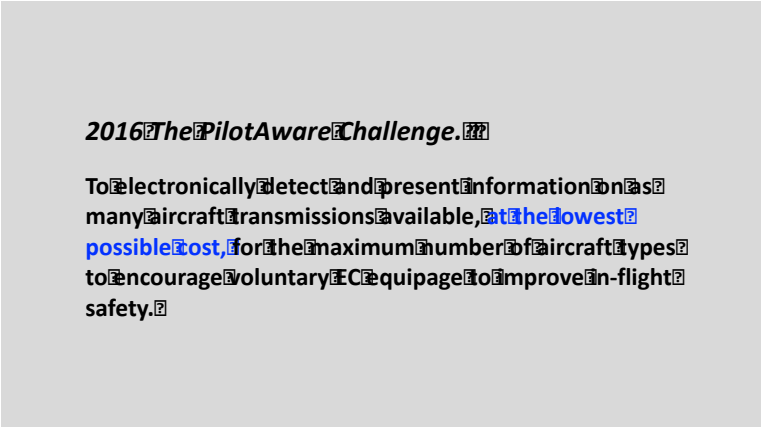
PILOTAWARE HOW IT WORKS, ITS BENEFITS AND LIMITATIONS.

Introduction.

Since 2016 PilotAware has been building equipment to meet the PilotAware Challenge



The transmissions that are available to be detected in the UK are;

1. Mode-C bearingless target transmissions at 1090MHz
2. Mode-S bearingless target transmissions at 1090MHz
3. ADSB targets with a GPS bearing, transmissions at 1090MHz
4. Flarm targets with a GPS bearing transmissions, at 868MHz (Encrypted)
5. PilotAware targets with a GPS bearing transmissions, at 869.5MHz.

The PilotAware philosophy is to detect and provide as much information as possible to the Pilot-in-Charge who can then ***volunteer*** to use this information or not, to augment their vital visual scan to improve situational awareness and to minimise the possibility of a mid-air collision. It is imperative, therefore, that the user fully understands the benefits and limitations of the methods that PilotAware uses to detect the various systems described above and the information provided so that **an informed decision can be made whether to use PilotAware or not.**

Bearingless Targets

To understand electronic conspicuity, it is necessary to fully understand what a bearingless target means in this context! For clarity, the bearing of a contact can not only be defined as the angle of the contact relative to your position, measured clockwise from the vertical direction, but also can include the distance that it is away from you.

It is also very important to understand the difference between *bearingless targets* and a target with electronic conspicuity equipment which also emits a GPS location signal that

can then be used to detect the exact latitude and longitude location of the target and hence calculate its bearing.

Older technologies such as Mode-C and Mode-S do not have an inbuilt GPS and are therefore naturally bearingless targets.

However, Mode-C and Mode-S transponders do transmit their altitude derived from an on-board barometric encoder. This is detected and used by PilotAware. In addition, PilotAware can also determine the *rate of change* of the power emitted from an individual Mode-S or Mode-C transponder. These two pieces of information allow PilotAware to inform the user of the height separation (+/-) between it and the target and its approximate distance based on the power received and the sensitivity that has been set by the user in PilotAware. The information provided from a Mode-C or Mode-S transponder does not allow PilotAware, or any other comparable system, to directly determine the bearing the aircraft in which it is fitted.

Therefore, when a bearingless target is detected, PilotAware will provide you with a height separation and an approximate distance only. The accuracy of the barometer in a Mode-C or a Mode-S transponder is usually +/- 100ft.

This means that the information available, from bearingless targets, for visual and voice alerts, provided either by PilotAware or external Flight bags, excludes GPS co-ordinates and therefore the exact bearing of the target aircraft cannot be shown on a screen or announced in a voice alert. This is the same for any comparable electronic conspicuity equipment providing information from bearingless targets.

However, this deficiency is catered for by PilotAware and the Flight Bag manufacturers by providing a visual and/or voice alert which describes the available information in the best way that they feel is appropriate for their product.

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Targets with a Bearing.

All modern systems such as PilotAware, Flarm and ADSB continuously broadcast the latitude and longitude of the host aircraft using onboard GPS units. PilotAware and ADSB do not encrypt their transmission so their location can be received by anyone with a suitable receiver. Flarm transmissions are encrypted air to air so that only other Flarm receivers can pick up these transmissions.

How PilotAware Works.

PilotAware interacts with 2 frequencies, using 2 separate antennas.

a) PilotAware **transmits and receives (Tx/Rx)** on the open, regulated but unlicensed frequency **869.5MHz** which uses FSK modulation.
b) PilotAware **receives (Rx)** on the regulated aviation Frequency **1090MHz** which uses an older modulation technique called pulse position modulation.

Direct Transmission and Reception

1. PilotAware directly transmits and receives to and from all other PilotAware users on 869.5MHz. This is a direct link, so you will see and be seen by other PilotAware users. **PilotAware broadcasts as a target with a bearing** provided by its onboard GPS. The design specification for a correctly installed PilotAware unit gives a 20Kms range air to air.

2. PilotAware directly receives the locations of all in range ADSB-out transmissions. The design specification for a correctly installed PilotAware unit is to receive ADSB transmissions at up to 50Kms. However, this is often exceeded. This is a direct link, receive only. The ADSB equipped aircraft received will NOT see you. **PilotAware and ADSB both present themselves as targets with a Bearing.**

3. PilotAware directly receives information from Mode-C and Mode-S transmissions. The design specification for a correctly installed PilotAware unit to detect Mode-C and Mode-S signals is 50Kms. However, this is often

exceeded. This is a direct link, receive only. The Mode-C and Mode-S equipped aircraft will not see you. **Mode-C and Mode-S are Bearingless targets.**

This, therefore, is the basic functionality of PilotAware using Direct Transmission and Reception.

1. **PilotAware and PilotAware units**
   THEY WILL SEE YOU AND YOU WILL SEE THEM.

2. **PilotAware and ADSB-out units**
   YOU WILL SEE THEM **THEY WILL NOT SEE YOU**

3. **PilotAware and Mode-C/S units.** **Bearing-less targets**
   YOU WILL SEE THEM **THEY WILL NOT SEE YOU**

When using the basic functions of PilotAware using Direct Transmission and Reception you must ensure that you understand how they work, their limitations and also to be comfortable when using them. This means that you must;

1. Accept that PilotAware must only be used as a secondary aid and that your continuous visual scan must be maintained as your primary source of data for situational awareness at all times.
2. Understand that PilotAware may fail at any time for many reasons.
3. Understand the difference between bearingless targets and those with a bearing so that you can use the information provided correctly, from whatever source you choose.
4. Understand that when using PilotAware, you will have the advantage of seeing ADSB, Mode-S and Mode-C targets directly**, but they will not see you**. (Unless of course, they have PilotAware Installed.)
5. Understand how PilotAware differentiates between bearingless targets and targets with a bearing in its voice and visual alerts. This is available on page 29 of the PilotAware Operating Instructions available here.
6. Understand how your chosen Electronic Flight Bag differentiates between bearingless targets and targets with a bearing in its voice and visual alerts. This is available from your chosen Electronic Flight Bag Operating Instructions.

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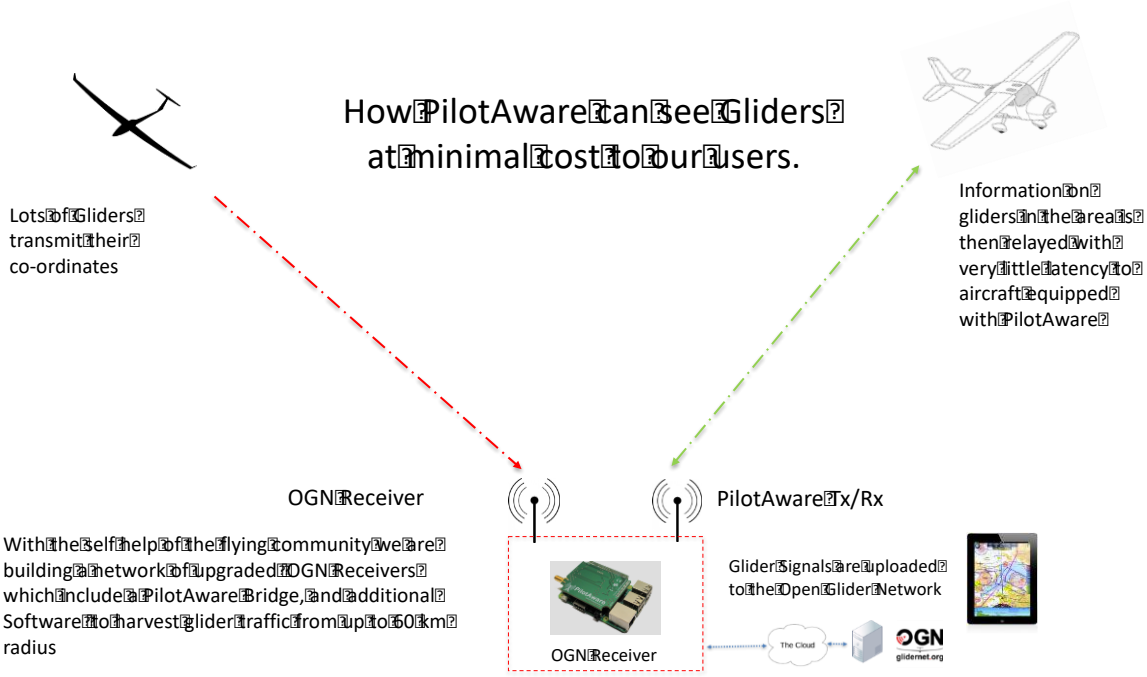
Reception of FLARM™ equipped aircraft

PilotAware cannot directly detect, see or be seen by Flarm™ equipped aircraft. This is for the following reasons:

1. Although Flarm™ is on an open frequency, it is on a different frequency to PilotAware.
2. Flarm™ is an encrypted solution that contains anti-collision algorithms not directly available to PilotAware
3. Flarm™ requires a separate license.

However, PilotAware uses the GPS co-ordinates of Flarm™ equipped aircraft available from modified receivers on the Open Glider Network and rebroadcasts their positions in real-time to PilotAware equipped aircraft. 150+ OGN base stations have been upgraded or newly installed as OGN-R (Rebroadcast) Ground-Based Stations. These are mainly in the UK although there is a growing number in Europe. This can be thought of as **Indirect Transmission and Reception**

The diagram below shows how PilotAware uses the OGN-R Ground-Based Stations to detect and rebroadcast Flarm™ equipped aircraft.



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PilotAware Indirect Transmission and Reception.

Things you should know about PilotAware Indirect Transmission and Reception.

1. Indirect transmission and reception is provided by a link between the OGN-R Ground-Based Station or Stations and your onboard PilotAware unit. It is a two-way transmission link on 869.5MHz within the regulated but unlicensed ISM band.
2. You must be within 15-30kms range of an OGN-R Ground-Based Station or Stations, to be able to communicate when airborne.
3. You must have the latest software installed (available at no additional price to licensed users) to receive any or all of the services provided by the OGN-R Ground-Based Station.
4. OGN-R Ground-Based Stations are built, maintained and operated by volunteers.
5. OGN-R Ground-Based Stations may periodically be down and unavailable due to maintenance, power failure or other engineering difficulties.
6. Whilst OGN-R Ground-Based Stations meet OFCOM broadcast standards they do not operate to an aviation standard. If it were necessary for them to meet aviation standards they would probably not exist at all, due to cost and difficulty of meeting the functionality required using aviation frequencies.
7. In some parts of the UK, you will be in range of up to 6 OGN-R Ground-Based Stations simultaneously.
8. In other parts of the UK, you will not be in range of any OGN-R Ground-Based Stations until they are installed by voluntary local patronage.
9. The target is to have 200 installed for the 2020 flying season.

When using PilotAware to see Flarm equipped aircraft you must be aware that:

1. You are not seeing Flarm equipped aircraft directly, air to air, but via an OGN-R Ground-Based Station uplink.
2. You must be in the range of an OGN-R Ground-Based Station.
3. To see the current UK coverage please visit the following site. Insert PW% in the search box and zoom in.
4. Reception of Flarm traffic
   YOU WILL SEE THEM **THEY WILL NOT SEE YOU**
5. You will NOT receive any Flarm™ derived collision avoidance information.
6. PilotAware will treat Flarm detected traffic similarly to other targets with a bearing for visual and audio warnings.
7. Not all gliders are equipped with Flarm.

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Mode-S/3D.

From June 2019, access to participate in the PilotAware trial of Mode-S/3D was included in the latest software, as a Beta function only, for use by advanced, experienced users. **This is a selectable item in software release 20190620 and must be enabled, only after understanding its operation, fidelity and limitations and you have decided that you are happy and prepared to accept its use in the extended trial.**

How Mode-S/3D works is explained here

https://pilotaware.com/Documents/Mode-S3D-Introduction-FINAL.pdf?_t=1561197743

The accuracy and limitations of PilotAware Mode-S/3D are explained here

https://pilotaware.com/modes3d-preliminary-trial-findings/

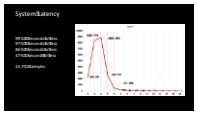
The results of the initial trial are shown below

Latency

A typical MLAT data journey introduces the following latency.

1.	Mode-S transmission to MLAT base station	Negligible (speed of light)
2.	MLAT station to server	Hundreds of milliseconds to 3 seconds
3.	Server Resolution	milliseconds (thousands of a second)
4.	Server to OGN-R station	Hundreds of milliseconds to 3 seconds
5.	OGN-R interrogation response	milliseconds (thousands of a second)
6.	PilotAware to OGN-R	Negligible (speed of light)
7.	PilotAware processing	milliseconds (thousands of a second)

61% is within 2 seconds
86% is within 3 seconds
96% is within 4 seconds
99% is within 5 seconds



Refresh Rate

The refresh rate is the time between the transmission of MLAT data for Unique aircraft.

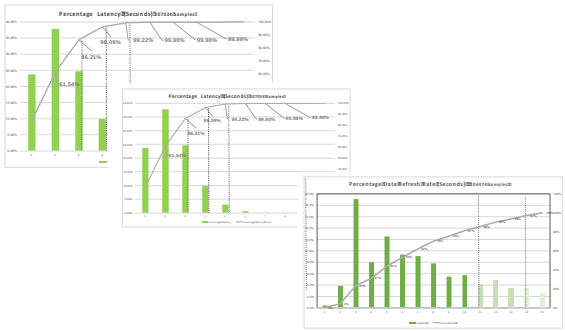
The following graph shows the % refresh rates of 104,474 samples.

53% of signals were refreshed within 6 seconds
81% of signals were refreshed within 10 seconds

Accuracy

17% have an error < 0.06 NM that is 111 M (length of a football pitch)
65% have an error < 0.12 NM that is 222 M (length of 2 football pitches)
86% have an error < 0.19 NM that is 351 M (length of 3 football pitches)
94% have an error < 0.25 NM that is 463 M (length of 4 football pitches)
97% have an error < 0.31 NM that is 574 M (length of 5 football pitches)
98% have an error < 0.37 NM that is 685 M (length of 6 football pitches)
99% have an error < 0.43 NM that is 796 M (length of 7 football pitches)

As a reference compare this error with the length of your landing strip. It compares very favourably with Bidford Gliding Club at 800M and Turweston at 1256M. Most landing strips will be at least 500M which fall into the distance comparison for the less than 97% error band.



The Limitations of Mode-S/3D are as follows.

1. OGN-R Ground-Based Stations are built, maintained and operated by volunteers.
2. The coverage of OGN-R Ground-Based Stations is good and growing but it is not universal
3. OGN-R Ground-Based Stations may periodically be down and unavailable due to maintenance, power failure or other engineering difficulties.

4. Whilst OGN-R Ground-Based Station meet OFCOM broadcast standards they do not operate to an aviation standard.
5. The Multilateration Data provided by 360RADAR is derived from base stations that are built, maintained and operated by volunteers.
6. The coverage of 360RADAR is good and growing but it is not universal.
7. 360RADAR Ground-Based Stations may periodically be down and unavailable due to maintenance, power failure or other engineering difficulties.

Mode-S/3D and Electronic Flight Bags.

As can be seen from the information above Mode-S/3D is an innovative way of augmenting directly received Mode-S targets with MLAT derived latitude and longitude information. This then enables the natural bearingless target to be converted to a target with a bearing.

The information provided has an element of delay and inaccuracy that is visually shown via the provision of an area of ambiguity plotted around each aircraft that is detected and enhanced with Mode-S/3D. This is shown on the Virtual RADAR Screen provided with PilotAware. An example is shown below.

As described in the document above the size of the ambiguity grows with age and the speed of the target aircraft. When used the amount of aircraft detected is significantly greater when using Mode-S/3D as a significant amount of the UK GA fleet is equipped with a Mode-S transponder. Information on the ambiguity is also passed to the Electronic Flight Bag manufacturers so that they can draw the circle of ambiguity around detected aircraft that are plotted on their screen. This is an example from an EFB.

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This is what it looks like on Easy VFR

In the Internationally agreed GDL90 specification each traffic report can contain information in a NACp (Navigational Accuracy) field to indicate the potential ambiguity/error of each position report.

These actually appear in bounding circles, as defined and catered for in a full implementation of the specification.

This can be seen here in the Easy VFR implementation.

Now we know the whereabouts of those elusive Mode-S targets! 6000+ of them in the UK.

SkyDemon

On the SkyDemon EFB, the information to produce the circle of ambiguity provided by PilotAware is not currently being implemented. PilotAware and SkyDemon are both willing to work to provide a solution for this. However, in the meantime we understand that the next version of SkyDemon, due to be released in November, will contain the following advice before connecting to PilotAware as a third-party device.

This device [PilotAware] *contains a feature where certain aircraft positions* [Mode-S/3D] *are estimated rather than known. Therefore, any guidance SkyDemon gives you on the relative positions of aircraft may not be correct*. [Words in brackets included by PilotAware for clarity]
Would you like to continue using this device?

Consequently, the Advice from PilotAware is also NOT to use SkyDemon for situational awareness when using Mode-S/3D as the circle of ambiguity will not be shown. Please use PilotAware RADAR or an alternative EFB that displays the circle of ambiguity until a solution has been found. This does not apply when using PilotAware with Mode-S/3D disabled.

Summary.

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The PilotAware challenge remains and we are committed to increasing interoperability between systems.

Greater Interoperability

PilotAware is an open system and is working with the providers of other technologies to increase interoperability in **both directions.** We encourage PilotAware users to integrate with their current systems if they have them. This then uses PilotAware to pull together all the technologies for greater interoperability.

The following section shows how this can be done.

ADSB-out

ADSB-out can be achieved by connecting PilotAware to a Mode-S Transponder such as Trig or Funke equipped with Extended Squitter and we encourage everyone who has such a transponder to do this to further increase interoperability.

This will mean that

ADSB-out YOU WILL SEE THEM **THEY WILL SEE YOU!**

This will cost less than £25 and the instructions on how to do this are available here.

https://pilotaware.com/wp-content/uploads/2018/08/Connecting-to-external-devices.pdf

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Flarm™

Similarly, if you have Flarm™ equipment installed you can also integrate this with PilotAware. We encourage everyone who has Flarm™ installed to do this to further increase interoperability.

This will mean that

Flarm™ YOU WILL SEE THEM **THEY WILL SEE YOU!**

This will cost less than £25 and the instructions on how to do this are available here.

https://pilotaware.com/Documents/FLARM-IN%20via%20LX%20Nav%20FlarmMouse.pdf?_t=1536411663

If you do both of these then you will the maximum interoperability between systems possible.

We hope that this paper has helped you understand the benefits and limitations of using PilotAware in your aircraft. What can be seen when and who can or cannot see you.

The following chart has been produced for a quick reminder.

This can be downloaded and laminated and kept in your aircraft as an aide memoir of the PilotAware functionality.

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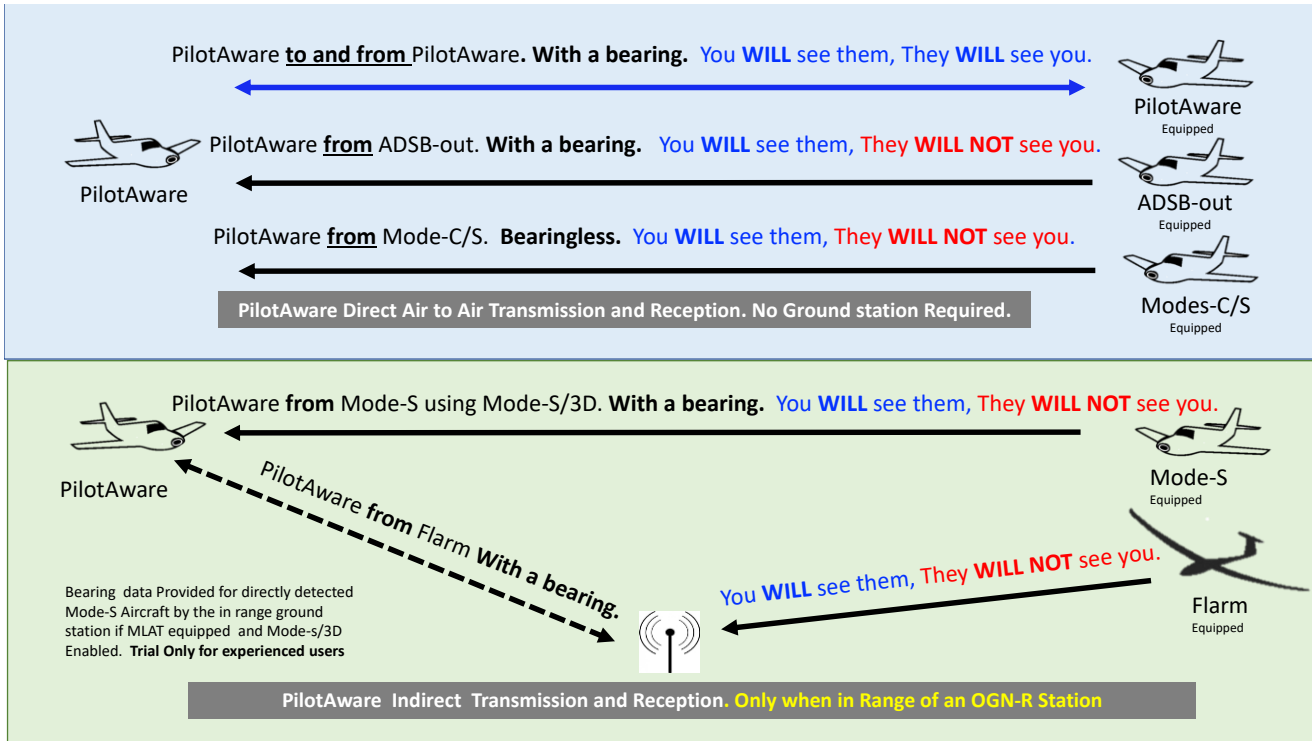
PilotAware Functionality Chart



PilotAware October 2019.