Scottish Gliding Union Flarm Trial

(With emphasis on use during training and local ridge soaring)

February to October 2007

CONTENTS

Page

Introduction

Flarm is a GPS based aid to the See and Avoid method of collision avoidance. It was originally developed by pilots whose main soaring domain was the Swiss Alps and was introduced in 2004. Since then there has been a rapid and voluntary uptake of Flarm and at the time of writing over 9000 units are in use in Europe, Australia & South Africa. English language trials of pilot opinion, based on questionnaire evidence after thermal flying, have been published in South Africa and Australia.

The basic operating method is that each unit computes a projection of its future path over the next 30 seconds and broadcasts that projection – other units receive all the other predicted paths within range and look for intersections with their own predicted paths. If there is such a predicted intersection then the Flarm unit displays both a visible and audible alert to the pilots of both aircraft. There are a number of different technical solutions for the display of this information but by far the most widely used at the present time is a small LED rose display either integral to, or mounted remote from, a small combined GPS/low power transceiver unit.

In addition to providing collision alerts, Flarm LED displays can optionally give a non-alarm indication of the direction to the single nearest Flarm transmitting glider within 2km range. Alternative display types are also available e.g. an LCD image giving a simulated "radar" picture of gliders within range.

When considering the possibility of introducing Flarm to UK gliders it became apparent that there are some local gliding conditions that might affect the effectiveness of Flarm and which deserved special consideration. Of particular relevance to the Scottish Gliding Union (and some other clubs) is the intensive use of short ridges for training and local soaring flights. This raised questions such as:

- What happens in a congested flying environment such as our local ridge? Previous experience of Flarm had been mainly in thermal soaring and Alpine mountain conditions and there was no published evidence about the value of Flarm in a congested UK ridge soaring environment.
- Does the frequency of alerts cause pilot overload or distraction in the cockpit?
- Does Flarm cause pilot complacency with regard to lookout?
- There was no published material about the integration of Flarm into ab initio or ongoing gliding training. Should this be developed?

It was with a view to answering some of these concerns that the Scottish Gliding Union decided to undertake a trial under the overview of the Chairman of the BGA Instructors Committee.

The trial leaders, listed below, came from backgrounds that ranged from enthusiasm for the concept of FLARM to some degree of scepticism, but all were committed to as objective an assessment as possible.

Colin Hamilton, Instructor, Scottish Gliding Union.
Donald Irving, Chairman of the BGA Instructors Committee
Neil McAulay, Chief Flying Instructor, Scottish Gliding Union
John Galloway, pilot.

This report covers the period of the trial between February and October 2007 during which time interim impressions and recommendations were fed back to Swiss Flarm (the original system developer). Some of these were included in software updates that progressed through versions 3.07 to 3.11 during the course of the trial. Several of the main trial conclusions and recommendations have already been submitted to Swiss Flarm who are actively considering whether and/or how to implement them. This report, therefore, details the current status of the trial, the outcomes to date and gives recommendations for further study and investigation into possible recommended practices. Where relevant, comments from Swiss Flarm regarding our findings have been inserted into the text of Appendix 1.

Trial Design

Seven Swiss Flarm units were loaned by LX Avionics Ltd to the Scottish Gliding Union for use in the trial. Units were fitted in the rear cockpit of four club two-seater gliders and three were fitted in privately owned single seaters belonging to trial participants. Two privately owned LX Flarm equipped gliders were also used when available. All gliders used small audio/LED displays. One single seater also had an LCD "radar" display available. One pilot had the LX voice unit installed in a single seater glider. Later in the trial, Artronic remote LED display units were fitted in the front cockpits of the club two-seaters.

Phase 1- Operational Performance and Collision Scenario Testing

This phase was designed to be a learning phase to assess the technical functioning and operability of Swiss Flarm units in the glider cockpit and to develop simplified instructions to use as briefing for other pilots. On safety grounds, it was felt essential to avoid general club members trying to fly unplanned test collision paths. These tests were performed using self-sustaining gliders remote from the high-density ridge soaring environment.

We assessed the collision detection performance of Flarm by means of the trial leaders flying a series of planned simulated collision scenarios in pairs of single seat gliders. Straight approaches from all angles were studied, as well as scenarios such as one glider turning into the path of the other and one glider approaching a circling second glider. Head on approaches were abandoned at the third stage (8 second) alert. Scenario testing was primarily to look for false negatives; we were deliberately flying on collision courses so an alarm was to be expected but the lack of an alarm was not.

It was judged that it would not always be possible to accurately assess the validity of Flarm warnings by in-flight pilot impression and, when necessary, we used post flight analysis of GPS flight recorder traces to distinguish between true collision courses and near misses. We established a Flarm trial internet discussion group, which enabled us to post and examine Flarm flight records of relevant flight scenarios during this and later phases of the trial.

Phase 2- Instructor Familiarisation and Flarm Flying Experience

After analysis of experience gained, we presented our preliminary findings and briefing materials to the club instructors with a view to disseminating understanding of the use of Flarm via the instructor cadre. This helped instructors to become familiar with the equipment in a way that allowed learning to be separated from operational performance assessment.

We fitted Flarm units into the rear cockpit of club two-seaters to give instructors experience in the use of Flarm and to increase the number of units in the SGC Flarm cluster. Particular attention was directed towards:

- the performance of Flarm in our busy ridge soaring environment
- the impact of Flarm use during instructional flights
- techniques that need to be developed for including FLARM instruction in future training
- the ease of use of the FLARM/pilot interface
- to determine whether there were any "human factors" (e.g. overload or complacency).

We were able to gain feedback from the principle club instructor staff over a period of months. This phase continued throughout the rest of the trial period and naturally progressed into issues not necessarily associated with the ridge soaring environment but of wider operational use. Lively discussion and debate amongst trial leaders and some club instructors on the SGU Flarm trial online bulletin board was very effective at identifying issues as they arose.

During this phase, Flarm trial pilots were also able to gain experience of using Flarm in thermal and wave conditions.

Unlike previous Flarm trials we decided not to use a questionnaire directed to the general club membership because the relatively small number of Flarm equipped gliders meant that most club members did not have the opportunity to become familiar with Flarm. On the other hand, we had a small number of experienced and professional club instructors who developed a deep understanding of the use of Flarm and good range of differing opinions about it.

Phase 3- Ridge Soaring Congestion trial and Targeted Questionnaire

Development and execution of a one-day "ridge soaring congestion trial" that was held on 20th May 2007.

This was a significant aspect of the trial at Portmoak in which we used simultaneously the available units to create a dense Flarm environment on our local 3.5km long ridge. None of the trial leaders flew in the congestion trial and only one was a respondent to the questionnaire.

By this time some of the pilots involved had experience of the use of Flarm in ridge soaring and on training flights but others had little Flarm experience. We were already aware of some of the human factor, training and technical issues reported. This phase enabled us to estimate to what extent these issues were manageable when a number of Flarm equipped gliders were soaring on the ridge in relatively close proximity to each other.

We used a targeted questionnaire directed to pilots in the "congestion trial" and to other Flarm-experienced pilots and instructors, to determine the aggregated, informed opinion as to the benefit or dis-benefit of Flarm in a congested ridge soaring and training environment. This gave us a method of checking that the impressions of the trial leaders were in accord with those of other Flarm users.

Results: *Phase 1*

Operational Performance and Collision Scenario Testing

These tests were performed using self-sustaining gliders remote from the high-density ridge soaring environment.

The well-briefed pilots found Flarm easy to understand, to give alerts when expected and not to omit alerts when they would be expected. In this first phase, we concluded that Flarm was extremely good at identifying and giving alerts of potential collision events. We could not identify any definite false negatives, however, in 90-degree side on approaches, one glider could pass very close behind the other without a collision warning. Analysis of GPS tracks in these cases confirmed that there had not been a path intersection, and so FLARM was correct, but we sometimes felt subjectively that we would have like to have had a warning in that situation.

In this phase, we thought that the height buffer zones were generally well judged. Although it was noticeable that there seemed to be some variation in vertical separations that did or did not cause an alert we felt that, given the variables of altitude measurement accuracy and glider speed/height exchanges, the altitude buffers were operating as we would wish for general cruising flight.

In head-on approaches, it was notable how small and far away the other glider looked when only 18 seconds from impact at normal cruising speeds.

Results: *Phase 2*

Instructor Familiarisation and Flarm Flying Experience

During this phase of the trial a number of issues emerged some of which carry over into other modes of flying. These are discussed in detail in Appendix 1 under three headings, **Technical Issues**, **Human Factors** and **Training Issues**.

Appendix 1 forms an integral and substantive part of this report, being the full text of the findings of this phase of the trial and the responses to date from Swiss Flarm regarding our feedback to them. It represents a snapshot in time of the issues and it should be appreciated that some aspects may become superseded because of ongoing development of Flarm software, but other aspects may remain as issues to be considered when operating Flarm.

To highlight some of the principal findings during this phase:

- The "nearest glider" indication was well received by most pilots. At the extremes of opinion, one pilot felt that it was more useful than the collision alert, whereas another did not think it was useful at all without some indication of when another glider was very close by – even if not currently on a collision course.

- For general flying, e.g. in low density thermal soaring and in cruising flight, there was overall agreement that Flarm collision alerts were given appropriately and that Flarm had the potential to be of significant benefit to flight safety if used appropriately.

- In the situations of thermalling in the close company of several other Flarm equipped gliders, or soaring on a congested ridge, there was general agreement that Flarm could be distracting to some pilots because of collision alerts that they felt were not necessary. The extent to which this was felt seemed to vary; some pilots were content to have the alerts displayed as a general "wake up call" to concentrate their mind on lookout but others felt that they preferred to turn off the alert volume or have Flarm alerts temporarily disabled in these circumstances.

- When ridge soaring in strong winds, the significant crab angles, and the fact that Flarm displays alerts relative to track and not to heading, often caused confusion about the exact direction of a threat. A difference of up to approximately 60 degrees was sometimes observed between the threat direction relative to the glider heading compared with that indicated relative to the 12 o'clock position on the Flarm display.

- In low speed flying in busy ridge or thermal conditions there was general agreement that we would prefer to have smaller altitude buffers if that is technically possible without undue loss of flight safety.

- The importance of human factors and education in the use of Flarm became ever clearer.

Results: *Phase 3*

Ridge soaring congestion trial

Those pilots flying with Flarm were asked to complete a two-part questionnaire regarding their experiences with Flarm. Part 1 asked about their previous experience flying with Flarm remote from the ridge soaring environment. Part 2 asked for their experience of Flarm in the ridge soaring.

In summary, pilots were asked their view of the safety benefit of Flarm ranking from "considerable dis-benefit" (1 point), to "considerable benefit" (6 points) from three perspectives: -

a) remote from the ridge;
b) in the ridge soaring environment; and
c) overall

The aggregated opinion of these pilots was as follows: -

Situation	**Average Benefit Score**
Remote from ridge	**5.6 / 6**
Ridge soaring	**3.8 / 6**
Overall	**5.1 / 6**

Appendix 2 gives fuller details of questionnaire and a summary of the results.

Discussion

The main function of Flarm is as an aid to See and Avoid that can alert the pilot to a potential intersection with a glider that he may not have been aware of because of e.g. poor visibility, poor look out, or the other glider being out of his field of view. Our experience has shown that in general cruising flight, and in low density thermal and ridge soaring, Flarm is very effective at giving appropriate warnings about gliders approaching from a distance on a collision or near miss flight path – the glider that "just appears out of the blue". However there is a trade-off between the benefit of alerts of this type that help the pilot to see and avoid such a collision or near miss and the distraction of those that do not give new information. **In general local soaring and thermal or wave cross-country flying we conclude that the trade-off is very favourable and that widespread use of Flarm will be of considerable benefit to flight safety.**

Club pilots and instructors gained a significant amount of experience of ridge soaring with Flarm. In a dense low speed environment such as local ridge soaring, especially, in high winds, we identified some issues that tended to reduce the acceptability of Flarm. We believe that a combination of technical refinement of the software (and, possibly, the hardware), combined with pilot education about the characteristics and use of Flarm, have the potential to increase the benefit of Flarm in that situation.

Although we had less experience of the use of Flarm in thermal gaggles our impressions tended to confirm the advice from the Flarm manufacturers about the primacy of See and Avoid over reliance on Flarm alerts in gaggles. For example, no technical solution can prevent poor airmanship such as one glider turning into the path of another glider that is very close to it.

Our experience has confirmed that gliding imposes very specialist requirements on aircraft collision alert systems because of the constant glider energy exchanges and, frequently, close proximity flying. The fact that each Flarm unit broadcasts a glider specific prediction of its own future path is necessary to enable Flarm to operate to function satisfactorily in gliding. However that characteristic (as well as the track versus heading issue that we have identified) also introduces the possibility that some Flarm alerts may not be not displayed exactly where the pilot might expect from a perfect "magic box" if one or other glider's flight path varies from Flarm's prediction. We believe that the best safety benefit from Flarm will be gained when pilots have gained a full and realistic idea of the characteristics of the system by briefing or training.

We believe that the Flarm software is already very useful for general gliding and we recognise that many of the issues and technical recommendations we have highlighted originate from our trial being carried out in a different soaring environment from previous trials. There are, however, several other busy ridge soaring sites in the UK for whom our finding may be directly relevant and, furthermore, we think that some of our technical recommendations may enhance the usability of Flarm for all users.

The trial group at Portmoak hope to undertake further analysis and, by providing feedback to the manufacturer, to help to enhance the contribution Flarm may make to flight safety in the future. The Board of Scottish Gliding Union have purchased Flarm units and displays for both cockpits of their two seaters and they are continuing to use them on an ongoing trial basis and are considering whether and how to integrate Flarm into their normal flying activities.

Conclusion and Recommendations

The main outcome was that, **overall, Flarm would be of considerable benefit to flight safety.**

This benefit will be maximised if the technical, human factor and training issues reported here are constructively addressed. To this end our recommendations are:

1. The British Gliding Association to consider whether it should encourage the voluntary uptake of Flarm compatible technology in the UK gliding fleet over the next two to three years.

2. Instructional techniques and materials to be developed to aid training about the use of Flarm for new and established glider pilots.

3. Swiss Flarm to continue addressing the specific technical issues raised in Appendix 1 of this report.

4. Further studies to be considered:

    - The Scottish Gliding Union Flarm Trial Group would like to repeat the ridge soaring congestion trial after possible future Flarm software revisions that address the relevant issues raised in Appendix 1.

    - Examination of alternative Flarm hardware solutions and displays.

    - Trials of Flarm in flatland thermal soaring gliding sites.

Appendices

1 Issues arising from Phase 2 Results.

2 Questionnaire and summary results.

3 A5 flight reference card.

4 Flarm Briefing sheet.

Acknowledgements

We would like to take this opportunity to thank:

The Board and Instructors of the Scottish Gliding Centre for their help and commitment.

Urs Rothacher of Swiss Flarm, for his support both during the trial and for his willingness to work with us to identify solutions to the issues that have emerged.

John Delafield of LX Avionics Ltd, for enabling the trial by lending the FLARM units.

John Ferguson, SGU member, for all the technical support.

Scottish Gliding Union, Flarm Trial Group. December 2007.

Appendix 1

Technical Issues

1.1 Display Operation

1.1.1 The operation of the LED rose Flarm display was not intuitive to most pilots, mainly due to the single button operation and the lack of indication as to the current settings of mode or volume or other parameters. For early flights with the unit, it was considered necessary to develop a condensed set of notes (one laminated double sided A5 sheet) for pilot reference before and after flight. In practice, this sheet also became a "flight reference card" allowing pilots to ensure that switching between modes and changing volume were done properly. (See Appendix 3 for a copy of the card.)

1.2 Height buffer zones

1.2.1 During thermalling flight, pilots occasionally found alerts to the only other equipped glider when there was a height difference with that glider estimated to be around 200ft. This was considered an excessive "buffer zone" and such alerts could be distracting pilots from attention that should be directed to gliders at similar levels rather than at such height differences.

In thermal gaggles, pilots have accepted flying in agreed close proximity and their height differences are often less than the size of the height buffers. Furthermore, normal centring manoeuvres tend to result in frequent transient predicted path intersections. The combination of these two factors can result in frequent alerts. Our experience tended to confirm the advice of the Flarm developers that pilot lookout performs better than Flarm in concentric gaggles. Pilots circling in close proximity with multiple other Flarm equipped gliders should not concentrate on the visual alert display but the audio alert serves to emphasise the need to maintain a continuous a look out in all directions - including looking outwards from the circling gliders towards gliders approaching the gaggle. It is worth remembering, however, that we found Flarm to be good at detecting and displaying possible intersections with gliders approaching the thermal.

1.2.2 During ridge soaring, flying experiences differed. On some occasions pilots reported that they would get warnings for other aircraft that were "comfortably" (comfortable being typically in excess of 200ft height difference) above or below. However, on other occasions pilots felt that no alerts had been given although flight paths were less than 100ft difference.

1.2.3 We speculated that inconsistency in the height buffer zone element of an alert might be the result of two issues; a) noise on GPS altitude from individual units and b) failure of student pilots to maintain attitude probably producing random changes in predicted vertical flight path.

1.2.4 We would suggest that the manufacturer looks at ways of making this height buffer more consistent.

Flarm comments:

We had to decide if we wanted to have the alarm levels to adapt to the situation as well as possible or keep it simple, with constant, understandable rules at the expense of significant more nuisance alarms. We have chosen the first therefore currently the "vertical buffer" and trajectory prediction includes:
- GPS accuracies (of both aircraft) - bigger buffer if position (altitude) is known to be inaccurate.
- Speed (fast speed increases probability of climbing trajectory).
- Relative track (aircraft flying parallel have smaller vertical buffer).
- Some other factors.

1.3 Track versus heading – understanding assimilation problems

1.3.1 During local ridge soaring gliders are flying at or close to their minimum speed and the wind on the face of the ridge can typically be 15-30kts. This produces a significant track versus heading difference. As Flarm only determines track, all alerts are given on the visual display in relation to a track rather than a heading. This makes it difficult for the pilots to assimilate where the threat is actually located.

1.3.2 Similar experiences would occur in both inter-thermal flight and on wave flights done on windy days.

1.3.3 We would suggest that the manufacturer examines way of determining a wind vector, even if this is just an approximation determined purely from GPS information (e.g. drift when circling) which could be used to correct the track and give a visual display that relates more closely to a heading in which to look for the threatening aircraft.

Flarm comments:

We will try a wind measurement algorithm in one of the future beta releases and would appreciate if you were be prepared to test it. For an improved system performance we don't have to have a very accurate wind measurement, but will aim for a conservative estimate (rather calculate too little wind than too much). We are also considering transmitting the wind information over the radio protocol, so the receiving units know what the sending units think the wind is and would have a "sanity test" on their own measurements.

1.4 Position display lag – understanding the location of the threat aircraft

1.4.1 During thermalling turns, when one pilot is established in the thermal and the other is racing to join him, the thermalling pilot has great difficulty in assimilating the position of the approaching glider. Pilots assumed this to be because of overall system computational lag. Depending on how tightly the thermalling pilot is turning the threat aircraft can be shown as much as 60 deg different from its actual true location. We would suggest that some modification is made to the algorithms controlling the display to advance it to show the true location of the threat direction.

Flarm comments:

This is already being done. We will check the proper implementation.

1.5 Collision alerts resulting from turn at end of a beat on ridge

1.5.1 Pilots found it difficult to find confidence in Flarm alerts given during or shortly after the turn at the end of a beat on the ridge. It was suspected that the unit switched in to a "thermalling" algorithm and remained in this mode for too long even though the turning pilot levelled his wings after 160 – 220 deg of turn.

1.5.2 It is understood that Flarm has an algorithm for predicting both straight and thermalling flight. Pilots consider that additionally a separate ridge soaring algorithm is needed to predict the path of aircraft operating in ridge soaring environments.

Flarm comments:

We will work on a ridge flight detection algorithm to better cover these flight dynamics.

1.6 **Transient collision threats from reciprocal gliders "contour following"**

1.6.1 As gliders on approximate reciprocal headings get closer whilst following the best lines of lift dictated by the local topography, alerts would be generated as expected. However, both pilots would be aware that within a few seconds their respective flight paths would be adjusted to avoid a collision. This happens on most beats and a resulting "numbing" of the alert effectiveness could materialise after long exposure. This is evidenced by some of those instructors who fly full time preferring to fly with the volume set to zero. Indeed, it was noted that some instructors would switch Flarm off altogether because of the high frequency of alerts being encountered.

1.6.2 Some pilots have suggested that the 18 and 13 second alerts should be silenced (leaving the visual alert only) when operating in a ridge soaring environment. This might be an appropriate setting in any situation where the frequency of alerts is greater than say 1 per minute.

Flarm comments:

But we would need a way of telling the PIL that the unit is in this mode. Again the trade-off here is between simple and transparent algorithms and fewer nuisance alarms.

1.7 Collision alerts from aircraft stationary on the ground

1.7.1 In the early stages of the trial it was noted that an alert would be produced against a glider on the ground, either stationary after landing or being ground handled. This caused at least one experienced pilot to react to the alert by reaching for the undercarriage lever. It was felt that such alerts could be seriously distracting especially for early solo pilots.

1.7.2 There is a user selectable option to switch off transmissions from an aircraft on the ground after it has been stationary for more than 10 seconds. This option was selected for the later part of the trial. It is recommended that this becomes the default setting. Additionally, from firmware 3.08 onwards the algorithms have been updated to eliminate such warnings.

1.7.3 Recent experience of the trial is that the combination of the above has eliminated this problem.

Flarm comments:

There was a bug in the "aircraft on ground" detection that prevented the units from entering that state under some circumstances. This has been resolved. The "no transmit on ground" is not needed as flying aircraft will never get an alert from an aircraft on the ground (unless it is moving fast e.g. tow planes on taxiing). The messages contain a status flag which clearly indicates if the other aircraft is airborne. We are therefore considering removing the "no transmit on ground" option as it only confuses the users and is of no practical value.

1.8 Stationary climbs in wave – unit stops transmitting

1.8.1 The algorithm that detects an aircraft is stationary on the ground after landing and therefore switches off the "transmission" of position etc., has been found to become active during a wave climb where the glider is turned directly into wind and can have virtually no ground speed even though it may (or may not) have a vertical speed. This would make the "stationary", wave-climbing glider invisible to any other Flarm equipped glider that may be transiting along the wave at high speed. The manufacturer has been alerted to this situation and is considering possible improvements.

Flarm comments:
To improve the "in motion" algorithm we would need the following data:-
Altitude of highest airport in the UK..
Minimum altitude where you could expect to be "standing" (groundspeed <15km/h) in ridge or wave lift for > 10 seconds

1.9 Configurable default required for setting volume at boot up

1.9.1 The current default at boot up is full volume. It could be the case that this level of volume may distract an inexperienced pilot unduly.

1.9.2 We would suggest that the volume at boot up should be user configurable and would normally be set slightly lower than maximum but not zero.

Flarm comments:

Suggestion for implementation: The unit keeps its last set volume unless it is 0 or 1 when it defaults to 2. (Volumes from 3 to 0 are possible) We will look into automatically changing volume according to speed.

Human Factors Issues

2.1 Frequency of alerts in a congested environment – becoming immune

2.1.1 During the main "congestion" trial the frequency of alerts was very high in each of the aircraft taking part. Such frequency produced different responses from the experienced pilots flying the test. These ranged from a mild comment that "I had them all in sight anyway" to "this is so disconcerting that I felt the need to switch the unit off".

2.1.2 Pilots flying with the equipment over several hundred hours of the trial gave two differing responses. In one case the pilot found that the "nearest" mode was a useful indicator as to the whereabouts of the other two-seater where typically there would only be two or at the most three equipped two seaters in the air. Another pilot said he found the unit a distraction during instruction and turned the unit off. He would also turn the unit off before allowing anyone to fly the two-seater solo so as to avoid unnecessary alerts to the front seat pilot. (The units were only installed in the back seat of the three two seaters with no front seat repeater display at this point in time).

2.1.3 Having Flarm only in the rear cockpit was a limitation of the trial. Flarm should always be controllable from the front seat of aircraft flown solo.

2.1.4 As a more recent phase of the trial, repeater units were installed in the front cockpits of the two seaters. This has necessitated configuring the master unit, mounted in the rear, to be silent. This then allows a solo pilot total control of audio in the cockpit.

2.1.5 When fitting Flarm in two seater training aircraft, consideration needs to be given to the choice of equipment and its configuration to address the controllability issues.

2.1.6 It is recommended that the various manufacturers collaborate to resolve inter-cockpit controllability issues.

Flarm comments:

The specification of the dataport is open to the public; we therefore don't have much control about what people connect to it (or what is being developed). Maybe an independent body could issue a set of "best practice" or even product recommendations. There are vast differences (already) between usability, upgradeability and configurability of seemingly similar displays.

2.2 Identifying threat position because of track versus heading

2.2.1 The technical aspect of this is given above. The human factor aspect is that despite briefing and apparent full understanding of the issue, most pilots still find it difficult to assimilate the direction of the threat when there is a large track versus heading difference and minimal time to react. This problem manifests itself in any high wind & slow flying speed environment.

2.2.2 Unless this issue can be addressed and corrected by software / firmware modification, most pilots will find the visual display detracts from the otherwise overall usefulness of the system. It is the conclusion of the trial to date that whilst audible alerts are potentially life saving, misleading visual alerts potentially detract from flight safety. It may be that a user configurable switch could be provided in the configuration file (or via the single button) allowing the visual display to be disabled in these circumstances for those pilots finding particular difficulty resolving this issue whilst flying.

Flarm comments:

This is the first report about this problem, we will look into it (could be solved with the wind estimate) but computing power is limited on this hardware.

2.3 Identifying threat position because of multiple threat in field of view

2.3.1 When the sky ahead is congested some pilots found it is easy to misidentify the threatening glider. Some pilots pick the glider on the nose say, as shown by the display, whereas in fact it is the glider off to the side. This combined with a "threat fixation" phenomenon, could be argued to reduce flight safety in the congested ridge soaring environment.

2.3.2 The "radar" display as discussed elsewhere, may go some way to resolving this issue but might introduce the problem of drawing attention into the cockpit to the detriment of look out.

2.4 Nearest indication from behind

2.4.1 Whether soaring on or remote from the ridge, some pilots found a "nearest" indication showing the other aircraft in the 4-8 o'clock sector to be of concern because it could not be acquired visually. The pilot was therefore left with no knowledge of the distance to this nearest glider behind. This resulted in some degree of mental effort wondering about this and whether it would become a threat giving an alert.

2.4.2 Clearly this mental effort detracts from look out in the normal field of view but the extent of this would vary from pilot to pilot and was not quantified as part of the trial.

2.4.3 This type of indication is one that would benefit from the 'radar' type of display but, again, to the possible detriment of look out.

2.5 Collision threat from behind

2.5.1 When a collision alert is activated showing a threat from behind, the pilot is left in a dilemma. Firstly, where is the exact location of the threat? Trying to mentally allow for the track versus heading issue when the threat is from behind is not particularly intuitive. Even if the pilot under threat gets that assessment correct, what is he then to do to avoid the potential collision?

2.5.2 It was found that, occasionally, pilots have reacted in the extreme to this type of alert. In some cases making serious violent manoeuvres, which would otherwise not have happened as, without Flarm, they would have remained blissfully ignorant of the other glider's presence. It was found by most pilots that not much more could be done than hope that the alert was enough to waken up the pilot behind in time for him to initiate a successful collision avoidance manoeuvre.

2.5.3 Obviously, the main way to deal with this is to re-emphasise the main (only!) purpose of Flarm - that **it is an aid to look out**. Without visually acquiring the threat aircraft pilots should not make any violent anti-collision manoeuvres.

2.5.4 Some pilots have suggested that perhaps a glider in front being threatened by a glider in the rear, say between 4 o'clock to 8 o'clock, should not receive the threat alert display on their Flarm unit and only the following glider should be given the alert.

Flarm comments:

Again, you are the first to report, but this is certainly worth a thought. Why alert if there is nothing the pilot can do?

2.6 Flarm in the circuit

2.6.1 Many discussions have taken place regarding the use of Flarm in the circuit. Concerns have been expressed that an alert may cause such distraction to the pilot that, for example, he might fail to adequately monitor his airspeed and then enter an inadvertent spin.

2.6.2 Comparisons have been made with the recommendations to disable undercarriage warnings to prevent similar distractions and consequences. It is reasonable to suggest that, as the consequence of landing with the wheel up is very unlikely to result in any injury to the pilot (other than damaged pride), we should disable undercarriage warning systems.

2.6.3 Pilots have to recognise that Flarm only gives an alert to aircraft, which are calculated to be on a potential collision path. It is clear that the consequence of a mid air collision is much greater than landing with the undercarriage up. Therefore, in this case, the warning is worth the risk of causing a distraction. After all, if the pilot has not already seen the conflicting aircraft then his attention has already been adversely distracted from the primary task of "look out".

2.6.4 Circuits are designed to provide for the orderly flow of traffic. In reality, we operate in an environment where aircraft travel at different speeds (tugs / gliders/ micro-lights) and often on differing merging/converging flight paths or even contra-rotating circuit directions. Accident statistics would suggest that collisions in the circuit are a reality. **It is recommended that we make use of Flarm in the circuit just the same as we would elsewhere.**

2.7 Terminology

2.7.1 There were a few instances where pilots reported feeling "panic" when an Flarm audio/visual alert sounded and the other glider was not in view – such as behind them. It is thought that this could be partly due to pilots not having a clear understanding of the meaning of Flarm alerts and that this may be exacerbated by the dramatic term, "Collision Alarm", used to describe them. This term suggests that if no, or wrong, action is taken then a collision is definitely going to occur. In fact Flarm is alerting the pilot to the fact that, if the predicted flight paths of both gliders continue, then, at the predicted time ahead, there will be some extent of intersection of the three dimensional buffer zones of the two gliders. A collision is a very possible outcome but not the inevitable one.

2.7.2 It is suggested that the term "**Intersection Alert**" would be more meaningful and accurate.

2.7.3

Training issues

3.1 Training issues

3.1.1 Many of the pilot training issues could be simplified or even eliminated if the various technical and human factor issues highlighted in this report were to be satisfactorily resolved.

3.2 Training of instructors

3.2.1 As part of the increasing use of Flarm in the UK there will be a need to ensure that Instructors are fully versed in how Flarm works so as not to introduce misconceptions into the training environment. The trial group recommend that BGA Instructors Committee produce guidance notes to aid Instructors in teaching the operational use of Flarm.

3.3 Phased training of pupils

3.3.1 We believe that a proper understanding of Flarm is essential if the safety benefits are to be realised in full and that training of new pupils in the use of Flarm must be by a phased approach. A one line introduction after “look out” at trial lesson stage through to a full operational understanding of the equipment before first solo in a two seater where both cockpits equipped. Otherwise, at first solo, the equipment, if installed only in the rear cockpit, must be set to zero volume before the aircraft is flown solo. Classroom briefing on the equipment should be carried out about mid way through the syllabus, especially, but not exclusively, at ridge soaring training sites.

3.3.2 The following sequence of “patter” is suggested: -

Air experience flight

After the lookout patter. "...Whenever you see another aircraft or glider, tell me, I’ll do the same.." Suggest " *we have an instrument which alerts us to aircraft (with a similar instrument) which might be heading in our direction and you might hear a few loud beeps and see flashing red lights. If we've been looking out ok we'll have seen it already. If not then we'd better look out quickly to find it*"

At points during the first 10 lessons during soaring flight and only after some classroom instruction. For example in normal flight on the ridge when an alert is likely:-

"...Look out in the 10 o'clock position and note we are TRACKING on a collision course with that other glider. The red lights flash and the Flarm beeps. We must check it is clear to turn and then manoeuvre to avoid the collision.... Flarm is an ***aid to look out. We must always look out to avoid collisions..."***

During subsequent soaring flights and after instruction on the ground regarding operating the single push button:-

"...Note that if we push the button: -

1 short press it does?
2 short presses it does?
3 etc..

Appendix 2

Questionnaire

<table>
<tr><td>Pilot Name & email</td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td>Date(s) of flights</td><td colspan="2">Flarm igc file</td><td colspan="2">Comment</td></tr>
<tr><td></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td>Number of sessions* with flarm</td><td>Remote from hill soaring gliders</td><td></td><td>Hill soaring with other flarm gliders</td><td></td></tr>
</table>

* If you had one flight but had a spell soaring away from the ridge(s) and then had 2 spells on the ridge that would count as 3 sessions.

Before flying with Flarm:-

1) Before flying with Flarm did you study the SGU Flarm Briefing Notes?

   Yes ☐ No☐ Comments:

2) Have you (flying without Flarm) ever been in a position where, notwithstanding your efforts to keep a good look out, you saw the other glider too late for your own comfort?

   Yes ☐ No☐ Comments

Summary

	Summary of questionnaires returned to date		
	Before flying with Flarm	%yes	%no
1	Did you study the SGU flarm briefing notes	90%	10%
2	Had pilots had previous “uncomfortable” close calls due to late observation of other aircraft?	90%	10%
	Flying with Flarm remote from ridge soaring gliders		
1	Did operating flarm increase the pilots’ in cockpit workload?	13%	88%
2	Did the flarm fail to produce warnings when it was felt it should have?	25%	75%
3	Did flarm produce any genuine false alerts?	13%	88%
4	Did flarm alerts cause you confusion?	0%	100%
5	Did flarm change your normal see and avoid procedures?	57%	43%
6	Did flarm make you complacent about looking out?	0%	100%
7	Reference to flarm igc data files	29%	71%
	Flying with Flarm amongst ridge soaring gliders also equipped with flarm	%yes	%no
1	Did operating flarm increase the pilots’ in cockpit workload?	20%	80%
2	Did the flarm fail to produce warnings when it was felt it should have?	20%	80%
3	Did flarm produce any genuine false alerts?	30%	70%
4	Did flarm alerts cause you confusion?	50%	50%
5	Did flarm change your normal see and avoid procedures?	44%	56%
6	Did flarm make you complacent about looking out?	0%	100%
7	Reference to flarm IGC data files	57%	43%
	Benefit (maximum score = 6)	Average	
	Remote from the ridge	5.6	
	On the ridge	3.8	
	Overall	5.1	

Appendix 3

Flight Reference Card

Operating Swiss FLARM

Version 3
Last modified - 29th January 2007

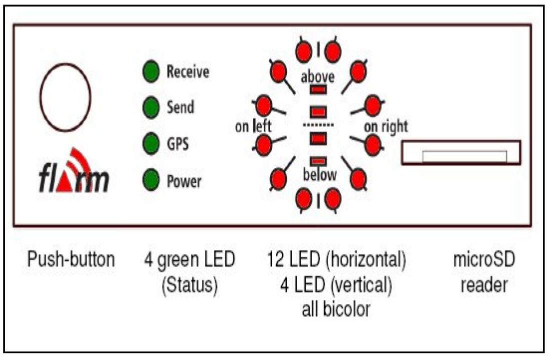
Start Up Sequence

When power is switched on the FLARM unit gives a one second beep and goes into a self-test mode during which time various LED patterns represent the hardware and software versions. It then begins normal operation and acquires a GPS fix. It is ready for operation only once the Power, GPS and Send green LEDs are continuously on.

Faults

If a fault is found then all 4 green status LEDs flash continuously for 30 seconds and the red collision LEDs give a binary indication of the nature of the fault. Refer to the manual.

Status Display (vertical row on the left)



Receive: Lights constantly when a signal is detected from another aircraft less than 2km away with a height separation of less than 500m

Send: Lights constantly during operation to indicate that FLARM is transmitting. NB it will not transmit without a GPS fix.

GPS: Flashes once per second while acquiring a fix and lights constantly when navigating.

Power: Lights constantly during normal operation as long as the power exceeds 8V.

Ready for Flight

Power, GPS and Send lights are continuously lit. The status of the Receive LED will depend on the presence or absence of other active FLARM units. The circular collision warning LEDs will all be unlit when the glider is stationary.

Push Button

Brief Push: Cycles the alarm volume from LOUD>MEDIUM>QUIET>SILENT>LOUD etc.

Longer Push: (2 sec) Changes mode between NEAREST and COLLISION. There is a visual confirmation on the warning display – the lights sweep to the TOP position for COLLISION mode and to the BOTTOM for NEAREST mode. Be sure you understand these modes.

Double Push: Suppresses visual and acoustic warnings for 5 minutes – confirmed by a descending melody. In this state the unit still transmits normally to other FLARM units. A second double push cancels the suppressed operation – confirmed by an ascending melody.

Long Push: (>8 sec) Re-boot. Recommended if a fault appears.

Longest Push: (>20 sec) Reset back to factory settings. Do not use.

Powering Down

Please wait 5 minutes after landing before switching off to allow time for the flight log file to be recorded. To then download flight onto the MicroSD card interrupt the power for over 5 seconds.

Appendix 4

Example of Briefing Notes

FLARM BRIEFING NOTES

(Please also read the FLARM Operating Manual)

FLARM is an aid to See and Avoid;

Its primary function is to alert the pilot to a potential collision threat *with another flarm equipped aircraft that he may not have seen or expected* because of, for example:

- **poor visibility,**
- ***poor look out,***
- *another glider flying in his blind area,*

and thus to help the pilot visually acquire the other glider and to use his own best judgement and airmanship to avoid any risk of collision.

FLARM is not intended or expected to:

- **replace the primacy of See and Avoid for collision avoidance,**
- *be able to prevent gliders that are flying in agreed close proximity (e.g. in thermal gaggles or hill soaring) from hitting each other due to unexpected manoeuvres or poor airmanship,*
- *be an avoidance manoeuvre flight director,*
- *be used to judge whether a deliberate manoeuvre close to an already visually acquired glider is safe or hazardous.*

How does it work?

Each Flarm unit predicts its own future positions (with 3 dimensional buffer zones) at intervals in time and space and then broadcasts these predictions over a range of 2km or more to be received by other Flarm equipped gliders. When predicted buffer zones from two gliders are found to intersect then increasingly urgent **Intersection Alerts** are displayed from 18, 13 and 8 seconds before possible collision.

FLARM units operate in one of ***two pilot-selectable modes***:

In "***Collision***" mode the display only signals potential **Intersection Alerts**.

In "***Nearest***" mode the display gives an indication (steady green) of the direction to the nearest FLARM equipped glider within range but switches to "***Collision***" mode (flashing red) whenever a potential intersection is detected

Swiss FLARM Warning Lights (Version 3)

The display is compass rose of 12 bicolour LEDs showing a bird's eye view. The top is ***track*** up and each LED covers a 30 degree sector and indicates the approximate direction of a threat relative to the glider ***track.*** There are also 4 bicolour LEDs in a vertical line to indicate the vertical bearing of the threat.

Intersection Alerts

An intersection alert is indicated by a beeping tone and a flashing red light in the relevant sector of the display.

The **urgency** of the alert is indicated in three ways:

Moderate threat (less than 18 seconds):

One red LED flashes and the tone beeps at 2Hz

Medium threat (less than 13 seconds):

Two adjacent red LEDs flash and the tone beeps at 4Hz

Immediate threat (less than 8 seconds):

Three adjacent red LEDs flash and the tone beeps at 6Hz

The **vertical indication** of the threat is given by the line of 4 red LEDs in the centre of the warning rose. The uppermost and lowest LEDs light up when the vertical bearing exceeds 14 degrees.

Traffic Indication (an additional display only in Nearest mode)

When no collision warning is necessary a steady green LED in the warning rose indicates the bearing to the closest FLARM equipped glider within a range limited to 2km horizontal and 500m vertical separation. There is no acoustic signal and no indication of the distance.

Notes

- FLARM intersection alerts are given to the single predicted intersection that is ***closest in time*** and not necessarily distance***.*** There are three levels - at 18, 13 and 8 seconds from possible collision.

- Alerts may begin at less than 18 seconds from impact when gliders turn onto collision paths at closer proximity.

- A collision alert can only arise when the flight path predictions for two gliders coincide at the same point in time and space and if this condition is not met then collision alerts cannot arise ***solely*** from:

  proximity,

  one glider pointing directly at another,

  or when the flight paths of two gliders cross without being on a collision path.

- In the event of an alert FLARM ***cannot know the future intentions*** of either pilot and it cannot know which glider a pilot may have already spotted***.*** The pilot, on the other hand, may have a good idea what he and the other pilot intends and may be happy with the situation. ***This is not a "false alarm"*** any more than it would be for a P2 to say, "have you spotted that glider ahead".

- The warning directions on the FLARM display are ***relative to the glider track*** (not the glider heading). In the case of a glider flying with a lot of drift then a warning shown as straight ahead on the display will represent a collision threat offset towards the direction of the track.