Transponders and Gliding

Good or evil? A summary of the 'pro's' and 'cons', without too much detail.

A bit of history.

Transponders, the airborne part of Secondary Surveillance Radar (SSR), were developed to enhance primary radar. Primary radar, which we all know from its impressive antennas seen rotating at airports (for approach control) or sometimes in the middle of the countryside (for long range surveillance), was developed during World War II. Strong pulses (in the order of a mega-Watt), bundled in a narrow beam, proved to be reflected by aircraft to give a weak, but sufficiently strong signal in the radar receiver, which is turned on immediately after each pulse has been transmitted and which obviously uses the same antenna 'to hear better'. The azimuth (geographical direction) of the antenna and the time interval between transmission of each pulse and the reception of the reflected energy determine the azimuth and distance of the aircraft. We are not surprised that this works well with Boeing 747's, but the metal and wiring in gliders often reflect enough energy to let the glider show on the radar screen as a 'blip' as well.
All this is fair enough, but there are two important things missing. One is the identity of the aircraft, the other is its altitude. During World War II, therefore, IFF (Identification Friend or Foe) was developed, later developed further for civil applications as SSR. A military version with special functions is still extensively used as IFF.

A bit of technique.

Primary radar is a passive system, because the weak reflections on the skin and other metal parts of the aircraft are detected on the ground. SSR transponders actively reply to interrogations with relatively strong pulses of up to 500 W. Apart from the information contained in the reply pulses, it will be clear that these relatively strong signals give a much better radar picture. In almost all modern radar systems, the primary and secondary radar returns are detected, combined and tracked in sophisticated algorithms, so that, for instance, also the heading can be derived and shown on the screen. Previously, the controller had to either ask the pilot for his heading or watch the afterglow of the blips on his screen.

Modes.

All interrogations are made on 1030 MHz, all replies on 1090 MHz. There are four ways of interrogating, called Modes. When interrogated in Mode A an aircraft is asked for his identity, when interrogated in Mode C he is asked for his altitude. The Modes B and D are not used. The civil Mode A coincides with the military Mode 3. That is why Mode A is often called Mode 3/A.
The replies are called Codes. The Mode A Code is set in the cockpit in four digits, the Mode C Code automatically transmits the altitude, with 1013.2 hPa as the reference pressure, just like in Flight Levels.
Coupling a dedicated Mode A Code to a flight plan allows the controller to see the callsign of a particular aircraft directly on his screen. Mode C does the same for him with the altitude. Together with the heading, derived from the tracking algorithm, we have now enormously improved the information available to the radar controller on his screen. This already explains why transponders without Mode C can no longer be accepted. We also begin to understand why controllers don't like to give clearances to aircraft (including gliders) that do not carry a transponder.
In motorised aircraft the altitude is usually derived from the altimeter (independent of the altimeter setting) or from a separate altitude coder, the so-called blind encoder. The Light Aviation SSR Transponder (LAST), which we will discuss later, has its own, built-in altitude coder.
There is now a new development, called Mode S.
The 'old' Mode A/C has a few problems. Because of the increasing commercial traffic (doubling in about 15 years) there is now a lack of Mode A codes. Also, the 1090 MHz reply frequency is becoming saturated, with two typical subsequent problems: garbling, which means that the reply pulse trains from more than one aircraft upon one interrogation may overlap, sometimes causing confusion, and 'fruit', replies received on the ground from transponders that were interrogated by other interrogators on the ground. The garbling problem has been amply shown during tests in France.
Mode S will solve this. In Mode S (S for selective) every aircraft has its own address - the so-called ICAO 24 bits address – so that every aircraft can be interrogated individually. When all aircraft are interrogated one after the other via their own address, there will be no 1090 MHz saturation problem any more and the code shortage, garbling and fruit problems will be over. In its Elementary Surveillance mode, which

applies to VFR flight, basically the real callsign (no longer a four digit code) will be transmitted, plus the altitude. In Enhanced Surveillance, for commercial traffic, a lot more data are transmitted. All this will improve the radar picture enormously again. It will be clear that Mode S is sensible and inevitable. It means a new generation of transponders, yes, and they will be more expensive, but not that much.
Mode S transponders automatically function like Mode A/C transponders when interrogated in Mode A/C, so Mode S transponders are 'backward compatible'. All in all, Mode A/C transponders will soon be outdated. They should no longer be bought.
The dates from which Mode S transponders are mandatory are published in national AIC's, but in general 31 March 2005 is the date for new installations. Existing Mode A/C transponders may in general be used until 31 March 2008. A Eurocontrol specimen AIC gives guidelines. Most national AIC's can be consulted on the various Civil Aviation Authority (CAA) websites. The Eurocontrol specimen AIC can be consulted on the Eurocontrol website, in the context of the Mode S programme.

ACAS.
Before we go on, another aspect must be mentioned: the Airborne Collision Avoidance System (ACAS). The American production version is called Traffic Collision Avoidance System (TCAS). The latest version is TCAS-7. Aircraft that are equipped with ACAS (most IFR flying/commercial aircraft) interrogate all aircraft with Mode A/C or Mode S transponders in their vicinity, deriving a picture from this and warnings when their own trajectory is in conflict with the trajectory of another aircraft. If found necessary, firstly a Traffic Advisory (TA) warning is generated. Secondly, and only if necessary, this is followed by a Resolution Advisory (RA), advising the pilot to climb or descend.
Although ACAS sometimes gives alarms unnecessarily, it has proven its worth as a back-up to Air Traffic Control. A typical example is an aircraft 1 that descends to FL 230 while aircraft 2, on an opposite heading, climbs to FL220, but overshoots that level. The pilot of aircraft 2 may react in time, but a warning here may save lives. A problem with ACAS shows when there is VFR traffic below a busy TMA. Aircraft in that TMA may well be cleared to descend to the lowest level of the TMA, below which there may well be VFR traffic. In practice, so many false alarms are triggered that sometimes the VFR traffic is asked to switch its transponders off.
ACAS also works with Mode A/C and even better with Mode S transponders. One can imagine that it is sensible to have VFR flying aircraft that fly in an environment with dense IFR traffic carry a transponder. This typically may happen in Class E airspace. What must be done then is to analyse where and when the IFR traffic density rises above an acceptable level. Our authorities seem reluctant to make such an analysis. The good old 'see-and-avoid' principle will do in the rest of the airspace concerned. It is questionable, to say the least, whether this should also apply to fast military jets.
ICAO Annex 6 states in 6.19: "All aeroplanes shall be equipped with a pressure-altitude reporting transponder which operates in accordance with the relevant provisions of Annex 10, volume IV." We note here that this refers to aeroplanes, not gliders. A note states: "This provision is intended to improve the effectiveness of air traffic services as well as airborne collision avoidance systems." That is fair enough, but far too general to let it apply to gliders in *all* Class E airspace, for instance. To do that, a good analysis of the situation is justified.

Are there transponders which are suitable for gliding?
That depends. There are several aspects, like size and cost. Especially for cases where there is only the usual 7 Ah battery and where little room is available. EUROCAE, the European organisation for airborne equipment, has laid down specifications for the Light Aviation SSR Transponder (LAST). The EGU has participated in the setting up of these specifications. Several firms are working on LAST's (Feb. 2004) and one firm, Filser, is marketing its TRT-600. It must be remembered that developing a transponder is one thing, having it certified to a Joint Technical Standard Order (JTSO) of the JAA (soon EASA) is another.
Details of the Becker, Dittel, Filser and Garrecht products can be found on their web sites.
The LAST is an ICAO-compliant Mode S transponder of a small size (usually with the standard 57 mm diameter front). The specifications allow three versions: a fully portable one, a version for cradle mounting where several gliders can have cradles and wiring for a limited number of transponders, as can be done with some VHF radios, and a version for fixed mounting.
The LAST also has a low power supply capacity warning system.
The cost of the LAST is in the order of EUR 2500, an antenna EUR 200, ex VAT. However, we must not forget the cost of installation, depreciation and especially the yearly or two-yearly technical check.

Technical checking is a special job with special equipment, which is not cheap. There are plans for so-called ramp test units which can be used by approved glider radio technicians. One ramp test could be used by specialists of several clubs. The firms which develop LAST's are aware of this problem. For the time being professional firms will have to be asked to do the checks on the spot or to do bench tests (with the transponder out of the glider) in their offices. In the latter case, usually a separate check of the wiring must still be done in the glider.
There are other aspects. First of all there is the question of the optimal positioning of the antenna. A transponder, like any transmitting/receiving device, only works properly with a well-placed antenna. That will normally be at the underside of the fuselage because of the 'visibility' for surveillance. The best place is supposed to be determined by the manufacturer of the glider and to be tested in the air, but up to now (Feb. 2004) only Glaser-Dirks provides antenna mounting instructions. Be aware that a transponder antenna, which is about 8 cm long (dependent on the type), may protrude far enough below the underside of the fuselage to be damaged when the fuselage is rolled into the trailer.
Then there is the question of the influence of radiation on the human body. The antenna will normally be one or two meters away from the body of the pilot(s). Experience shows that it is very unlikely that harm is done. Fortunately the *average* power which is transmitted is only a fraction of a Watt.
Last but not least, there is the problem of the power consumption. As long as Mode S is not universally used, the number of interrogations will remain high or even very high, depending on the number of radar stations on the ground. A high interrogation rate means a high reply rate, and thus a high power consumption. In the core area of Europe (Belgium, a part of England, a part of France, Germany, Luxembourg, the Netherlands and Switzerland) this will often be the case, resulting in a current drawn of up to 1A at 12V. It goes without saying that our batteries can't stand that for very long. The interrogation rate should go down drastically, however, after Mode S has been fully introduced (2008)?
Often solar panels are mentioned, and they can help, but they are unable to deliver 1A as yet. Also a really flush mounting is next to impossible, let alone when one considers types like the good old Ka-6.

Operational aspects.
We all know how the airspace, available to cross-country gliding and even to local flying if you happen to live in a bad spot, is closing in upon us. In short it can be said that priority is given to commercial traffic. The air forces are not even such a problem, because they want to continue to be allowed to fly relatively low and VFR.
A typical trend is the conversion of Class E airspace into Class D or even Class C airspace, 'to protect the IFR traffic better'. First of all we must query the sizes of the new, upgraded airspace. Next we must make sure that we can have access to all Class D and Class C airspace by asking for a clearance. If such a clearance is bluntly refused, which unfortunately happens, we must file complaints via our federations. We must understand, on the other hand, that an air traffic controller who is responsible for a fair amount of IFR traffic will only be able to give a clearance if we carry a transponder, and we must also understand that gliders are a difficult sort of VFR traffic. We rarely maintain a heading or an altitude.
Things become different when the controlled airspace concerned is limited in size. In that case we will be in that airspace for a limited amount of time, and normally on a well predictable path. As long as we are competent in our R/T there need not be any problem, and the transponder only needs to be switched on for an equally short time.
There are other possibilities. The German idea of the Transponder Mandatory Zone (TMZ) is a good compromise, for instance. No clearance is needed to cross a TMZ (so no R/T) as long as the transponder is active. This solution typically applies to less busy CTR's and TMA's. Then there is the Swedish idea of blocks of airspace that can be opened upon a telephone call.
A last, good possibility is to agree on areas that only require a clearance or just a transponder (the TMZ principle) at certain times. This typically applies to some military areas.
All these aspects must be discussed with the national authorities. Sometimes the authorities are politically driven, so that they don't want to listen. Here only patience may help.
The last aspect is our own interest in carrying a transponder. Since the Montpellier (France) 'mid-air' (that ended well, fortunately) many glider pilots realize that a transponder a) helps to be seen by ACAS-equipped IFR traffic just like an electronic strobe light, and b) to obtain a clearance where that normally is refused.

A look at the future.

A promising new system is coming: Automatic Dependent Surveillance – Broadcast (ADS-B). In ADS-B aircraft transmit their own positions, as derived on-board (so not via radar on the ground) to all who are interested, including ATC. One can imagine that this is ideal for well-equipped aircraft over areas where there is little or no radar coverage. Because we often have GPS already, one would think that this is ideal for us too, but as usual there are practical problems. The first one is the data transmission medium. There basically are three possibilities. The first one, VDL-4 (VHF Data Link type 4), uses VHF channels, the second, UAT (Universal Access Transceiver), uses frequencies in the UHF band, and the third uses the Mode S reply frequency of 1090 MHz, in what is called 1090 Extended Squitter (1090 ES). In the first case some VHF channels are used for the ADS-B data link. Apart from the shortage of VHF channels (that is why the new 8.33 kHz system is being introduced) we will not readily accept another generation of equipment on board after we have been obliged to accept transponders. UAT is not compatible with the European frequency allocation system. 1090 ES would be the simplest system to accept in this respect, but it would mean a serious addition to our LAST. Then there is the fact that ADS-B is not compatible with ACAS. No, interesting as it seems, ADS-B is not for us now. Still its developments deserve to be followed closely with regard to the future. We are doing that in Europe Air Sports and the EGU.

What is closer to us, and a simple addition in principle, is the possibility to let our LAST transmit ('squitter') our GPS co-ordinates for tracking purposes during competitions. This possibility is known in the industry. It is a subject to be followed up. It would make the LAST a lot more acceptable to us.

Fransois van Haaff
EGU Technical Officer Airspace/Equipment
2004-02-20

Abbreviations and acronyms

ACAS	Airborne Collision Avoidance System
ADS-B	Automatic Dependent Surveillance-Broadcast
AIC	Aeronautical Information Circular
ATC	Air Traffic Control
CAA	Civil Aviation Authority
CTR	Control Zone
EASA	European Aviation Safety Agency
EGU	European Gliding Union
ES	Extended Squitter
EUROCAE	European Organisation for Civil Aviation Equipment
GPS	Global Positioning System
IFF	Identification Friend or Foe
IFR	Instrument Flight Rules
JAA	Joint Aviation Authorities
JTSO	Joint Technical Standard Order
LAST	Light Aviation SSR Transponder
RA	Resolution Advisory
SSR	Secondary Surveillance Radar
TA	Traffic Alert
TCAS	Traffic Collision Avoidance System
TMA	Terminal Area
TMZ	Transponder Mandatory Service
UAT	Universal Access Transceiver
VAT	Value Added Tax
VDL	VHF Data Link
VFR	Visual Flight Rules
VHF	Very High Frequency