

A Guide to Transponders in Sailplanes - 2010B

Note: changes in this version are marked with a vertical line on the left

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Introduction

Significant changes to this version of the article are marked with a vertical line to the left of the paragraph with the changes.

NOTE: information in this article is current as of Feb 2010, except for some prices. Prices, availability, equipment specifications, and procedures may change by the time you read this.

This article is intended for pilots flying in the USA. Note that the required equipment and procedures vary from country to country.

If you discover any errors, additions that should be made, or think there might be a better way to present the information, please contact the author:

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A Glider Pilot's Guide to Transponders

Transponders are much discussed lately. Most power planes have them; rather few gliders do. Many pilots, especially those who fly in busy airspace, are taking a close look at these devices and what they can mean to glider pilots.

This article will examine transponders (and some alternatives) from a glider pilot's point of view.

What is a Transponder?

Basically, it's a radio whose purpose is to help an aircraft be "seen" by the Air Traffic Control (ATC) system. Here's what the Aeronautical Information Manual (AIM) has to say (paraphrased):

The ATC Radar Beacon System (ATCRBS) consists of three main components:

1. Interrogator: Primary radar relies on a signal being transmitted from the radar site, reflected from an aircraft, and displayed as a "target" on a radarscope. In the ATCRBS, the Interrogator (a radar beacon transmitter-receiver) transmits discrete radio signals, which repetitiously request all transponders to reply.
2. Transponder: This airborne transmitter-receiver automatically receives the signals from the Interrogator and selectively replies with a specific code only to those interrogations received on the mode to which it is set. These transponder replies are independent of, and much stronger than, a primary radar return.
3. Radarscope: The radarscope can display returns from both the primary radar system and the ATCRBS. These returns, called targets, are used in the control and separation of traffic.

Physically and electrically, transponders are similar to the VHF communications radios we are all familiar with, though they use a higher frequency and so have smaller antennas. The newest units mount in standard 2-1/4" instrument cutouts and have about half the current drain of older units. Frequency is not selectable, but the pilot sets the transmitted code, which consists of four digits from 0 through 7

(gliders most often use 1200 -- the standard code for VFR flying). Instead of a small dot on the radar screen, a controller sees a bright target with the 4-digit code clearly displayed.

Transponder Modes

Not all transponders are created equal. There are three "modes" for civilian use:

- Mode A - the basic transponder ability to reply to interrogations with a 4-digit code (no altitude information)
- Mode C - the reply signal includes both a 4-digit code and the aircraft's pressure altitude, usually obtained from a separate altitude encoder connected to the static system like the altimeter.
- Mode S - a more sophisticated system, the reply signal also includes information identifying the aircraft, and other data.

Of these, most small aircraft use the first two.

On their own, ATC radars don't determine altitude information for the targets they are tracking -- they need the help of the Mode C or Mode S transponders. If you have a Mode A transponder, ATC will detect you; with Mode C or S, they'll also know how high you are. For effective collision avoidance and efficient traffic control, altitude information has obvious value.

TCAS - Traffic Alert and Collision Avoidance System

This is a complex device found in larger passenger-carrying airplanes that assists the pilot in avoiding conflicting traffic. It sends out its own interrogations and processes the signals from transponders that reply. Because it doesn't depend on ground radar or a controller to alert the pilot, it provides an additional layer of safety from conflicts with transponder-equipped aircraft.

There are two levels of TCAS:

- TCAS I - provides traffic advisories to the pilot.
- TCAS II - provides traffic advisories (warnings) and resolution advisories (commands to the pilot to "push" or "pull")

US air carriers have been required to have TCAS since 1992. Many corporate aircraft use it as well. Unfortunately, TCAS is expensive and unsuitable for installation in small aircraft.

There are also passive airborne traffic alert systems that receive and process signals from nearby transponders replying to interrogations from ATC or TCAS. While not as effective as TCAS systems, they do provide additional protection from collisions with transponder-equipped aircraft. Some are suitable for use in gliders, and can warn of approaching transponder-equipped airplanes and gliders.

Should *YOU* have a transponder?

Take a look at this diagram of arrival and departure paths for the Reno airport.

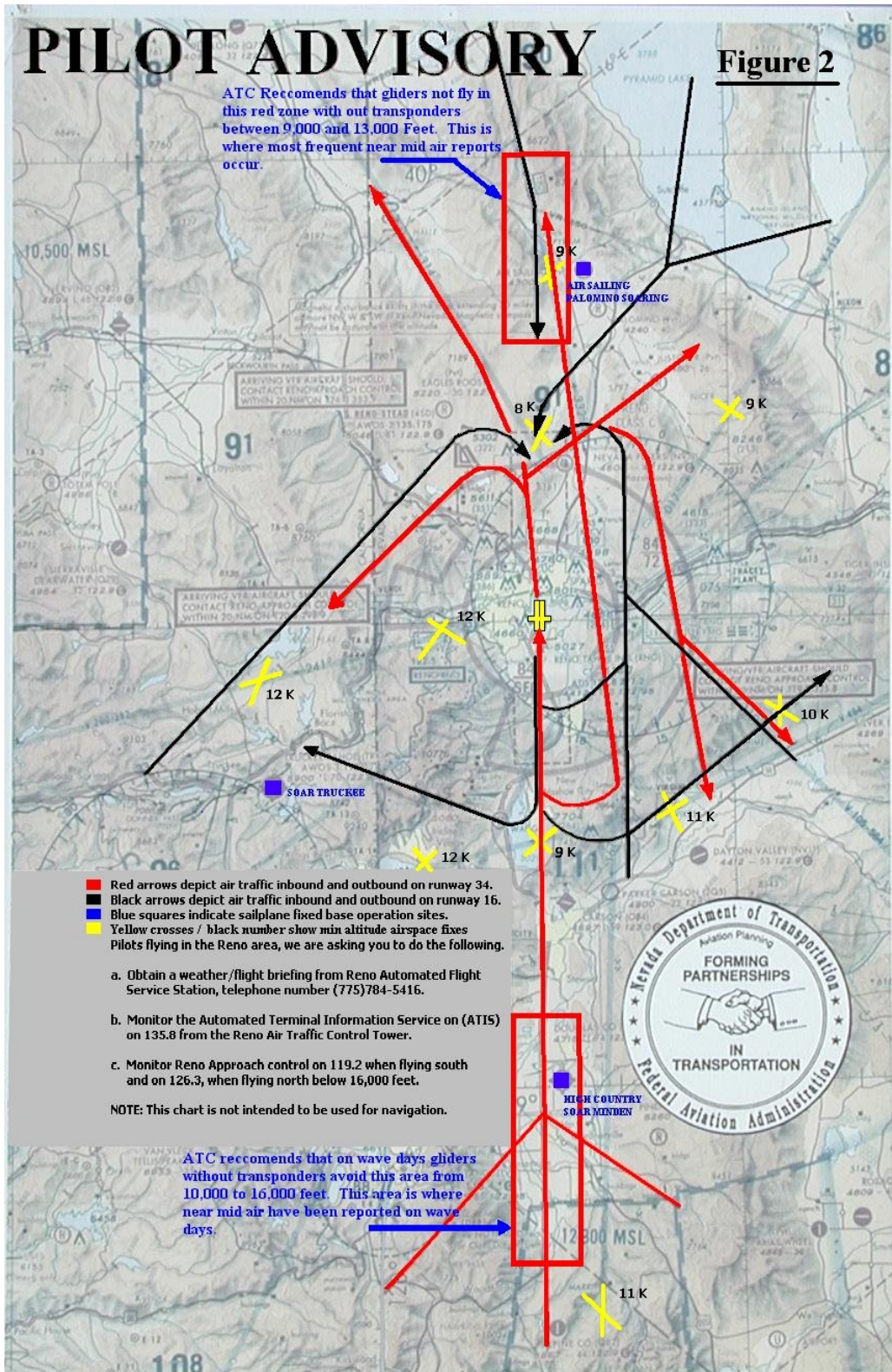


Figure 1 Pilot advisory chart for operation in the vicinity of Reno, Nevada. This is an area that sees both significant glider traffic and many commercial flights.

It's easy to see how conflicts could arise between gliders and jet traffic using the Reno airport; in fact, there was collision between a glider and a Hawker corporate jet in 2006 (remarkably, no fatalities). The

glider did not have an operating transponder, and neither aircraft saw the other in time to avoid the collision. While Minden has a high potential for conflicts, it's not the only area, as there are many other airports, and areas between airports, with a lot of traffic.

Are you worried about a collision with an airliner or other aircraft?

As you can imagine, a collision with an airliner would likely be a disaster for you and its passengers. Further, it could easily lead to restrictions on our sport, especially in these post-Sept. 11 days, when any airplane, even a small one, can be considered a threat.

A glider, cruising or turning, is often difficult to see, even from another glider. For the pilot of an airliner, it is more difficult because cockpit visibility isn't as good and speeds are much higher -- as high as 300 knots TAS (one statute mile in 10 seconds) below 10,000', and much higher above that. Primary radar is unreliable for detecting a glider due to the low reflectivity of gliders, normal ground clutter (reflections from buildings, vehicles, hills, etc), and typical radar settings that emphasize transponder tracking. Besides looking about frequently and carefully, what can we do? A transponder is one answer.

A transponder makes you visible both on ATC radar screens and to the TCAS systems on larger aircraft (primarily airliners and business jets). ATC can direct aircraft around you, while TCAS-equipped aircraft can avoid you even without the help of ATC; in fact, TCAS systems will work even where there is no ATC radar coverage.

Some areas have such heavy "heavy" (airliner) traffic that it's difficult to fly there safely without a transponder. By "safely", I mean, somewhat humorously, staying far enough away that you can't read the airline's name when you see the airliner go by. Chicago and Las Vegas are two of these places. Near most Class B airspace, and even some Class C airspace (like the Reno area), qualifies.

A transponder will also provide protection from military aircraft that are coordinating with ATC, and from some types of transport aircraft equipped with TCAS, but not from tactical aircraft like fighters that don't use TCAS.

And finally, your transponder can also alert pilots of small planes, including other glider pilots, to your presence if they are using "flight following" (ATC radar advisories while flying VFR), or if they are using a portable collision avoidance system (PCAS/TPAS units – see Glossary) that can detect transponders.

Do you want access to more airspace?

Unless otherwise authorized by ATC, flying in Class A, B, and C airspace requires a Mode C transponder, as does flying *above* Class B and C airspace *below* 10,000'. Transponder-equipped gliders can and do operate in these places. Note: Class A flight generally requires IFR ratings, unless you are in a "wave window" or other operating area where the requirements are waived by a Letter of Agreement with the FAA.

Do you want to be found quicker if you go down?

Under some circumstances, ATC computer tapes can be useful in constructing the radar history of a downed or crashed aircraft. This will reduce the area that must be searched, which can speed up rescue operations considerably.

Transponder Disadvantages

Transponders aren't cheap. I'll get into details in the next section, but figure on at least \$2000 to \$2500 for the hardware, plus installation costs.

Since they're mostly sold for powered aircraft, almost all transponders use power as if it's freely available -- they don't have batteries in mind as the sole power source. Power drain is also affected by how often a transponder is interrogated -- something that a pilot can't control. New models on the market since 2002 do considerably better than older ones, but many glider pilots will find that providing adequate battery power beyond the radio, vario, GPS, and flight computer they already have is an issue.

Installation can vary from easy to difficult. You have to find room for the transponder in your panel; a place for the altitude encoder behind the panel; and you'll need to install an antenna and the cable to it. You might need more battery power, and you might need a new altimeter if you plan to fly IFR.

Once installed, a transponder and encoder must be tested to ensure it meets standards, and retested every 24 months.

Summary

A transponder doesn't help you detect or avoid other traffic¹ -- your own eyes still have to do that job. A transponder does help other traffic (especially passenger-carrying aircraft) detect and avoid *you*. Any aircraft in contact with ATC or equipped with TCAS will be alerted to your presence and usually be given advice (by ATC or the airplane's TCAS) about whether and how to maneuver to avoid conflicts.

The benefit of a transponder thus has a lot to do with how often conflicts between you and ATC-controlled or TCAS-equipped aircraft might happen. If you exclusively fly close to a remote rural field where airliners are never seen at glider altitudes, a transponder is probably a waste of time and money. If you often fly near a large metropolitan area and frequently see airliners at the altitudes you fly, it's time to give serious thought to a transponder. Most of us probably lie somewhere between these two extremes, and each will have to make their own evaluation.

Choosing the equipment

A transponder installation consists of the transponder, an altitude encoder (most are external, a few are integral), an antenna, as well as a "large enough" battery. Your present battery might be acceptable, but some pilots will have to enlarge it or add another one.

Transponder

¹ PCAS units WILL help you do that – the last section covers them

As of this writing there are several suitable units for gliders that are certified and sold for use in the USA. Other units are available in Europe that are attractive, but are not certified or sold for use in the USA.

The Trig TT21 is currently the most attractive unit (Jan. 2010), though it is new and not many are in use compared to Becker and Microair units. All these units mount in a standard 2.25" cutout, are relatively short at about 7"-8", and have low current drain compared to other units. They work over a wide input voltage range of about 10-30 volts, so a standard 12-volt battery pack has sufficient voltage (a 14 volt pack is not needed). Each has an LCD to display the code setting, encoder altitude reading, and a number of other values.

NOTE: specifications can and do change, so use a current data sheet, and consult the dealer or manufacturer for the latest information.

What output power should I get?

Transponders are available in two "altitude ranges":

- for a maximum altitude below 15,000': power rating under ~175 watts
- for a maximum altitude above 15,000': power rating above ~200 watts

The power rating numbers aren't exact, because the rating is at the *antenna*, not the transponder output.

The TSO certification requires a somewhat higher power output and reply rate for operation above 15,000 feet. Practically speaking, the units are otherwise identical. Most glider pilots that don't exceed 18,000 feet except in a "wave window" opt for the 15,000' rated unit to save money and power. If you intend to fly IFR in Class A airspace outside of a "window", the 250 watt version would be a better choice.

Here are units typically installed in gliders:



Trig TT21 Mode S Transponders

- 130 watts nominal output power - TT21

- Rated operating altitude to 15,000 feet
- Integral altitude encoder
- separate control head and remote transponder
- Maximum current drain about 0.30 amps on 12 volts *including* encoder
- Price: about \$1900 from dealers (Jan. 2010)
- 250 watts nominal output power - TT22:
 - Rated operating altitude to 35,000 feet
 - Integral altitude encoder
 - Maximum current drain about 0.36 amps on 12 volts *including* encoder
 - Price: unknown (Jan. 2010)



Becker ATC 4401 Mode C transponder

- 175 watt output power (ATC-4401-175):
 - Rated operating altitude to 15,000 feet
 - Maximum current drain about 0.44 amps on 12 volts (not including an encoder)
 - Encoder required for Mode C operation
 - Price: about \$1900+encoder from dealers (Dec. 2007)
- 250 watt output power (ATC-4401-250):
 - Operating altitude to 50,000 feet
 - Maximum current drain about 0.55 amps on 12 volts (not including an encoder)
 - Encoder required for Mode C operation
 - Price: about \$2100+encoder from dealers. (Dec. 2007)



Microair T2000 Mode C transponder

- 200 watt output (nominal)
- Operating altitude to 35,000' (perhaps more – data sheet is incomplete)
- Maximum current drain about 0.46 amps on 12 volts (not including the encoder)
- Encoder required for Mode C operation
- Price: about \$1900+encoder from dealers (Dec. 2007)

Units typically NOT installed in a glider



Garmin GTX-320A Mode C transponder and similar units

“Airplane” units by Bendix, Garmin, Narco, etc, are generally too big and too power-hungry to be desirable, and the cheaper units don’t have the encoder readout and other features of the new designs. Specifications for the Garmin (pictured):

- Current drain: 1.0+ amps at 12 volts
- Panel size: 6.3”W x 1.7”H (8.2” deep)
- Weight: 2.2 lbs (0.5 lbs more than the Becker)
- Encoder required for Mode C operation
- Price: about \$1350 from dealers (Dec. 2007)

Mode S transponders

Mode S transponders look better on paper, compared to the Mode C units. Typical features are:

1. lower power drain compared to similar Mode C units
2. an encoder is built into the transponder, eliminating the purchase, mounting, and wiring of a separate encoder
3. support of “ADS-B out”
4. reception of TIS (Traffic Information Service – see below)

The Trig TT21 has all of these, and a remarkably low price (~\$1900 Jan 2010) besides, making it not just the favored Mode S transponder, but as cheap as the older Mode C variety. The Becker BXP6401 is another “glider friendly” Mode S unit currently available in the USA. It does require an external encoder, but works with the TIS. It’s current drain in operation will be slightly less than the Becker ATC4401 (Mode C unit) in low traffic areas, but perhaps as much as 0.3 amps less in areas with lots of radars and traffic (~\$2900+encoder, Jan 2010).

The Filser TRT800H and Garrecht VT-01 UltraCompact Mode S transponders are also attractive, at least on paper, because they have a built-in encoders (but no ES or TIS capability), and perhaps lower power consumption than the Becker BXP6401. Only the VT-01 seems to be available in the USA (Jan 2010). You may need to contact the Filser directly about availability of their transponder.

The TIS system provides position data of transponder-equipped traffic near your aircraft, but is only available within a 55 nm radius from about 125 sites in “busy” locations (see a map on the Garmin website: www8.garmin.com/aviation/tis.jsp). Weather radar images are also transmitted by the TIS.

Besides the TIS capable Mode S transponder, a display is required to see the data. This can be a Garmin 396 (~\$1800), or an even more expensive multifunction display. The FAA is shutting down about 20 TIS sites over the next few years, and it’s not clear what their 5 to 10 year commitment to the remaining TIS sites will be. Eventually, the service will be taken over by the ADS-B system.

For pilots that routinely fly in the TIS covered areas, the traffic information and the radar images might make a Mode S transponder and display worth the extra cost. If you also fly your glider in Europe, you’ll need a Mode S unit to do so.

Encoder



Typical encoders are about half the size of a medium pocket book, are powered by the sailplane’s battery, and connected to the static system and the transponder. Inside the box, a well-insulated, temperature stabilized, solid state pressure sensor measures the static pressure, then other circuitry converts the sensor voltage to a digital altitude signal with 100 foot increments. The digital signal is sent to the transponder, which adds this data to the reply it transmits when interrogated by the ATC radar.

Encoders are available with maximum altitudes from 20,000' to far higher than a sailplane has gone. The typical temperature range is -4°F to $+131^{\circ}\text{F}$, sufficient for most people's summer thermal and winter wave flying. A 30,000' unit is the minimum recommended, as there is little cost savings for lower altitude units.

The encoder circuitry itself doesn't consume much power, but the heater that temperature stabilizes the pressure sensor does. Typical units draw about 300-500 ma during warm-up, then drop to about 80-100 ma after a few minutes. Operating current will be greater in cold temperatures as the heater works harder. Here are the factory figures and typical dealer prices for some popular units:

Altitude Encoder Characteristics		
<i>Encoder Model (30,000' units)</i>	<i>Ma at -4°F</i>	<i>Typical dealer price (12/2007)</i>
Ameri-King AK-350	~240	\$165
ACK Technologies A-30	~90	\$240
Trans-Cal SSD120-30A	~400	\$240
Microair EC2002	~100	\$285

Antenna



Rod antenna



Blade or Fin antenna

Most glider manufacturers now provide technical bulletins for transponder antenna installations in their gliders. The antenna is a critical part of the system, so get those bulletins and follow them for your best chance of a successful installation.

There are basically three types of antennas, two of which require a ground plane (typically, a 6"-12" diameter thin metal sheet), and an internally mounted type that doesn't require a ground plane. The following advice may help pilots whose gliders do not have factory approved installations.

Antenna Characteristics

<i>Type</i>	<i>Mounting</i>	<i>Ground plane req'd</i>	<i>Drag</i>	<i>Damage possible?</i>	<i>Cost</i>
<i>Rod</i>	External/internal bolt-on	Yes	Very small	Likely only to antenna	\$40-\$60
<i>Blade/Fin</i>	External bolt-on	Yes	Even smaller	Might damage fuselage	\$140-\$160
<i>Dipole</i>	Internal with adhesive	No	None	No	\$80-\$90

Which antenna is best for you depends mainly on where you want to mount it, and that depends on your trade-offs between health concerns, signal distribution, antenna/fuselage damage potential, and mounting access.

While the transmitting power of a transponder is rated at a relatively high 150-250 watts, the transmissions are very short, making the average power less than a sailplane radio when it is transmitting. It's not easy to determine the health risk, since there is little documentation about the health effects of the transponder signal. The usual recommendation is at least 6' from the pilot, or to provide shielding if it's closer. Metal and carbon fiber gliders can provide this shielding if there is structure between the pilot and the antenna, but fiberglass gliders will not. Some pilots have used the antenna on the glare shield or near their feet without apparent ill effects.

Mounting the antenna on the bottom of an aircraft (the usual recommendation) gives it the "best" signal distribution, but the antenna has been successfully used inside the tail boom on fiberglass gliders, on top of the turtle deck or the tail boom, in the nose of the glider, and on top of the glare shield. Ideally, the antenna will be mounted so it isn't susceptible to damage when the fuselage is moved from/into the trailer, during rigging, or by careless bystanders, outlandings, and gear-up landings.

Battery

The power requirements of the typical Mode C transponder can exceed the total of the radio, vario, and GPS, though a PDA-based flight computer might draw as much, so you must ensure the battery capacity is adequate. This section assumes you are using the usual sealed lead/acid battery that most gliders have.

Will you need a 14-volt battery? No! Some pilots, usually those with really old radios, use 14-volt batteries. The new transponders use "switching" style power supplies and operate properly over a wide input voltage range of at least 10 to 30 volts. So, if you are using a 14 volt battery, you can continue to use it. The only advantage to using a 14-volt battery for the transponder will be a 15% reduction in the current required.

Likely battery solutions:

The absolute minimum is a single 12 volt, 7 amp-hour (AH) battery in new condition with the standard Mode C transponders. That will be barely enough to power the typical glider with one of the Becker

Microair, or Trig transponders continuously for about 5-6 hours (the Trig somewhat longer) in warm conditions, in addition to the radio, vario, and GPS. You'll have to charge it after every flight and buy a new battery every couple of years as it loses its peak capacity, but that might be the easiest, cheapest solution for your glider.

There are a few higher capacity batteries the same size, and even one or two even higher than those that fit the same footprint, but are taller. These may be good options if they fit in your battery box.

A more practical solution, if you have the room for it, will be the original battery for the original instruments, and an additional 7 AH battery (bigger if you can manage it) for the transponder, giving an operation time of about 10 to 12 hours in warm conditions, and about half that in cold conditions when the battery is a few years old. You'd have the "oomph" for longer flights, you might not have to charge after every flight, and your batteries won't need replacement as often.

If you use Trig TT21 (and perhaps the Garreth VT-01, or other Mode S transponder), the power drain should be low enough that even a 4 amp-hour battery would be adequate - not ideal, but adequate for 8-10 hour flights in cold weather. At a size that is 40% less weight and volume than the usual 7 amp-hour battery, almost everyone should be able to mount a battery just for the transponder, if needed.

Determining your actual capacity requirements:

If you've decided increasing your battery capacity is worthwhile, you'll need to determine how much current you are using now. If you've already decided you will use a separate battery for the transponder and encoder, you'll just need the current values for the transponder and encoder from the specification sheets or installation manuals. Other factors are the length of your flights, battery lifespan, and how frequently you want to charge the battery. Temperature is also important, as the cold in high altitude waves or winter soaring reduces nominal battery capacity 20% at 32° F, and 40% at 0° F.

To measure the current your glider uses now:

Put a 0-500 ma or 0-1000 ma meter in series with the battery lead.

Turn on all equipment that will be normally used in flight, except the motor controller in a powered sailplane.

Read the current.

Add 10% for radio transmissions and more vario audio volume while flying.

Or, add it up if you don't have the glider handy, like a new one on order: Soaring computer, vario, flight recorder, radio, etc, but not the motor controller in a powered sailplane. Then...

Add in the transponder and encoder current requirements.

Decide on the maximum flight duration, assuming an "always on" transponder.

Pick your “Cold Weather Factor”: 1.0 for 60° F and up, 1.25 for 32° F, 1.7 for 0° F (batteries don’t deliver their full capacity when cold).

Minimum capacity required = (total equipment current in amps) x (duration in hours) x (cold weather factor)

Other capacity factors:

How many years do you want the battery to last? At least double the minimum size for optimum lifespan.

How often do you want to charge the battery? Multiply the minimum size by the number of flights you want per charge.

Can’t figure out how to install enough batteries?

Each glider type poses a different challenge – consult with the dealer, the factory, and especially with other owners of your type.

1. There are larger capacity batteries (8 to 9 AH) now available that fit the same space as the typical 7 AH battery (and other common sizes, too). This is the cheapest and easiest way to get more capacity.
2. If your battery mount will accept a taller battery, you can get a 10.5 AH battery in the same “footprint” as your original battery.
3. You may be able to use solar cells to extend capacity sufficiently. Some gliders can be ordered with them, or the cells obtained from the factory, the dealer, or the manufacturer of the cells for retrofitting. With typical instruments plus transponder drawing around 0.8 amps, you will need solar panels delivering 0.4 amps average for a meaningful (50%) increase in duration. The solar panel will need to be rated at about 0.8 amps to compensate for poor alignment with the sun while flying, and time in the shadow under clouds. Cost will be in the \$500-\$1000 range, unmounted, for the typical small, high efficiency, flexible panel used on gliders. Cheaper panels are significantly larger, rigid or both.

What about using Lithium or Nickel-metal hydride batteries?

Lithium batteries are potentially more dangerous than sealed lead-acid batteries (SLA) – remember all the laptop battery recalls? So, DON’T cobble up a Lithium battery for your glider! **IF** you can find a 12 to 14 volt, commercially produced lithium battery pack, **AND** rated for operation to 18,000’ (or your highest operating altitude) **AND** with a matching charger, **THEN** you might consider using it. I couldn’t find any that met all these conditions (Dec. 2007), the best matches I could find cost several hundred dollars, and they wouldn’t fit a standard glider battery mounting.

Nickel metal hydride (NiMH) batteries pose a lower potential hazard and are cheaper than lithium batteries, but still much more expensive (3 to 5 times) than sealed lead-acid batteries of the same capacity. I’m not aware of any NiMH “drop-in” replacement for the ubiquitous 12 volt, 7 AH, SLA battery, so you would have to make your own battery pack from individual cells and obtain a proper

charger for it (NOT one for an SLA battery). The cells aren't the best fit in a rectangular battery box, so the additional capacity over a "high capacity" SLA battery of the same size might not be as much as it seems it should be. Finally, the self-discharge rate for some NiMH cells is quite high, typically about 20% per month, compared to about 3% for SLA batteries.

For lithium batteries, I think the risk and cost are too high to be worth the increase in capacity; the NiMH battery cost and (perhaps) the high self-discharge rate make it unattractive for most pilots. Better to increase the capacity with a higher capacity battery, add another battery box, or add solar panels.

There is a feature of all these transponders that might make it possible to find a suitable, commercially manufactured NiMH battery, possibly even a Li battery (I still don't recommend one). Their 10 to 30 volt input range means you don't need to use a 12 volt battery *as long as you use for only the transponder*. Is it worth the trouble to have a separate battery, switch, fuse, wiring, and charger for the just the transponder? I don't think so, as it definitely doesn't meet the "KISS" principle, and leaves more room for errors than putting in sufficient lead-acid batteries.

Can I turn the transponder off to save the battery?

FAR 91.215(c) requires aircraft with a properly functioning transponder to operate it at all times while flying. We all know that some transponder-equipped sailplane owners conserve their battery by using the transponder only in areas where traffic is heaviest, and there have been no official reprimands so far. This is better than having a dead battery later on in the flight, when a transponder might be most useful, and being without a radio and other instruments. The best solution is still to have enough capacity to last more the entire flight.

Altimeter

Unless you stay out of airspace where Mode C is usually required for gliders (Class A outside a wave window, B, and C), you might need a new altimeter that can meet the requirements of FAR Part 43 Appendix E. Generally, however, this only applies to IFR operations.

If your present altimeter isn't sufficiently accurate, your best bet is to replace it with a 3.125" face, TSO'd unit having the altitude range you are interested in. The 2.25" units and non-TSO'd 3.125" units are much less likely to meet the requirements initially or hold their calibration over the years.

Installing the equipment

Be sure to follow the normal procedures for installing new equipment in your glider. As usual, this will vary depending on its certification. A weight and balance calculation is particularly valuable (and required in any case) if you add or change the batteries.

Transponder

Most gliders will have the panel space for a 2 ¼” transponder, though some might have to remove a seldom used instrument. The main issue for some gliders, like the DG series, is the depth behind the panel may not be sufficient, except in one particular spot on the panel or pedestal.

In extreme cases, pilots have mounted units on top of the glare shield when visibility wouldn't be affected much.

Encoder

The encoder is small enough that a mounting place can usually be easily found under the glare shield behind the panel. Its adjustments will be used at most every two years, so good access isn't needed. The required connections are the flexible tubing to the static system and the electrical cable to the transponder. If the transponder doesn't provide power to the encoder, separate connections to a fuse, switch and battery will be required. Note that the altimeter must also be connected to the static system, and not cockpit static.

Antenna

Mounting considerations were covered in the “Choosing the Equipment” section. With the location already selected, the actual mounting is straightforward, but running the coaxial cable can be tedious. If you are ordering a new glider, order it with the cable and antenna installed, even if you aren't planning on a transponder initially. Ensure the installation manual is followed carefully. In particular, use proper coaxial cable with good connectors for the antenna lead. The high frequency (1090 MHz) requires a better cable than our lower communications frequencies (123 MHz) to avoid substantial power loss.

A bottom-mounted antenna can be placed in the upward curve of the fuselage a short distance behind the landing gear doors, which allows most gliders to avoid these problems. A rod style antenna will bend before causing damage to the fuselage, but the stiffer fin/blade style probably won't. Some pilots make the bottom-mounted rod style antenna easily removable, but then there is the possibility of forgetting to attach it (the transponder won't work, of course, and the transponder could be damaged).



Rod antenna behind gear



Blade antenna just behind wing

Good access to the mounting area will make it easier to route the coaxial cable and install the ground plane, if required. The actual “bolting on” of the antenna is easy once these are done. Mounting it in the

front of the cockpit is easy, but exposes the pilot to more RF radiation (the position of the ground plane helps in this case) and the battery in this glider partially shields the antenna from receiving/sending signals towards the right side.



Rod antenna and ground plane mounted under thigh area



Ground plane removed from antenna

Contact your dealer or manufacturer first, as the antenna problem may already be solved; next, ask other owners of your model of glider locally or on an owners newsgroup. A posting on the newsgroups (rec.aviation.soaring and others) will often bring a solution. If you do come up with a good solution, please pass it on to your dealer for the next pilot!

Testing the installed system

This is a simple procedure for VFR aircraft, taking less than an hour and typically costing \$50-\$100.

If you will be flying IFR (as some glider pilots do), then you must adhere to the more stringent requirements of Part 43 Appendix E. My shop said this adds \$200-\$250 beyond the VFR testing, as these additional tests are required (his estimates were based on airplane experience):

- Static system: moisture, restrictions, and leakage
- Altimeter: scale error, hysteresis, after effect, friction, case leakage, and barometric scale error to the maximum desired altitude
- Encoder: agreement with the altimeter to the same altitude
- Transponder: correct transmission of the encoder altitude signal

The most important test is done while you are flying: contact ATC, and ask them if your transponder is displaying properly. This check is cheap, easy, can be done any time you fly, so you should do it several times a year. If ATC can't detect you, you need to determine why, as you may have an equipment or procedural problem.

Continuing maintenance requirements

FAR 91.413 requires testing of the transponder (including the encoder, if used) every 24 months to ensure it still meets the standards, or its use is not allowed. Again, for VFR use, quick, easy, and cheap.

Using the transponder

Transponders are easy to operate, though proper use requires some knowledge that airplane pilots usually have, but glider pilots usually don't. The basics are covered in AIM 4-1-19 (Transponder Operation). The AIM is available as book or CD from the local airport or catalog dealers, or you can get the specific section from FAA website (www.faa.gov/ATpubs/AIM). The following are the basics, but the specifics will vary a bit with your equipment and the area you fly.

Standard transponder controls:

- Mode selector
 - Off: unit is off
 - Standby: warm up with no transmissions
 - On: unit replies to interrogations but without the altitude information
 - Altitude: the replies include altitude information from the encoder
- Code selector: Changes the transmitted code (older units); changes the standby code (newer units)
- Ident: pressing this button makes your blip easily identifiable by brightening it on the controllers radar display

Typical displays are:

- Active code: the code being transmitted
- Reply indicator: flashes when the unit is replying to interrogations
- Encoder altitude: shows the pressure altimeter that the encoder is reporting

Study the transponder manual carefully, as each model will implement these features a little differently, and all have additional features.

When you are ready to fly

- Select Standby when you are on the flight line as part of your pre-takeoff checklist. Confirm that the transponder code displayed is 1200, for VFR flying. Local agreements with ATC may allow/require a different code (Reno area pilots generally use 0440).
- Select On (if you don't have an encoder) or Altitude (if you have an encoder). If you were flying from a towered field, you would generally only do this after takeoff to avoid confusing reflections to ATC radar.
- Continue to use "see and avoid" even with your transponder in operation. Other gliders and most smaller airplanes are NOT under the control of ATC and do not have TCAS. Transponders operate "line of sight" so even aircraft operating in contact with the ATC system might not be warned of your presence if a ridge blocks the radar beam.
- If practical, leave the transponder on the entire flight. Some pilots do conserve the battery by using the transponder only in areas where traffic is heaviest, and there have been no official reprimands so far. This should be considered a "work-around" until you can improve your battery duration
- Turn off the transponder immediately after landing to preserve the hard-working battery.

- Charge the battery as soon as possible. This will increase its life and ensure it's ready for the next flight.

Beyond the basics: the material in AIM 4-1-19 reminds you of several important rules (but be sure to read it yourself):

- You are not required to contact ATC as long as you remain VFR. Don't use a code other than 1200, except by local agreement, or unless you are in contact with an ATC facility by radio and are specifically asked to do so. If you do wish to contact ATC, be sure you have read the relevant sections of the AIM and are familiar with the terminology to use, ask a pilot who is ATC fluent for help, or even consider the taking (or at least reviewing the material for) the part of an "airplane" ground school that covers ATC communication.
- If you use an older unit where the code being changed is also the code transmitted, be especially careful to avoid changing codes through 7500 (hijack code), 7600 (radio failure), 7700 (emergency), or 7777 (military intercept). All will draw ATC's immediate attention. Newer units make the code change to the "standby" code, or after a delay, so changes aren't transmitted until the entire code is entered.
- Don't use the "Ident" button unless requested by ATC. The button causes an additional signal to be sent to ground controllers and will not be welcome unless requested.

Alternatives to transponders

These devices (and one procedure) can reduce your collision risk, and they can all be used with a transponder for even more risk reduction. Which one (or combination) will provide satisfactory risk reduction depends very much on where you fly and what else is flying in the same airspace. My personal choice is a transponder and a Zaon MRX.

Contact ATC

This can be surprisingly effective. In the Eastern Washington State where I usually fly, glider pilots without transponders can contact, by radio, the ATC approach controllers for the area, and ATC can usually spot and follow us on their radar. Sometimes they'll even offer Flight Following! Generally we do this when near a towered airport or on a busy airway, when it's value is the highest.

Contacting ATC will almost always help, but how much depends a lot on how busy they are. Keeping track of unequipped aircraft is harder and takes more time; e.g., the radar can display your location but not your altitude. Still, it's worth attempting. At the very least, it will make ATC aware of the extra "stealth" traffic, and they can pass that info on to the airplanes in their airspace; at best, you'll get most of the benefit of having a transponder for just the cost of a few radio calls.

Portable Transponder Detectors

These are also called PCAS (Portable Collision Avoidance System – trademark of Zaon Flight Systems) or TPAS (Traffic Proximity Alert System – trademark of SureCheck Aviation). They all use the same basic technique: detecting transponder replies from nearby aircraft to ATC radar and TCAS interrogations.

How they work

The transponder signal strength is used to calculate the approximate distance; altitude is determined by reading the Mode C (altitude) code in the transponder signal. By tracking the distance and relative altitude of other aircraft, the unit estimates when a collision threat might exist, then warns the pilot with a combination of audible alerts and displays of the target distance and relative altitude. One of the units can also display the direction of the target.

Limitations

These units do not alert other aircraft to your presence; for that, a transponder is still required. They can only detect aircraft with a properly operating transponder. This includes almost all airplanes, but only some gliders, so you still need to scan for other aircraft. Of course, you also need to visually find an aircraft after receiving an alert/warning, so you can avoid it if necessary.

Typical detection distances are 5 miles horizontally and 2000 to 5000 feet above and below you. These distances can be significantly affected by antenna location, transponder output power, and even antenna cleanliness. Generally, an airliner will be detected farther away than a small airplane, because it has a higher power transponder and multiple antennas.

Only one (Zaon XRX) of the four currently available units indicates the direction of the target. With the others, you don't know the direction, which makes it harder to visually find the target. You do know the relative altitude and distance, so you do know the approximate vertical angle to the target. With use, it becomes easier, but it sometimes means making a 90 degree turn to see behind you.

Should I get one?

My personal experience and reports from other pilots (glider and airplane) indicate that they work well. By "well", I mean they alert the pilot to aircraft that would otherwise not be seen at all, or not seen as soon as desirable. "Not seen" doesn't mean the aircraft was so far away the pilot couldn't see it! Aircraft can approach from behind (especially while we are cruising), and one coming directly at us, even from ahead, can be almost as hard to see. Small, fast aircraft can be upon us in the 30 seconds or so it takes to look a map, punch a new task into our soaring computer, or other distractions from scanning.

My suggestion: if you are "surprised" by at least one airplane every year you fly, it means you are missing traffic you ought to see, and a PCAS/TPAS unit can help you eliminate these surprises. Even if you have a transponder, these units are useful; remember, the majority of airplanes don't have TCAS and aren't in contact with ATC, so they will not be alerted to your presence.

Note that all of these units can be easily transferred to your airplane or a borrowed/rented glider, and some will run on self-contained batteries in addition to the aircraft power.

Which one should I get?

There are currently four units available (Dec. 2007). Because these are portable units, they do not require installation or periodic testing. In order of list price:

MRX (Zaon Flight Systems - \$549)



This is the one most popular with glider pilots. It does a good job of distinguishing between nearby aircraft that are potential threats and those that aren't. The built-in altitude sensor means you don't need a transponder to get relative altitude. Visit zaon.aero for more information.

ATD-300 Traffic Watch (Monroy Aerospace - \$795)



This unit does not have a built-in altimeter, so it can't provide relative altitude unless your glider has a transponder with encoder. Without a transponder in your glider, alerts will be based on distance only, so you receive the same warning for an airplane a mile directly above you that you do for the one a mile away at the same altitude. It is not as versatile as the Zaon MRX, uses twice the current, and I'm not aware of any glider pilot using it. Visit monroyaero.com for more information.

Proxalert (Proxalert - \$795)



This unit displays up to three targets, including their squawk code, and monitors up to ten aircraft at once. This extra information might be useful in high traffic areas, where many airplanes will have codes besides 1200 (VFR). While larger than the MRX or ATD-300, it still fits well on the top of a glider glare shield. Visit proxalert.com for more information.

PCAS XRX (Zaon Flight Systems - \$1795)



Unique in this group, the XRX can display the direction to a target, in addition to the distance and relative altitude. Direction resolution is limited to eight 45 degree sectors, but this still makes it quicker and easier to locate a target, compared to the other units, which give no direction information. The target information can be interfaced to moving map units like the Garmin 396/496, programs like Anywhere Map that run on iPqgs, and other devices. Perhaps soaring software providers could be persuaded to connect to it also! Visit zaon.aero for more information.

ADS-B

From a Jan 2006 AOPA article:

“Automatic Dependent Surveillance-Broadcast (ADS-B) is a datalink technology that uses satellite-based navigation and positioning information to transmit aircraft location and altitude to air traffic controllers and other nearby aircraft. The Federal Aviation Administration (FAA) plans to use ADS-B as the replacement to air traffic control radar over the next 10 to 15 years. This means that aircraft owners will likely be required to equip with ADS-B receivers to fly wherever a transponder with Mode C is mandated today.”

(To read the entire article - www.aopa.org/whatsnew/air_traffic/ads-b.html)

As of late 2007, there is good coverage on the East coast, very sparse elsewhere, but probably the entire USA by 2020.

If you aren't happy about getting a transponder, you are going to hate getting ADS-B! The minimum equipment required for general aviation aircraft is a Universal Access Transceiver, currently available only from Garmin (the GDL 90). It's a 4" x 8" x 12" box that weighs 6 pounds, requires 1.5 amps, and costs ~\$7000 (Oct. 2007 price) uninstalled! If you want a display so you can see surrounding traffic, get weather updates, etc., you'll need something between the \$1000 PDA/software solution and a Multi-function Display (MFD) like the \$7000 Garmin GMX 200.

ADS-B has a lot of promise, and eventually the equipment will be smaller, cheaper, lighter and use less power, but it's unlikely to be a solution for glider pilots for many years. Fortunately, transponders will be part of the ATC system for many years (12-15 years for airplanes, probably longer for gliders), providing most of the safety benefits that ADS-B can provide.

On October 4, 2007, the FAA issued an NPRM announcing their intent to require ADS-B in the National Airspace System (NAS) by 2020. In responding to that NPRM, the AOPA, SSA, and other general aviation groups will assert that the FAA should be setting a unit cost requirement that the avionics manufacturer must meet before the regulations become mandatory, and that transponders and ADS-B must not be mandatory at the same time.

I encourage all pilots to aid these efforts by joining the SSA, AOPA, and other organizations that support your aviation interest, and contribute the dollars and skills that you can to achieve an ATC system we can live with. I belong to both SSA and AOPA: the SSA (though small) will promote our very special interests, and the AOPA (with it's much larger size and clout) to promote our broader interests.

FLARM

Flarm (it's name is not an acronym) is a portable, low-cost (~\$800), low-power anticollision system originally developed for gliders flying in Europe. It is a remarkable system that is spreading to other aircraft and other continents, now (Oct 2007) with over 9000 in use.

A Flarm unit detects other Flarm units within a few miles, tracks their position, and issues warnings and collision avoidance guidance; in essence, a "mini-TCAS"! Besides it's use in gliders, it can be installed in towplanes for more protection at busy airfields, and used on the ground at the club, where it can track the location of the club gliders, and even provide towing and club aircraft usage data to an automated billing system.

Unfortunately, FLARM is not a solution to our airliner/airplane collision avoidance problem, starting with the fact that it is not currently available in the USA. Even if it were, persuading airliners and other general aviation aircraft to install a non-certified unit would be a tough task.

There is some chance it may be sold here, and if it's built-in logger becomes IGC approved, it would be an attractive alternative to a standalone logger for not much extra money. Possibly, enough might be sold in areas with a lot of gliders to improve overall safety. If, if, if – lot's of ifs, so it's future here is uncertain.

Visit flarm.com for more information.

“Myth-information” about transponders

There are a number of myths circulating about transponders and the ATC system they operate in. Usually, people that aren't familiar with the ATC system pass them on; surprisingly, I sometimes hear them from pilots that should know better, including very experienced airline pilots. It demonstrates that the ability to turn the right knob, flick the right switch, and say the right things, all at the right time, does not require a technical understanding of the system!

Here are some that are the worst myths, because they might cause a pilot to forego installing a transponder when he would benefit from one.

Mode A/C Transponders aren't detected by TCAS

This myth makes the claim that only Mode S transmissions are used by TCAS; in fact, TCAS does detect Mode A/C transponders. Very few airplanes have Mode S; almost all airplanes have Mode A/C, so a “Mode S only” TCAS would not protect against the vast majority of airplanes. Doesn't make sense, does it?

Perhaps this myth comes from the fact that airliners do use Mode S transponders, and the fact that the TCAS responds differently to TCAS equipped and non-TCAS equipped aircraft. If the both aircraft have TCAS II, the pilots in both planes will be given resolution advisories (commands to the pilot to “push” or “pull”); otherwise, the pilots in the TCAS equipped aircraft are given traffic advisories (warnings).

ATC ignores/can't detect VFR code 1200

ATC can detect the VFR code 1200, but there are a few very high traffic places when ATC will filter out 1200 codes. These are NOT places where IFR and VFR traffic are flying in the same airspace, but where heavily used, but separate, VFR and IFR airspace are next to each other. This happens in the Los Angeles area, for example, and most areas like it aren't where you'll find many gliders in the air!

You aren't detected when circling or standing still in a wave

This won't happen to a transponder equipped glider, but it can happen if the glider doesn't have a transponder, because ATC must use primary radar to detect the glider. Primary radar uses filters to eliminate the display clutter caused by reflections from stationary objects (building, mountains, etc) and slow-moving vehicles (trucks, cars, etc). If you aren't moving very fast, you might be filtered out. If ATC knows you are out there, they may be able to adjust the filtering so you still display on their screen (a good reason to contact them when near a busy airport or airway).

Why Doesn't the SSA ...?

These are the top three questions that SSA directors get asked about the transponder situation.

... get an exemption from the “always on” rule?

Summarizing what an SSA director involved with SSA/FAA matters told me:

What we spent years doing was trying to get the FAA to agree that we could turn them [transponders] off if necessary. The irony here is that we are asking the FAA to legalize is what the pilots are already doing, and the FAA knows they are doing it.

The conversation basically went something like this...

SSA: "The pilots are turning them off to save battery power and keep the radio operating".

FAA: "Yeah, we know".

SSA: "We think they should be allowed to do it in remote areas".

FAA: "We agree".

SSA: "How do we legalize this?"

FAA: "File a petition".

So the FAA wanted us to submit a petition for "legal" reasons, and we did (Jan. 2004). We have glider pilots throughout the FAA building in DC and they already know all about low power transponders. We know that ATC has even told pilots to leave them on and turn the radio off - we all agree that's nuts, but it's what the rule says. They also have told us that the day after a mid-air between a glider and a commercial transport, we will lose our exemption. What we're trying to do is get agreed to procedures and policies in place before that day happens.

Currently (Oct. 2007), the petition is still awaiting action from the FAA.

... get the 0440 code for the entire country?

The Reno area can have 100 or more gliders flying in it from the airports at Minden, Truckee, Stead, and Air Sailing; in addition, there is considerable traffic using the Reno airport. The mountains in the area tend to channel the airline and other Reno traffic primarily into north and south approaches, and these same mountains also attract the glider traffic to the same area. This high density of glider and airplane traffic led to the adoption of the 0440 transponder code for gliders with transponders to use in place of the normal 1200 VFR code.

The code has two advantages for the tower operators:

1. Knowing which aircraft are gliders makes it easier for the operator to predict what an aircraft is likely to do, and to give more useful traffic advice (“glider at your one o’clock”) to aircraft in contact with them.

2. They can avoid distracting and irrelevant collision warnings from the radar computers by setting the radar computers to ignore potential collisions between 0440 coded aircraft. Because gliders frequently fly close to each other, they can provoke a lot of warnings, even though no collision hazard exists.

The high density of VFR glider and IFR airplane traffic in the Reno area, coupled with ATC operators that are knowledgeable about glider flight, makes the 0440 code a useful safety tool. The density is almost unique in the country, so there is little value to using it nationwide, and without sufficient glider traffic, it would be hard to keep the operators trained enough to make use of the code. An additional problem is the 0440 code is already assigned for other purposes in parts of the country, and with a shortage of codes, the FAA is reluctant to dedicate one to something that isn't much of a problem.

... get someone to build a cheap, low power transponder?

Again summarizing what an SSA director involved with SSA/FAA matters told me:

The basic problem is that the FAA, like other nations, is prevented by international agreements from certifying transponders that do not meet the current standards. Without being able to obtain certification, there is no business case. A foreign manufacturer several years ago did develop a prototype handheld transponder unit but was unable to obtain certification from any country because the power output was too low.

Even if low power units were legal, developing a "cheap, low power transponder" is a market driven decision; the SSA can only make manufacturers aware of the market. The development costs for such a limited market make them expensive, as we've seen with the newer transponder units developed for gliders that have entered the market place in the last several years. In addition, ADS-B will render transponders obsolete as a technology within the next decade or so, further eroding the potential marketplace for new designs.

It now makes more sense to work for "cheap, low power" ADS-B equipment, and the SSA, AOPA, and others are pursuing this strategy.

Appendix

Glossary

ADS-B "Automatic Dependent Surveillance – Broadcast" A GPS based system to replace ATC radar and transponders.

AH amp-hours; ampere-hours: a measurement of a battery's current capacity

AIM "Aeronautical Information Manual" -- the FAA's official guide to basic flight information and ATC procedures. The AIM is available as book or CD from the local airport or catalog dealers, or you can get it from the FAA website under "Manuals" at:

www.faa.gov/airports_airtraffic/air_traffic/publications/

AOPA Aircraft Owners and Pilots Association (www.aopa.org)

ATC Air Traffic Control

ATCRBS ATC Radar Beacon System - the system of interrogators, airborne transponders and display screens that allows ATC personnel to track aircraft.

Encoder A device that measures pressure altitude and reports it to a transponder.

FARs Federal Aviation Regulations - the rules that U.S. aircraft and pilots must follow. Rules pertaining to transponders are found in FARs 91.215, 91.217 and 91.413. You can read these on the FAA website at: tinyurl.com/2dp9hr

FLARM the name (not an acronym) of a collision avoidance system originally developed for gliders (see www.flarm.com).

Flight Following Getting VFR radar advisories from ATC.

ma milliamperes; milliamps: 1 amp = 1000 ma

PCAS “Portable Collision Avoidance System” – trademark of Zaon Flight Systems, used to describe portable devices that detect transponder signals and warn users of their presence.

Primary radar Radar that uses the radar signal’s reflection from the aircraft to detect it.

SLA “Sealed Lead Acid” – refers to lead acid batteries that are “sealed”, so they don’t leak, can be used in almost any position, and fluid can not be added. Normal charging doesn’t release any gas from the battery, but a safety valve prevents excessive pressure if a problem develops. The most common type of battery used in our gliders.

Squawk The term used by ATC to specify a transponder code. A pilot told to “Squawk 1234” sets the transponder code to 1234. Except by special arrangement, pilots not in touch with ATC squawk 1200 -- the standard VFR code.

TAS True airspeed.

TCAS “Traffic Alert and Collision Avoidance System” – a device found on most commercial passenger-carrying aircraft that interrogates nearby transponder-equipped aircraft and provides traffic advisories to the pilots.

TIS “Traffic Information Service” - a first-generation traffic system that supports cockpit depiction of traffic, using a TIS service available from 107 Mode S terminal radars

TPAS “Traffic Proximity Alert System” – trademark of Monroy Aerospace.

Transponder A device that receives and then transmits a signal. In an aircraft, a transponder receives a signal from ATC or a TCAS-equipped aircraft and responds with a signal that includes a numeric code and possibly altitude and other information.

TSO “Technical Standard Order” - a minimum performance standard issued by the FAA for specified materials, parts, processes, and appliances (e.g. instruments and avionics) used on civil aircraft. When a device is “TSO’d”, it has been certified to conform to applicable standards and is thus legal to install and

use in aircraft. For brain numbing detail, see:

www.faa.gov/aircraft/air_cert/design_approvals/tso/