The PilotAware Mode-S/3D October 2020

Introduction

PilotAware Mode-S/3D is unique to PilotAware users. No other EC product has this facility – at any price.

Mode-S/3D uses the network of PilotAware ATOM GRID ground based stations and multilateration to supply the latitude and longitude of local aircraft transmitting a Mode-S signal. This means that Mode-S transmitting aircraft can then be plotted on an in-flight screen. This is Big News because the majority of powered GA aircraft in UK and Europe are equipped with Mode-S transponders allowing PilotAware users to detect them.

If want to see a video on how the ATOM GRID works then please see the videos we have posted on You tube. Search for ATOM GRID. Here is the one on Mode-S/3D

https://www.youtube.com/watch?v=wCjRKH3F_Wo&t=0s

When does a Mode-S transponder transmit its signal?

It comes as a surprise to many that a mode S transponder is **not transmitting all of the time.** In fact, unless it is interrogated by a secondary RADAR signal operating at 1030MHz a mode-S transponder is silent!

Let's remind ourselves about Primary RADAR

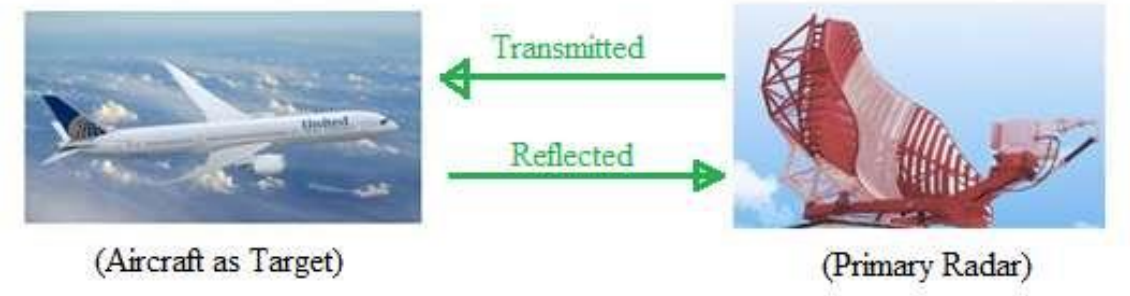


Figure-1 depicts the **primary radar** principle of operation. As shown, Primary Surveillance Radar (PSR) transmits electromagnetic signal energy towards the target aircraft. The aircraft acts as **a passive element** and reflects the EM energy back towards the primary radar antenna.

……..and Secondary RADAR

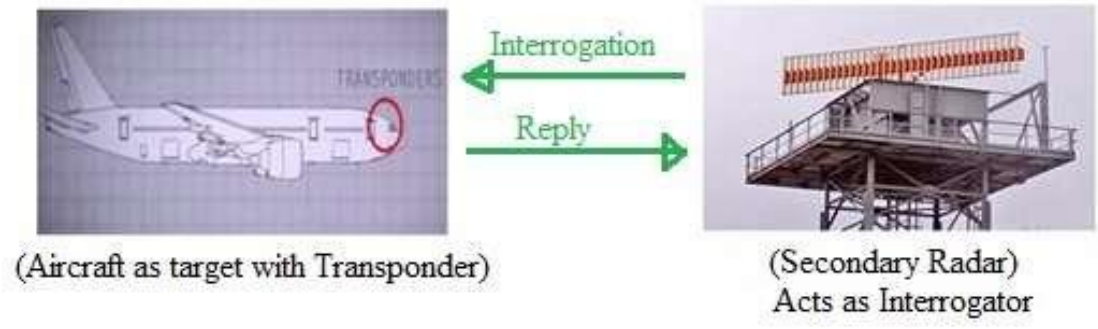
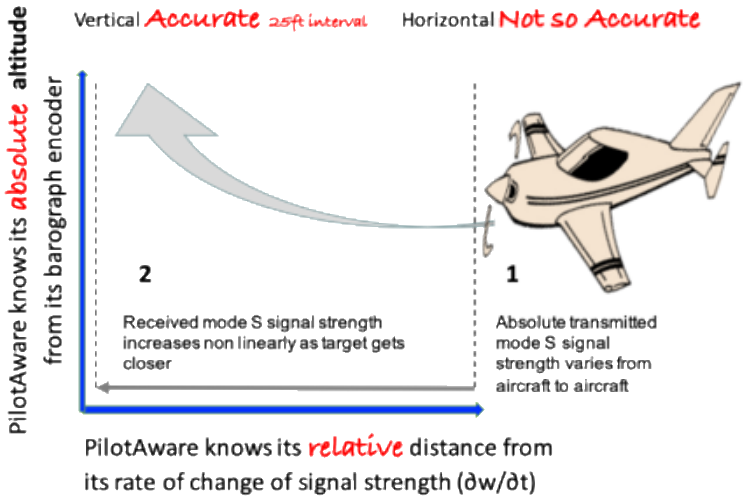


Figure-2 shows the **secondary radar** principle of operation. As shown, Secondary Surveillance Radar (SSR) transmits a signal at 1030MHz towards the target aircraft. The aircraft acts as an **active element** and its Mode-S transponder responds to this interrogation by transmitting a coded reply signal back at 1090MHz. The response contains information including its unique ICAO (Hex) Code and altitude data.

So, if the target aircraft is not interrogated by the Secondary RADAR, because it is out of range or very low IT WILL NOT TRANSMIT ANY ELECTRONIC CONSPICUITY signal. It is worth considering this if you expect to see a Mode-S signal but don't get one. For example, at a remote farm strip aircraft or shadow of a mountain, aircraft will not be interrogated until they are high enough for the SSR Radar to be within effective range.

Mode-S transmissions

When an aircraft is interrogated, its Mode-S transponder will respond with its unique ICAO code and its altitude relative to 1013.2mB, its signal strength is also measured at the receiver. Mode-S transponder signals are high power and will be easily picked up by PilotAware. The diagram below shows that on receipt of this signal, PilotAware captures the (i) altitude (within the accuracy of the aircraft altitude encoder) the (ii) unique ICAO identifier and (iii) the received signal strength.



Mode-S is a bearingless target.

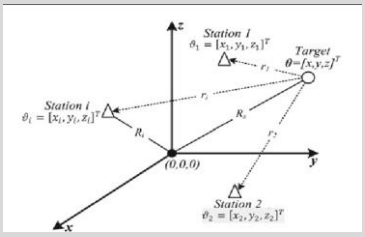
It is very important to note that in its standard form a Mode-S transmission contains no GPS co-ordinates. This means PilotAware can determine the target aircraft's vertical separation and its approximate distance, based on the rate of change of power, but it cannot inform the pilot of its relative bearing to the PilotAware equipped aircraft. Mode-S/3D provides this missing information.

Multilateration

The screenshot below shows how multilateration, sometimes called triangulation works

Introduction into Multilateration.

- Multilateration or MLAT is a technique used to determine the location of a transmission, when no positional data is transmitted.
- MLAT is achieved by using 3 or more receivers to calculate the position of an aircraft by the **accurately timed arrival** of the unique Mode-S broadcasts.



- This data is then sent to a central server, modified, and the result is used as a geographic co-ordinate.
- The position is sufficiently accurate, but the height is not so precise.

Multilateration Endorsement by SESAR

Multilateration is a very accurate technique and is recommended for use by the Single European Sky ATM Research organisation **SESAR**

SESAR Report Confirms the Power and Accuracy of Multilateration

2.2. Multilateration††
Multilateration is a surveillance technique based on the time difference of arrival of a radio signal at a number of geographically remote stations at known times. The ground infrastructure consists of a number of receiving stations that listen for replies to Mode A/C or Mode S interrogations, much like a Secondary Radar would. The system can also operate passively by intercepting broadcast transmission (ASD-B) or aircraft to aircraft transmissions (ACAS6).

Since an aircraft will be at different distances from each of the ground stations, their replies will be received by each station at fractionally different times allowing an aircraft's position to be precisely calculated provided that a sufficient number of receivers were able to detect and decode the reply simultaneously.

Multilateration requires no additional avionic equipment and no actions from pilots beyond what is required for legacy radar surveillance; in fact, the aircraft systems perceive the system no different than they would a regular MSSR.

†† https://ec.europa.eu/transport/sites/transport/files/20180515-sesar-ads-b-report.pdf **SESAR 15 May 2018**

Provision of MLAT Data

The multilateration data for Mode-S/3D is provided by 360 RADAR. The slide below shows how.

The network is growing so fast that there are now over 1100 stations providing the Multilateration data rather than the 830 shown in the slide below.

Over the last 3 years, Phil Lee pictured left, has developed the aircraft tracking site 360Radar.co.uk.
Over 830 receivers in the UK continuously track ADSB and Mode-S transponders.
The Network includes most of England, Wales, Scotland and Ireland.

For Mode-S only transmissions, the 360Radar MLAT servers calculate the aircraft position, if it is in sight of at least five 360Radar receivers.
The 360Radar Network gives good coverage, down to a few hundred feet above the surface in many places.††
360Radar shows all ADSB and MLAT transmissions including all private and military aircraft with an active Mode S transponder

†† https://360radar.co.uk

The PilotAware ATOM GRID Network

At 1st October 2020 220+ ATOM ground stations have been installed with a target of 300 by the end of 2021. These are used to ;

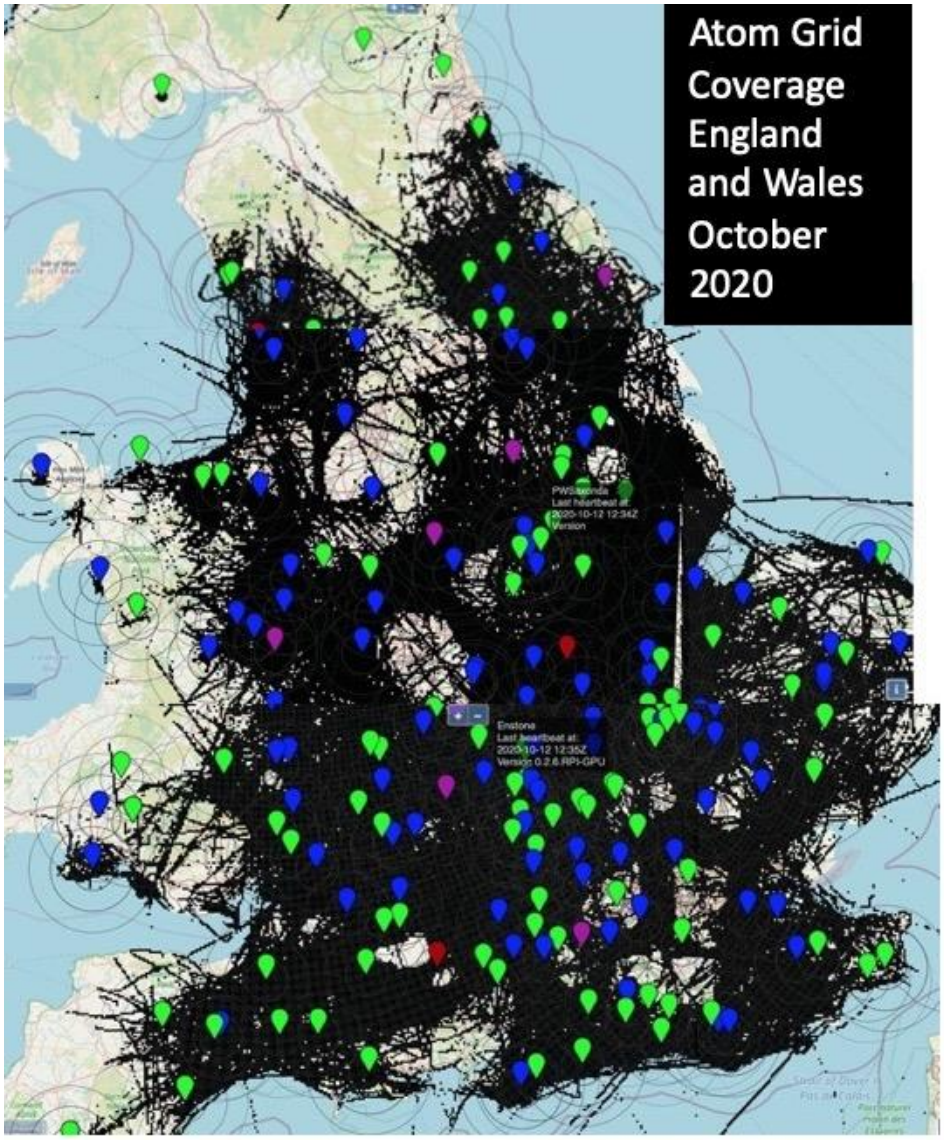
- uplink the locations of FLARM and Power FLARM equipped aircraft
- uplink the GPS co-ordinates of local Mode-S equipped aircraft
- uplink METARS to all in-range aircraft

PilotAware ATOM GRID and OGN Network Coverage

To see how the UK coverage is growing you can visit

https://ognrange.glidernet.org/#,max,d30,54.55037_2.09501,8.059999999999988,#000000ff:#000000ff,circles;

By typing in PW% you will be able to see the up to date coverage with the black shaded area being the availability heat map. The picture below shows England and Wales at October 2020.

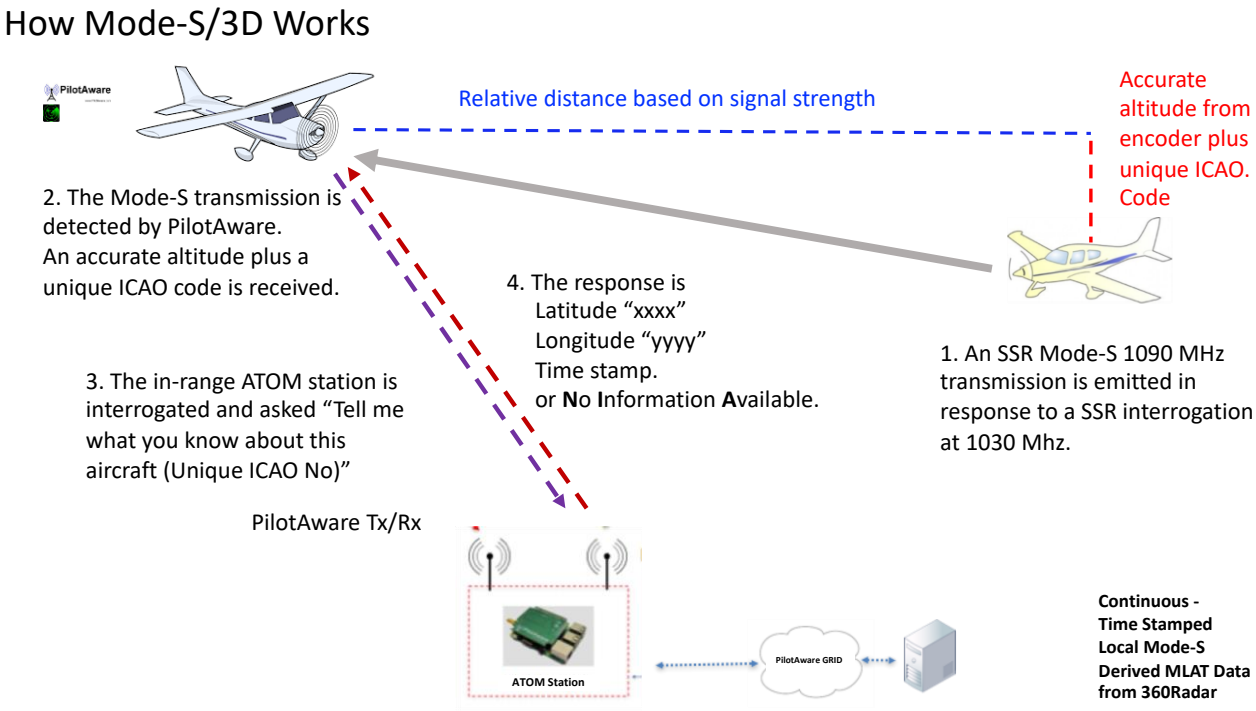


Detailed step through of the Mode-S/3D Operation

Mode-S/3D provides a huge step change in the number of aircraft that can be detected when PiotAware is used. It is important before use that you understand how the system works, its benefits and its limitations. This is explained by breaking down the process in the following manner.

1. All 220+ ATOM GRID stations are continuously fed with the MLAT data of all Mode-S aircraft captured within 50Kms.
2. This MLAT data is time stamped at the point of resolution by the server.
3. PilotAware equipped aircraft directly detect a unique Mode-S transmission(s) in the normal way.
4. This target information, is cross referenced using the unique ICAO code with the MLAT data provided by the ATOM GRID Station
5. There will be one of two possible results.
    a. The latitude and longitude are (x) and before (y) and the time stamp is (z)
    b. I know nothing about this aircraft
6. With this information, the following actions are taken;
    a. the position and height at time t=0 is plotted on the PilotAware RADAR screen or Electronic Flight Bag if the x, y coordinates are known
    b. the target aircraft is reported as a bearingless target as normal, providing height and a signal strength derived distance
7. Appropriate voice alerts will also be given.

This is represented below for clarity



What about the delay.

Whereas up-linking FLARM data from the ATOM station introduces negligible delay, MLAT is provided by the GRID using the internet to get the data from the MLAT Clients, to the MLAT Server, to the ATOM stations. This will introduce a delay or latency.

A typical MLAT 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 seconds
3. Server Resolution	milliseconds
4. Server to ATOM station	Hundreds of milliseconds to seconds
5. ATOM Interrogation response	milliseconds
6. PilotAware to ATOM	Negligible (speed of light)
7. PilotAware processing	milliseconds

How does the ATOM GRID handle the positional inaccuracies caused by the latency?
As you will recognise from this short explanation the data that is ultimately presented on the RADAR screen or EFB could be a few seconds old. To help you better visualise the importance of this we use the recognised concept of ambiguity circles, or degraded targets.

When the data is first received by PilotAware it will be from a few milliseconds to a second or so old. From a situational awareness position this is not important. However, as the data ages this could become a problem if the two aircraft are travelling fast, close together or on a reciprocal track.

The assist with this, the icon on the screen will be surrounded by an ambiguity circle the size of which will be determined by the speed of the target aircraft and the age of the data. The ambiguity circle shows as an area in which the target aircraft could be in any location, in practice it is most likely to be further along the original track projection.

With new data, this circle will be very small and will grow as the data ages. Hence the circle will grow until new data is received at which point the icon will jump and the ambiguity circle contract. The cycle will then continue until the target goes out of range, or is lost.

In tests, so far, these quantization jumps are very similar to those exhibited by ADSB, PilotAware, FLARM etc but just a little longer. In practice we have found that pilot adjustment to this is achieved very quickly but it depends on the individuals spatial awareness ability as to whether it is suitable for them.

This is what the ambiguity circles look like on PilotAware RADAR. One thing to note, is that the ambiguity circles are quantized at values defined by the NACp figure in the GDL90 specification. So, for example the specification defines a circle of 0.1nm, the next being 0.3nm. This means that if the calculated figure is 0.11nm, the actual ambiguity represented on the navigation device will be 0.3nm erring on the side of caution.

This is how Ambiguity circles are depicted on the PilotAware RADAR Screen.

This is what it looks like on an Electronic Flight Bag. In this case EasyVFR

Things to consider when using Mode-S 3D.

1. Read this introduction a few times to fully understand how Mode-S/3D works and what to expect.
2. Remember that you will not be given MLAT data on any aircraft that you are not directly picking up via PilotAware so make sure that your PilotAware unit has a good location in your aircraft.
3. If you are not within range of an OGN station Mode-S-3D will revert to reporting bearingless targets
4. Mode-S transponders may not receive an interrogation signal if they are low (below 500ft) so they will not transmit anything to detect.
5. You will need to have your EFB and PilotAware configured correctly. See separate instructions.

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