 PAW. PAW, carried in 21% of GA aircraft, can see and be seen within that cohort. Because PAW devices provide ADS-B In they can also see ADS-B Out aircraft which do not have PAW (8%) providing a total of some 29% of GA aircraft that can be seen. PAW devices also have a bearingless Mode C and S detection function which is described in 10.1.1 above. Some PAW ground stations offer a FLARM relay uplink but the numbers and coverage are not known. Some PAW ground stations also offer an unregulated Mode S MLAT rebroadcast service. PAW is not interoperable with ATS radar and TCAS functions but is processed and distributed by a wide network of unregulated ground stations; there are 165 PAW ground relay stations and some 1000 other ground stations processing and distributing Mode S traffic and other data.



10.1.5 FLARM. FLARM, carried in 7% of GA aircraft, can see and be seen within that cohort and with the majority of the 2200 gliders. Because PowerFLARM devices provide ADS-B In they can also see ADS-B Out aircraft which do not have FLARM (12%) providing a total interoperability of 19% not including gliders. PowerFLARM devices also have a bearingless transponders detection function which is listed in 10.1.1 above. FLARM is not interoperable with ATS radar and TCAS functions but is processed and distributed by a wide network of unregulated ground stations as set out in 10.1.4 above.



10.2 The A4A report into collision risk[2] demonstrated that 85% of the collision risk to light aircraft is from other light aircraft and 57% of that risk occurs at or near an airfield. Disregarding other factors, if we assume that interoperable EC mitigates that risk, the equipage figures derived in this report can be used to assess its operational effectiveness.

[2] Mid-Air Collisions: An Evidence-Based Analysis of Risk – 1975 to 2018 dated 24 Apr 2019

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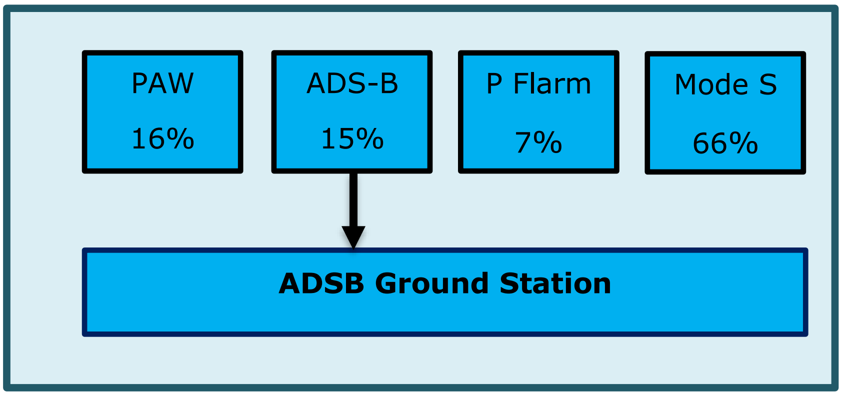
10.3 Interoperability with Ground Stations – Other ATS and AGCS Units. The A4A ADS-B trials run during 2019 suggest there is an effective low-cost role for other ATS and AGCS units in the EC equation. Currently, 15% of all GA aircraft (not including gliders or balloons) could be detected by an ADS-B ground station. Were a ground station able to display PAW and FLARM tracks, it would be able to detect 34% of all GA aircraft. If it were also able to display transponder tracks, it would be able to detect 72% of all GA aircraft.



10.4 Scope of Results. Nothing is perfect. None of the above assessments take account of factors such as display and warning system effectiveness, distraction and change in lookout effectiveness or range and screening effects. Nor do they take account of the requirement for an aircraft hub to concentrate inputs and coordinate warnings. The practical limits of effective installation have not been considered. Organisational and institutional issues have also not been included in this review. These need separate consideration to complete the EC environment picture.

10.4.1 From the viewpoint of a pilot searching for other aircraft conflicts, a display of other aircraft tracks in the cockpit is compelling. However, regardless of the equipment fitted the figures above demonstrate that today, the number of interoperable aircraft that could possibly be displayed or warned would represent no more than one third of the potential collision risk and may be much less. Effective lookout for unalerted collision risks remains very important to safety.

11 Conclusion

11.1 EC Equipment Deployment.

11.1.1 Data collected during the LAA Rally 2019 created a snapshot of the EC equipage in the major part of the UK GA aircraft sector. 29% of aircraft had no EC device and 71% had one or more EC Systems. The transponder distribution recorded correlates closely with the UK aircraft register and licensing database suggesting that these results are indicative of EC distribution in the GA sector.

11.1.2 Mode S. Mode S transponders are the dominant system with 66% of aircraft equipped. Out of the aircraft that carried EC, only 4% had an unregulated equipment (PAW and/or FLARM) as its sole system and less than 1% had ADS-B alone. The overwhelming majority of installations were either:

- Mode S as the sole system (58%)
- Mode S with ADS-B either alone or with PAW or FLARM (22%)
- Mode S with PAW or FLARM (13%)

11.1.3 ADS-B. ADS-B out was fitted to 15% of aircraft, most commonly in conjunction with Mode S (95%). Less than 1% of non-Mode S aircraft had ADS-B. Of the ADS-B installations, 56% had a SIL of zero so would not be interoperable with ATC radars or TCAS systems.

11.1.4 PAW. PAW was fitted to 21% of aircraft, most commonly in conjunction with Mode S (85%). It was commonly fitted as the ADS-B In element of an installation using ADS-B Out though a transponder. Because PAW does not include ADS-B Out it is not included in the ADS-B figures in para 11.1.3 but it does contribute to interoperability through ADS-B In.

11.1.5 FLARM. FLARM is designed to improve glider safety but PowerFLARM includes ADS-B In and a bearingless transponder detection. It was fitted to 7% of aircraft most commonly in conjunction with Mode S. Because FLARM does not include ADS-B Out it is not included in the ADS-B figures in para 11.1.3 but it does contribute to ADS-B interoperability.

11.2 EC Interoperability

11.2.1 Mode S. Whilst Mode S can be seen by ATC radar and aircraft TCAS systems it does not independently interoperate with other GA aircraft or ground systems. At 66% it remains the dominant EC system. PAW and PowerFLARM offer bearingless transponder detection and some unregulated ground stations offer rebroadcast of MLAT. Neither system is assessed in this report.

11.2.2 ADS-B. The 15% of aircraft with ADS-B Out can see and be seen by each other and seen by a total of 18% of other aircraft with PAW and PowerFLARM, the latter 2 having an ADS-B In capability; a total GA interoperability of 33%. In addition, these 33% of aircraft can see ADS-B Out broadcast by most CAT aircraft and commercial helicopters providing significant further interoperability.

11.2.3 PAW. The 21% of aircraft with PAW can see and be seen by each other and can see 8% of other aircraft with ADS-B Out; a total interoperability of 29%.

11.2.4 FLARM. The 7% of aircraft with PowerFLARM can see and be seen by each other and with most cross-country gliders and can see 12% of other aircraft with ADS-B Out; a total interoperability of 19% of aircraft plus most gliders.

12 Observations and Recommendations

12.1 Diversity of Systems. Although the systems discussed use different frequencies and technologies, the inclusion of, for example, an ADS-B In function within PAW and PowerFLARM, is powerful in increasing overall interoperability. With only 15% of aircraft fitted with ADSB Out, the other devices increase GA ADS-B interoperability to 33% plus a large (and unquantified) ADS-B In interoperability with CAT aeroplanes and large helicopters helping to redress the very limited GA interoperability with transponders.

12.2 Unregulated Development. EC systems also provide innovation platforms for the development of features and facilities. It is apparent that this development is proceeding apace and whilst it may not follow the norms of the regulated sector it is there to be exploited.

12.3 ADS-B Out Ground Stations. Even though trials have demonstrated the utility of ADS-B ground stations in AFIS and AGS situations, the relatively low incidence of ADS-B Out in GA aircraft (15%) today is probably too low to enable an effective AFIS. Other technologies used between aircraft more than double interoperability but they are not approved for ground station use.

12.4 SIL Level. The regulation related to SIL=0 is out of step with modern equipment which is accurate and reliable with a low MTBF. This regulation is breaking the interoperability link between TCAS and the many aircraft that use ADS-B Out via a Mode S transponder. This would reduce future interoperability and potentially reduce air safety.

12.5 System Effectiveness. An aircraft equipped with all 4 of the EC systems mentioned in this paper, has interoperability with almost all CAT aircraft but only a third of GA aircraft. As the GA risk of collision is almost entirely with other GA aircraft[3], the pilot needs to maintain an effective lookout although the displays of traffic are compelling and can suggest a complete picture. It is possible that attention to EC displays may reduce lookout and increase risk.

12.6 ADS-B Loss of Signal. During the recent ADS-B trial at Manchester Barton, range and loss of signal during manoeuvre were cited as issues[4] for portable devices. Whilst it was hoped that this event would provide data to investigate these it did not. Data collection used multiple sensors whereas a single point receiver is needed to record loss of signal and range/aspect. A4A now has the capability to collect and analyse this data using existing national EC infrastructure subject to future funding.

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[3] Mid-Air Collisions: An Evidence-Based Analysis of Risk – 1975 to 2018 dated 24 Apr 2019
[4] Airspace4All GA Airfield ATS ADS-B Traffic Display Trial Report 30 Sep 2019