School of Engineering

Glider conspicuity trials held at RAF Bicester in June and October 2002

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Executive Summary

These trials were a continuation from conspicuity trials carried out in June 2000. There were 6 separate trials.

Mirror Film

The aim of trials 1, 2 and 3 was to assess the effects on conspicuity of a reflective mirror film affixed to the leading edges and the control surfaces of a Grob 109 Motor Glider. In trial 1, two motor gliders were on a converging, constant bearing path. The motor glider with the mirror film was not detected significantly earlier than a clean motor glider. However, the weather was poor for this trial, with very little sunlight. Trial 2, assessed the effect of the same mirror film, but during simulated circuits, with another glider following. In this trial, the glider with the mirror film affixed to the control surfaces was detected significantly earlier than a clean motor glider. Trial 3 again assessed the effect of the mirror film, but with a thermalling motor glider. The motor glider with mirror film affixed to the leading edges and control surfaces was detected significantly earlier than a clean motor glider. We conclude that the mirror film is very effective in improving conspicuity, providing that there is some sunlight.

DayGlo

Trials 4 and 5 assessed the effect on conspicuity of DayGlo patches on the wings of a motor glider. Trial 4 assessed the effectiveness of DayGlo during converging paths and trial 5 assessed the effect of DayGlo during thermalling turns. The motor glider with the DayGlo patches was not detected any earlier than a clean motor glider. We conclude that the DayGlo patches did not improve conspicuity.

Black Underside

Trial 6 assessed the effect on conspicuity of a black underside on the wings of a motor glider during thermalling turns. The motor glider with the black underside was detected significantly earlier than a clean motor glider. We conclude that a black underside significantly improves conspicuity during thermalling turns.

The mirror film improved conspicuity and facilitated earlier detection of the motor glider when the aircraft was turning and when in straight and level flight whilst flying simulated circuits. Whenever there was sunlight available to reflect on the mirror film, the detection distances increased significantly. The precise area of mirror film required to improve conspicuity was not determined and requires further evaluation. Similarly, although no adverse handling effects were reported with mirror film attached to the control surfaces, further evaluation is required before any recommendation of fitting mirror film to the control surfaces of gliders.
The black underside of the wings also improved conspicuity and facilitated earlier detection whilst the motor glider was executing thermal style turns. The longer term effect of the black adhesive upon the surface or structure of the GRP finish is not known, and again, further evaluation would be required before any such modifications to fleet gliders.

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Background

Following a number of mid air collisions involving gliders and considerable voiced concerns regarding glider conspicuity, preliminary trials were carried out at RAF Bicester during June 2000. The trials examined the utility of Day-Glo patches on the wings of motor gliders. A summary of the results of these trials was presented to the general gliding population in Sailplane and Gliding Magazine (Dec 2000). The findings showed that there was no significant increase in detection distance when the motor gliders carried Day-Glo patches on the wings. However, the trials provided some useful baseline data on the mean detection distances that were achievable for alerted crews. The findings of the trials raised many questions and promoted much discussion among the gliding community, particularly regarding the perceived benefits of coloured patches. With the co-operation of RAF CFS Gliding, Syerston, further trials were planned. The trials carried out in June 2000 highlighted the importance of both silhouette and reflection in detection of gliders. The following trials aimed to explore these factors and, in addition, to evaluate the Air Cadet's use of large Day-Glo stripes.

See and Avoid

The principle of see and avoid is the foundation of all flight under visual flight rules (VFR). To avoid another aircraft, it must first be seen, its presence attended to, and then, avoiding action taken as necessary. The human visual system has evolved over many millions of years for existence on the Earth's surface at walking and running pace. Human eyes did not evolve for comparatively high speed flight in open and empty space. Thus, there are a number of inadequacies with the human visual system which must be considered. The natural focal length of the eye is only a metre or so and in the absence of visual cues may even be as little as 50cm (Roscoe and Hull 1982). The capacity to focus on objects at greater distances requires some effort and is termed 'accommodation'. The human eye has evolved with a compromise capability to detect prey and threats and to then focus upon such items for identification. The eye must also have the capacity to focus on fine detail to allow intricate work. Movement is a key feature of detection, and for our ancestors, detecting movement was an important aid to survival. The same is true in aviation.

Student pilots are usually informed of the importance of a good lookout and some will be given a strategy with which to perform the task. For example, the RAF teach the art of lookout to their students in flying exercise number six 'straight and level flight'. The student is informed that:

> "the area of clear focus of the eye is very small, and so it is necessary to keep scanning to ensure the detection of distant aircraft. However, it is not possible to see a small object while the eyeball is in motion unless the eye is tracking the object. Therefore it is necessary to move the eye and then stop and look – continually moving the eyes around the sky won't help. With practice this can be a rapid process – up to 3 stops/second" (FTP3225G Vol 1, 6.1).

Thus, military pilots at least, are taught a specific lookout strategy which, it is hoped, will improve their chances of detecting another aircraft.

However, it has already been stated that movement plays a key role in detection. The frozen stance of many animals when they are threatened suggests that lack of movement aids concealment – if it did not, then the gene for such behaviour would not have proliferated. Unfortunately, an aircraft on a collision course with another aircraft has no relative movement to the other – it stays in the same position in the visual field until a few seconds before impact, when it then appears to grow in size very rapidly. At this point, depending upon the closing speeds involved, it may be too late to take avoiding action.

A further difficulty in visually detecting aircraft, is that caused by 'contour interaction'. This occurs when complex backgrounds such as clouds or ground features interact with the contours of the target aircraft and mask the outline – a form of camouflage. Thus, without movement and without a clear silhouette, aircraft will often not be detected. The RAF training manual (FTP3225G Vol 1, 6.1) suggests that pilots should look out for about 70% of the time during a flight. Combine the fact that 30% of the time pilots may not look out at all, with the lack of ability of the eye to detect an object that has a poor silhouette and little or no relative movement, and it is easy to imagine the existence of a significant collision risk. It is also questionable that any civil GA or glider pilot 'looks out' for 70% of their flight.

Studies carried out in the 1970s and 1980s, demonstrated that, during routine flights, other aircraft are often not detected. For example in one study, pilots on a cross country flight were (unknown to them) intercepted a number of times during the flight. The target aircraft was detected only 56% of the time. Furthermore, the interceptions were planned to take place during a period of low workload (Andrews 1977, 1984, 1987). A further study of U.S. private pilots reported that they only looked out for other traffic for 50% of the flight (Suzler and Skelton 1976).

Gliders

Gliders are notoriously difficult to see, partly due to their very thin wing section and small profile area, and partly due to their colour, which is usually white. There is little that can be done about the profile of a glider to increase its conspicuity. The colour of gliders is also difficult to change, and this is due to the manufacturing process of glass reinforced plastic construction (GRP). GRP aircraft must remain predominantly white in order to avoid overheating of the structure due to solar heating. It is not the colour *per se* which makes an object more or less conspicuous, but the contrast with its background. Dark colours create greater contrast with a light background and vice versa. Thus there is no ideal colour for all conditions.

Some light coloured materials have been placed on gliders in an effort to make them more conspicuous – Day-Glo orange patches have become popular, particularly with the Air Cadets. A concern with the use of such patches is that the outline of the glider or aircraft may be disrupted, thereby inadvertently causing a 'contour effect' which may camouflage the aircraft. In previous studies using RAF Hawk trainers, the standard RAF red white and blue colour scheme was shown to have a similar effect to that of grey camouflage: the aircraft was less conspicuous, perhaps due to the disrupted outline (Chappelow et al 1993). Flourescent paint has been used in past studies in a attempt to increase (powered) aircraft conspicuity, but without success (Graham 1989). A further potential problem with bright or light coloured aircraft (or patches) is that the contrast with a light background sky is further reduced.

Chappelow et al (1993) carried out trials with RAF Hawk aircraft and concluded that black aircraft were detected more easily than grey or red and white aircraft. Even so, in some trials, aircraft passed each other without detection, even though the crews were engaged in an active search for the other aircraft. With gliders being more difficult to detect than Hawk training aircraft, one can imagine that the risk of collision with a glider must be somewhat increased. Thus, this study will investigate a number of strategies to improve glider conspicuity, in an effort to reduce the risk of mid air collision with other gliders and/or aircraft.

In the previous glider trials (Head et al 2000), some factors were identified which seemed to aid detection of another glider or motor glider. The first was movement: any correction to course or 'wing levelling' seemed to make the motor glider easier to detect. The second factor was reflecting sunlight: when the sunlight glinted on any part of the motor glider, then it was detected very easily, and sometimes even when it was too far away to really make out the shape.

Reflected sunlight

To accentuate the potential to reflect sunlight, 3M© 'Mirror Film' (see Appendix) was procured for fixation to the motor glider wing leading edges. Furthermore, one of the concerns expressed by both military and civilian instructors was that of powered GRP aircraft being difficult to see whilst in the aerodrome circuit pattern, particularly from behind. In an attempt to increase the conspicuity to a following aircraft, the same 3M© Mirror Film was also affixed to the moving control surfaces of the motor glider. Samples of the mirror film and pictures of the MG with mirror film attached are presented in the appendix.

Contrast

One of the other factors which had previously been highlighted as improving (RAF Hawk) aircraft conspicuity was contrast with the background. The best colour for increasing contrast against a background sky, was black (Chapelow et al 1993). For the reasons of solar heating described above, it is impractical to paint the upper side of a GRP constructed aircraft black, but it was considered that if the underside were to be black, then this would increase contrast, and therefore conspicuity, at least during turns and thermalling manouvres, when the underside of the wing was presented. Furthermore, the solar heating problem would not be present with the underside of the wing. Thus it was proposed to test the utility of such black undersides to the wings of the motor glider. The black self adhesive material used to colour the underside of the wings is presented in the appendix together with a picture of the MG in the air.

DayGlo©

The previous conspicuity trials (Head 2000) had demonstrated no significant improvement in conspicuity and detectability with DayGlo© patches affixed to the top of the motor glider wings. However, the Air Training Corps expressed an interest in testing their own larger Day-Glo© design, as fitted to their Squadron gliders and motor gliders. Thus, it was proposed that a trial would also be carried out using large Day-Glo patches on the motor glider wings. The DayGlo© colour used is presented in the appendix together with pictures of the pattern used.

Aims of Study

1. To assess the effect on conspicuity of 3M© Mirror Film, fixed to the leading edge of the wings, tailplane and rudder of a motor glider, during constant bearing convergence.

2. To assess the effect on conspicuity of 3M© Mirror Film, fixed to the control surfaces (ailerons, elevators and rudder), of a motor glider, during simulated circuits.

3. To assess the effect on conspicuity of reflective 3M© Mirror Film on the leading edges and control surfaces, during simulating ‘thermal’ turns.

4. To assess the effect on conspicuity of the DayGlo© pattern currently being used by the Air Cadets on their gliders, during constant bearing convergence.

5. To assess the effect on conspicuity of the DayGlo© pattern currently being used by the Air Cadets on their gliders, during simulating ‘thermal’ turns

6. To assess the effect on conspicuity of a black underside of the motor glider, during simulating ‘thermal’ turns.

Aircraft involved

Two Grob 109 Motor Gliders (MG) were used for the trials. One aircraft was supplied by the RAFGSA and one by RAF CFS (Air Cadets). The aircraft were predominantly white, and were effectively identical apart from minor differences in tail markings and on-board equipment.

Crew

The aircraft were flown by experienced pilots, each accompanied by an observer. Each aircraft was crewed by both RAF and non RAF personnel: the first pilot was a 38 yr old male RAF officer with 14 years experience and 450 hours in gliders and 4,000 hours in powered aircraft and the first observer was a 61 year old male PPL holder with 30 years experience and 1700 hours in gliders and 1100 hours in powered aircraft (plus a further 9000 hours as RAF aircrew). The second pilot was a 51 year old male with 10 years experience and 800 hours in gliders and 2,500 hours in powered aircraft and the second observer was a 36 year old male with 560 hours in gliders and 180 hours in powered aircraft.

Protocol

Trial 1: 3M©Mirror Film fitted to the leading edges of the wings, tailplane and fin

Crews were briefed to fly away from a central point at 2,000 ft AGL and 70 knots ground speed (as indicated by GPS). Each pair of crew was given a set of headings to fly for both outward and inward tracks. Runs were divided into blocks of six with both MG beginning their runs at the same time, co-ordinated by a radio call.

For the first six runs, one MG flew in on a track of 225^0 for all six runs, whilst the other flew a randomised (and therefore unpredictable) track of 045^0, 135^0 and 315^0. This produced a pattern of the target MG appearing from either left, right or head on, with the direction being predictable for one MG but not for the other. When crews sighted the other MG, they called "Mark" on the radio and noted their distance from the central point as indicated by GPS. Once both MG had been sighted or the minimum distance was reached (see 'safety' below), crews reversed track and began the next run. Following six runs, the MG roles’ were reversed and another six runs were completed. Initially, the inbound runs were commenced at 5 nm from the central point. After 12 runs, crews swapped aircraft so that the 'other' crew were now searching for the MG with the 3M mirror film and vice versa. Thus the trial was fully randomised. An example of the randomisation and the direction of runs is shown in Figure 1.

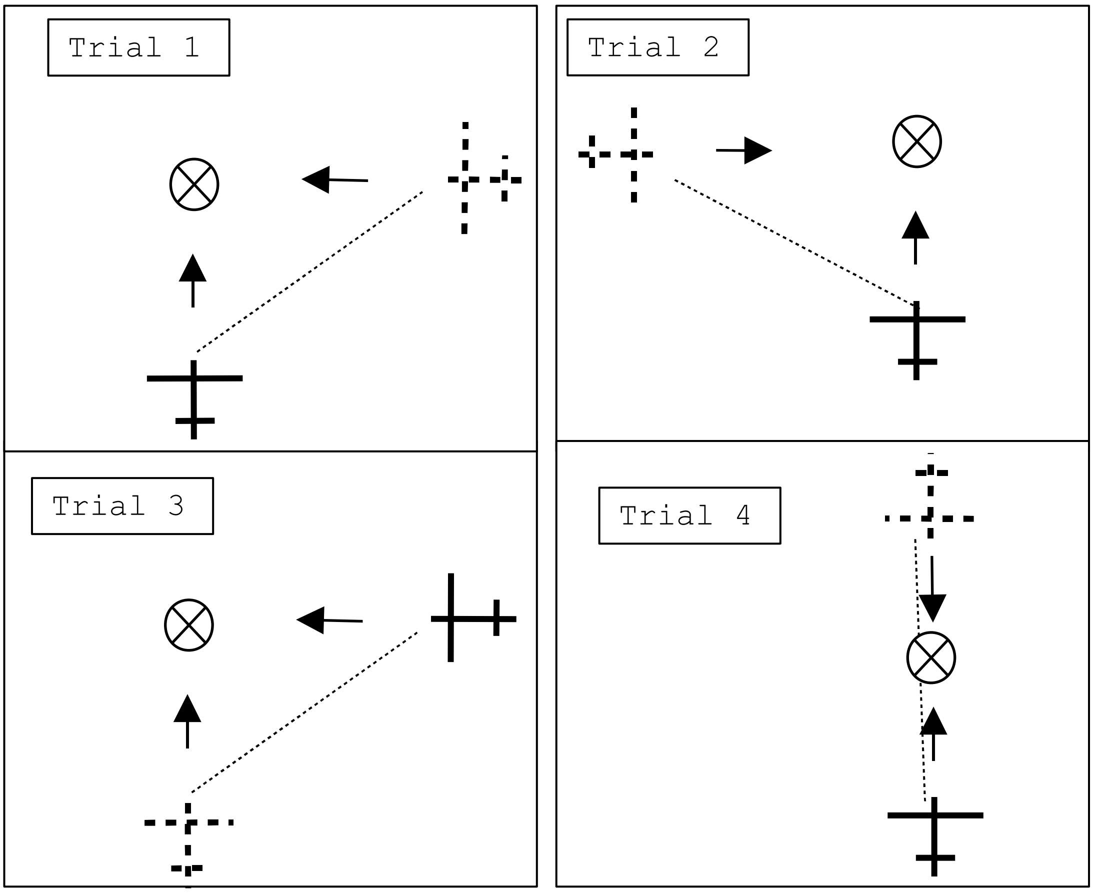

Figure 1. Example randomisation of trials.

Calculations

The distance between the aircraft was calculated by simple trigonometry, the distances of both MG from the central point being noted and recorded at the time of visual contact.

Weather

Weather was less than ideal for the trials. For the first 12 runs, visibility was 10-20 km, with only occasional sunlight and 7-8 cloud cover at approximately 2,300 ft. There were also occasional rain showers in the vicinity. For the second 12 runs, there was 8/8 cloud cover and little sunlight.

Safety

Crews were instructed to fly at the same height of 2,000 ft AGL. To minimise any collision risk, crews were instructed to turn right upon reaching a distance of 0.2 nm from the central point as indicated by GPS or by visual reference.

Results

Results are presented as mean detection distance in nautical miles (nm) ± standard deviation. An analysis of variance statistical test was applied to the data using the SPSS (version 11) statistical package.

Detection distance with and without 3M mirror film

The mean detection distance for all of the trials was 1.69 nm, with ranges from zero (i.e. undetected) to 7 nm. The MG with 3M mirror film on the leading edges was detected at a mean distance of 1.88 ± 1.71 nm and the clean MG was detected at a distance of 1.49 ± 1.07 nm. The difference between the two distances was not statistically significant ($p = 0.371$).

Predictable or non-predictable target direction

When a MG was on a predictable (i.e. known to the other crew who were searching for it) inbound track, allowing the crew of the other MG to search in only one direction, then the target MG was detected at a range of 1.48 ± 1.28 nm. When the path of the target MG was not predictable, then the MG was detected at a range of 1.9 ± 1.56 nm. The difference between the two detection distances was not significant ($p = 0.28$).

Crew differences

Crew One obtained a mean detection distance of 1.39 ± 1.23 nm, and Crew Two obtained a mean detection distance of 1.98 ± 1.57 nm. Again, the difference between the two crew's detection distances was not significant ($p = 0.135$).

Discussion and conclusions

Although every effort was made to standardise conditions and randomise variables, the trial was held in less than ideal weather conditions with only occasional sunlight. The overall mean detection distance of only 1.69 nm with a range of zero (undetected) to 7 nm, reflects the poor conditions. During previous trials, in much more representative weather conditions, the overall mean detection distance was 2.54 nm, with a range of 0 to 5 nm. However, even though the mean detection difference between the MG with the mirror film and the clean MG was not significant, the crews commented enthusiastically that when there was any sunlight, then the MG with the mirror film could be easily seen due to the flashes of sunlight being reflected. Indeed, the fact that the MG with the mirror film was detected at 7 nm on a relatively poor day suggests that the system has considerable potential. A further subjective and unprompted observation was made by duty airfield personnel, that the motor glider with the mirror film was very noticeable upon return to the airfield following the trials, particularly when the MG was approaching into the sun.

It is interesting to note the variation in detection distances with random and predictable target paths. When the path of the target MG was predictable, allowing the crew to search in a limited area, the mean detection distance was 1.48 nm. When the path of the target MG was unpredictable, forcing the crews to search over a much wider area, then the mean detection distance was non-significantly greater at 1.9 nm. This trend toward a difference in detection distance could have been due to the variable weather conditions on the day, but could also be a demonstration of the superior ability to detect target movement utilising peripheral rather than foveal vision.

The variation in detection distances with different crews should not be understated. One crew member consistently outperformed the others and was usually the first to detect a target, regardless of the configuration. However, the randomization of the crews ensured that this variation did not affect the overall result.

The mean detection distance for all runs was 1.69 nm which, at a ground speed of 70 knots for each aircraft represents a head-on closing speed of 140 knots and a time to collision of only 43 seconds. The danger of failing to maintain a very good lookout for only a short period of time is obvious, especially in less than perfect weather conditions.

In conclusion, the present study did not demonstrate a significant increase in detection distance with the use of the reflective mirror film on the leading edges of the MG. The adverse weather influenced the study, and the conditions were not representative of normal soaring conditions. However, there was a trend toward increased conspicuity with the mirror film and, the subjective evaluation from the crews was that the system worked very well when there was sunlight present to create a reflection.

Further research

Gliding usually takes place when there is sunlight available to initiate thermals. The present study was held, through operational necessity, in weather that was not representative of normal soaring conditions. It is unsurprising therefore that there was no significant increase in conspicuity with the use of reflective Mirror Film in such overcast conditions.

Trial 2: 3M© Mirror Film affixed to control surfaces (and wing leading edges) during simulated circuits

The aim of trial 2 was to simulate aircraft in a circuit pattern, and to determine if 3M© Mirror Film affixed to the control surfaces: ailerons, elevator and rudder, would increase the conspicuity of the leading aircraft and therefore, its detectability by a following aircraft. The MG had 3M© Mirror Film affixed also to the leading edges, but of course these would not be visible from a pursuing MG.

Aircraft, crews and randomisation were similar to those in trial 1. The pattern flown by the MG is shown in Fig 2.

The motor glider (MG) with the 3M© Mirror Film fixed to the control surfaces departed first from the central point and flew for four to five minutes at a randomised, predetermined speed, on a known GPS track. The speed was not disclosed to the crew of the detector (following) aircraft to ensure that they could not anticipate where they should make visual contact with the MG to be detected. The altitude flown by both lead and follow MG was 1000ft (standard altitude for most circuits).

After five minutes, the following (detector) MG began following along the same GPS track as the lead MG, but at 90 knots IAS. At a predetermined and randomised time, the lead MG slowed to 60 knots indicated air speed and continued at this speed until detected or until the trial was terminated. On visual contact each aircraft logged their GPS positions and noted their distance from the run start point. Once spotted, the target MG then began another run in a different but pre-determined direction and the process began again. 6 runs were completed with the clean MG leading and 6 with 3M© Mirror Film MG leading. Crews then swapped and the two sets of 6 runs were repeated. Thus the aircraft and the crews were fully randomised. 24 runs were carried out in total.

The runs followed a pattern similar to that demonstrated in Figure 2, to allow for the different positions of the sun within the simulated circuit.

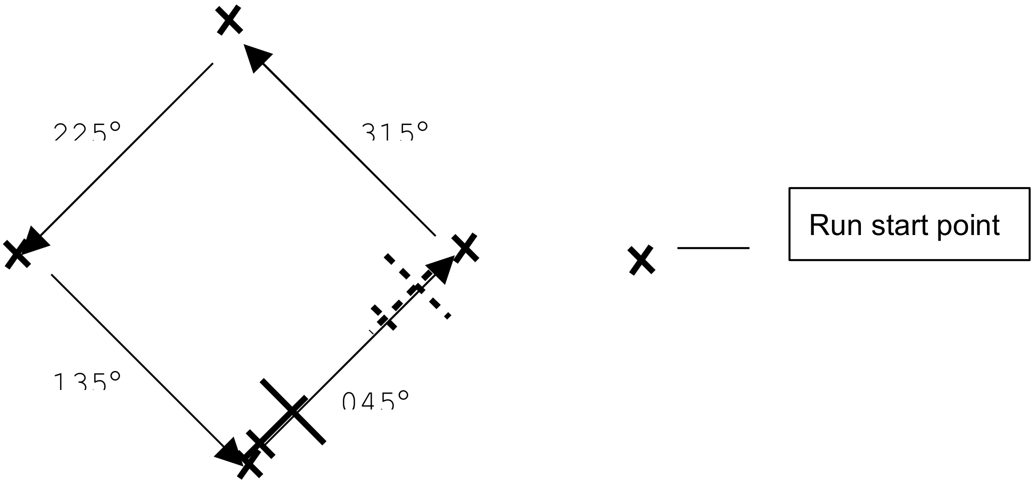

Figure 2: Simulated circuit runs

Calculations

When the leading MG was detected, a radio call was made and the distance between the two MG was calculated by noting the distance of each from the start point of each run.

Weather

Visibility was 10-20 km, with sunshine and showers. The order of the runs was amended to avoid the direction of the showers.

Safety

Crews were instructed to fly at the same height of 1,000 ft AGL. The closing speed between the leading and following MG was only 30 knots, therefore crews were not required to break off at any point, but were asked to continue until the lead MG was spotted.

Results

Results are presented as mean detection distance in nautical miles (nm) ± standard deviation. An independent samples t-test was applied to compare the data from the two trials, using the SPSS (version 11) statistical package.

Detection distance with and without 3M mirror film

There were 3 runs, one with the clean MG leading, and two with the mirror filmed MG leading, when no contact was made and pursuit was abandoned due to both MG encountering adverse weather. The data from these runs was omitted from the results, thus data is from a total of 21 runs.

The mean detection distance for all of the trials was 2.85 ± 1.2 nm, with ranges from 0.6 to 5.2 nm. The MG with 3M mirror film on the leading edges and control surfaces was detected at a mean distance of 3.39 ± 1.10 nm and the clean MG was detected at a distance of 2.36 ± 1.12 nm. The difference between the two distances was statistically significant (19 d.f., $t = 2.14$, $p = 0.045$).

Conclusions

In the simulated circuits, the MG with the Mirror film affixed to the leading edges and the control surfaces, was detected significantly earlier than the clean MG. It is assumed that the mirror film on the leading edges did not contribute to the earlier detection, as this would have been facing away from the pursuing MG. Therefore, we conclude that the 3M© Mirror Film on the control surfaces increased the mean detection range by approximately 1nm. Even in the less than ideal weather conditions of the trials, with only intermittent sunshine in between the showers, this is a most encouraging finding. It is proposed that the constant movement of the control surfaces assists in the likelihood of there being a reflection and a glint of light which facilitates conspicuity, and of course, earlier detection. The addition of Mirror Film tape to the control surfaces would appear to be a simple and effective aid to safety, allowing earlier detection of another aircraft in the circuit pattern.

The mirror film is only a few thousands of an inch thick, and the crews reported no adverse effects upon the handling of the MG. However, further engineering investigation would be required before any recommendation to widely fit such reflective material on a fleet of gliders or motor gliders.

Trial 3: **3M©Mirror Film on leading edges and control surfaces, during simulated 'thermal' turns.**

The aim of trial 3 was to simulate Gliders in thermalling turns, and to determine if 3M© Mirror Film affixed to the leading edges of the wings, tailplane and fin and to the control surfaces: ailerons, elevator and rudder of the motor glider (MG), would increase the conspicuity of the MG whilst thermalling and therefore, its detectability by an approaching aircraft.

Aircraft, crews and randomisation were similar to those in trial 1. The pattern flown by the MG is shown in Fig 3.

The motor glider (MG) with the 3M© Mirror Film was positioned at randomised distances from a known point, at right angle to an approaching MG.
The approaching MG was flown from an initial distance of 5 nm at 60 knots on a direct track toward the known GPS location. The crew of the approaching MG therefore were required to search for the thermalling MG, which was either to the left or the right of the GPS co-ordinates, and at random distances of approximately 0.5, 0.7, or 0.9 nm. The altitude flown by both lead and follow MG was 2000ft.

On visual contact, each aircraft logged their GPS positions and noted their distance from the run GPS co-ordinates. Once spotted, both MG re-positioned and commenced the next run. 6 runs were completed with the clean MG thermalling and 6 with 3M© Mirror Film MG thermalling. Crews then swapped and the two sets of 6 runs were repeated. Thus the crews were fully randomised. 24 runs were carried out in total.

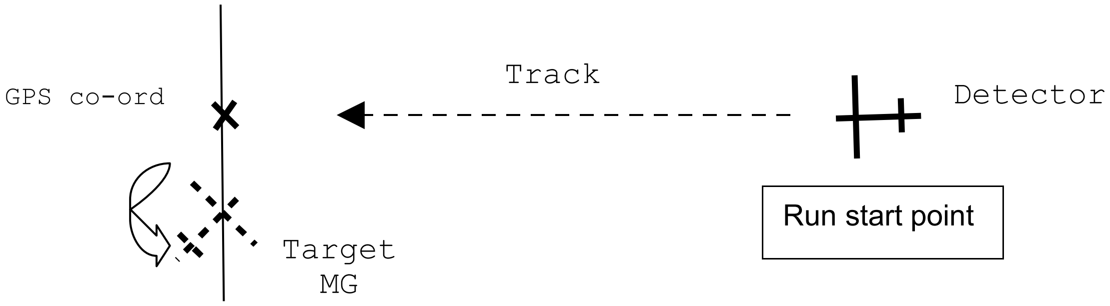

Figure 3: Simulated thermalling trials

Calculations
When the thermalling MG was detected, a radio call was given and the distance between the two MG was calculated by noting the distance of each from the GPS co-ordinates.

Weather

Visibility was more than 20 km, with sunshine and broken cloud.

Safety

Crews were instructed to fly at the same height of 2,000 ft AGL, but were asked to break off should they close to a distance of 0.2 nm from the GPS co-ordinate.

Results

Results are presented as mean detection distance in nautical miles (nm) ± standard deviation. An independent samples t-test was applied to compare the data from the two trials, using the SPSS (version 11) statistical package.

Detection distance with and without 3M mirror film

The mean detection distance for all of the trials was 4.13 ± 1.18 nm, with ranges from 1.8 to 6.5 nm. The MG with 3M Mirror Film on the leading edges and control surfaces was detected at a mean distance of 4.80 ± 1.2 nm and the clean MG was detected at a distance of 3.46 ± 0.66 nm. The difference between the two distances was statistically significant (22 d.f., $t = 3.3$, $p = 0.003$).

Conclusions

In the simulated thermalling condition, the MG with the 3M© Mirror Film affixed to the leading edges and the control surfaces, was detected significantly earlier (1.34 nm) than the clean MG. Therefore, we conclude that the 3M© Mirror Film on the leading edges and/or control surfaces increased the mean detection range by approximately 1.3 nm. The weather was not perfect for the trails, with considerable cloud being present. The finding of this trial is very encouraging. It is not possible to determine if the increased conspicuity was due to the 3M© Mirror Film affixed to the leading edges or to that on the control surfaces. However, it is likely that the constant movement of the control surfaces assists in the likelihood of there being a reflection and a glint of light which facilitates conspicuity, and of course, earlier detection. The addition of Mirror Film tape to both the leading edges and/or to the control surfaces would appear to be a simple and effective aid to safety, allowing earlier detection of another aircraft in the circuit pattern. Further trials would be required to determine the minimum area of 3M© Mirror Film that is required to elicit a significant increase in detection distance.

As with the previous trials, the crews reported no adverse effects upon the handling of the MG, but again, further engineering investigation would be required before any recommendation to widely fit such reflective material on a fleet of gliders or motor gliders.

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Trial 4: Air Cadets' DayGlo© pattern during random converging paths

As for trial 1 Crews were briefed to fly away from a central point at 2,000 ft AGL and 70 knots ground speed (as indicated by GPS). Each crew were given a set of headings to fly for both outward and inward tracks. Runs were divided into blocks of six with both MG beginning their runs at the same time, co-ordinated by a radio call. For the first six runs, one MG flew in on a track of 225^0 for all six runs, whilst the other flew a randomised (and therefore unpredictable) track of 045^0, 135^0 and 315^0. This produced a pattern of the target MG appearing from either left, right or head on, with the direction being predictable for one MG but not for the other. When crews sighted the other MG, they called "Mark" on the radio and noted their distance from the central point as indicated by GPS. Once both MG had been sighted or the minimum distance was reached (see 'safety' below), crews reversed track and began the next run. Following six runs, the MG roles' were reversed and another six runs were completed. Initially, the inbound runs were commenced at 5 nm from the central point. After 12 runs, crews swapped aircraft so that the 'other' crew were now searching for the MG with the DayGlo and vice versa. Thus the trial was fully randomised. The randomisation and the direction of runs was as for study 1, and Figure 1.

Calculations

As for trial 1, the distance between the aircraft was calculated by simple trigonometry, the distances of both MG from the central point being noted and recorded at the time of visual contact.

Weather

Weather was excellent for the trials with scattered cloud and visibility in excess of 25km.

Safety

Crews were instructed to fly at the same height of 2,000 ft AGL. To minimise any collision risk, crews were instructed to turn right upon reaching a distance of 0.2 nm from the central point as indicated by GPS or by visual reference.

Results

Results are presented as mean detection distance in nautical miles (nm) ± standard deviation. An analysis of variance statistical test was applied to the data using the SPSS (version 11) statistical package.

Detection distance with and without DayGlo©

The mean detection distance for all of the trials was 2.75nm, with ranges from 0.88 to 5.3 nm. The MG with DayGlo© was detected at a mean distance of 2.82 ± 1.29 nm and the clean MG was detected at a distance of 2.67 ± 1.26 nm. The difference between the two distances was not statistically significant ($p = 0.371$).

Predictable or non-predictable target direction

When a MG was on a predictable (i.e. known to the other crew who were searching for it) inbound track, allowing the crew of the other MG to search in only one direction, then the target MG was detected at a range of 3.05 ± 1.36 nm. When the path of the target MG was not predictable, then the MG was detected at a range of 2.45 ± 1.10 nm. The difference between the two detection distances was not significant (F=1.38, $p = 0.253$).

Crew differences

Crew One obtained a mean detection distance of 2.63 ± 1.8 nm, and Crew Two obtained a mean detection distance of 2.86 ± 1.36 nm. Again, the difference between the two crew's detection distances was not significant (F= 0.197, $p = 0.662$).

Discussion and conclusions

The weather for these trials was ideal, with sunlight and scattered cloud. The overall mean detection distance of 2.75 nm was considerably better than in trial 1 (1.69 nm) reported here, when the weather was less than ideal. In the previous trials carried out in 2000 (Head 2000), where similar DayGlo© patches were applied to the MG, the overall mean detection distance was a comparable 2.54 nm. In the 2000 trials, the MG with DayGlo© was detected at a mean distance of 2.59 ± 1.25 nm, and in the present trial the DayGlo© MG was detected at a mean and comparable distance of 2.82nm. This confirms that there was no significant improvement in conspicuity with the Air Cadet DayGlo© pattern. As the crews were different for the 2000 and 2002 trials, there can be no meaningful statistical comparison. However, the mean detection distance, in good conditions, with hyper vigilant crews, for all MG with or without DayGlo©, is only 2.64 nm.

The crews, who were initially very enthusiastic about the larger DayGlo© patches used by the Air Cadets, confirmed that they did not appear to aid conspicuity.

In conclusion, the two studies, in 2000 and 2002, which examined conspicuity of MG during constant bearing convergence, have failed to demonstrate a significant increase in detection distance with the use of the DayGlo© patches on the MG. However, there appeared to be no measurable negative effect upon conspicuity either. Any detection was consistently reported to be due to the silhouette of the MG or to a glint, and not to the DayGlo©.

Trial 5: **Air Cadets DayGlo© patches, during simulated 'thermal' turns.**

The aim of trial 5 was to simulate Gliders in thermalling turns, and to determine if the Air Cadets' DayGlo© pattern of patches would increase the conspicuity of the MG whilst thermalling and therefore, its detectability by an approaching aircraft.

Aircraft and crews were the same as for trial 4, and randomisation was the same as for trial 3, The pattern flown by the MG was the same as shown in Fig 3.

The motor glider (MG) with the DayGlo© was positioned at randomised distances from a known point, at right angle to an approaching MG.
The approaching MG was flown from an initial distance of 5 nm at 60 knots on a direct track toward the known GPS location. The crew of the approaching MG therefore were required to search for the thermalling MG, which was either to the left or the right of the GPS co-ordinates, at random distances of approximately 0.5, 0.7, or 0.9 nm. The altitude flown by both lead and follow MG was 2000ft.

On visual contact each aircraft logged their GPS positions and noted their distance from the run GPS co-ordinates. Once spotted, both MG re-positioned and commenced the next run. 6 runs were completed with the clean MG thermalling and 6 with the DayGlo© MG thermalling. Crews then swapped and the two sets of 6 runs were repeated. Thus the crews were fully randomised. 24 runs were carried out in total.

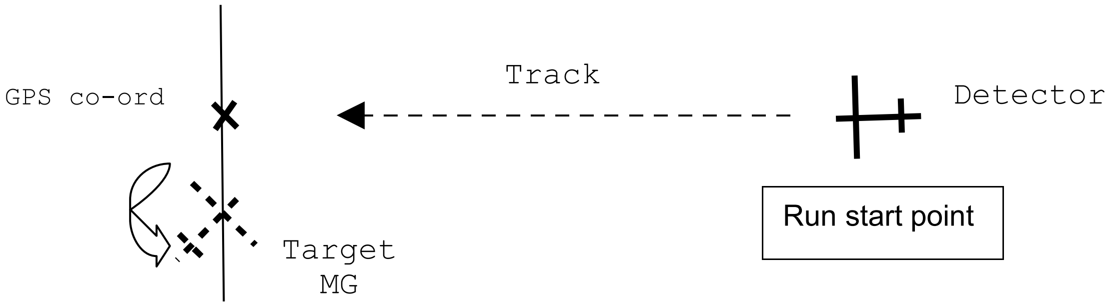

Figure 3: Simulated thermalling trials

Calculations
Upon being spotted, a radio call was given and the distance between the two MG was calculated by noting the distance of each from the GPS co-ordinates.

Weather
Visibility was 10-20 km, with sunshine and broken cloud.

Safety

Crews were instructed to fly at the same height of 2,000 ft AGL, but were asked to break off should they close to a distance of 0.2 nm from the GPS co-ordinate.

Results

Results are presented as mean detection distance in nautical miles (nm) ± standard deviation. An independent samples t-test was applied to compare the data from the two trials, using the SPSS (version 11) statistical package.

Detection distance with and without DayGlo©

The mean detection distance for all of the trials was 6.17 ± 0.77 nm, with ranges from 3.84 to 7.26 nm. The MG with DayGlo© was detected at a mean distance of 5.9 ± 0.92 nm and the clean MG was detected at a distance of 6.3 ± 0.54 nm. The difference between the two distances was not statistically significant (22 d.f., t = 1.3, $p = 0.203$).

Conclusions

In the simulated thermalling condition, the MG with the Air Cadets' DayGlo© pattern patches was not detected at any greater distance than the clean MG. In fact, the clean MG was detected slightly earlier, but not significantly so. Overall, the mean detection distance for this trial (6.13 nm) was greater than in trial 3 (4.13 nm), and could be attributed to better weather conditions.

Trial 6: Black underside of the motor glider wings, whilst simulating 'thermal' turns

The aim of trial 6 was to simulate Gliders in thermalling turns, and to determine if the black underside of the wings would increase the conspicuity of the MG whilst thermalling and therefore, its detectability to an approaching aircraft.

One MG had 3M© Black Film placed on the underside of the main wings. For operational reasons, the data from trial 5, for the clean MG was used for comparison as the 'control' condition.

As in trials 3 and 5, the motor glider (MG) with the 3M black film on the underside of the wings was positioned at randomised distances from a known point, at right angle to the approaching MG (Fig 3).
The approaching MG was flown from an initial distance of 5 nm at 60 knots on a direct track toward the known GPS location. The crew of the approaching MG therefore were required to search for the thermalling MG, which was either to the left or the right of the GPS co-ordinates, at random distances of approximately 0.5, 0.7, or 0.9 nm. The altitude flown by both thermalling and detecting MG was 2000ft.

On visual contact each aircraft logged their GPS positions and noted their distance from the run GPS co-ordinates. Once spotted, both MG re-positioned and commenced the next run. 6 runs were completed with the clean MG thermalling and 6 with the black underside MG thermalling. Crews then swapped and the two sets of 6 runs were repeated. Thus the crews were fully randomised and 24 runs were carried out in total.

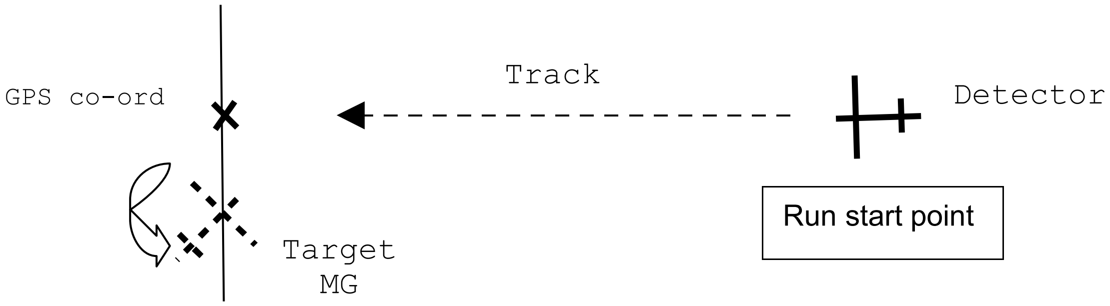

Figure 3: Simulated thermalling trials

Calculations
When the thermalling MG was detected, a radio call was given and the distance between the two MG was calculated by noting the distance of each from the GPS co-ordinates.

Weather

Visibility was more than 20 km, with sunshine and broken high cloud.

Safety

Crews were instructed to fly at the same height of 2,000 ft AGL, but were asked to break off should they close to a distance of 0.2 nm from the GPS co-ordinate.

Results

Results are presented as mean detection distance in nautical miles (nm) ± standard deviation. An independent samples t-test was applied to compare the data from the two trials, using the SPSS (version 11) statistical package.

Detection distance with and without black underside to wings

The mean detection distance for all of the trials was 6.96 ± 0.80 nm, with ranges from 5.55 to 8.52 nm. The MG with black underside was detected at a mean distance of 7.5 ± 0.54 nm and the clean MG was detected at a distance of 6.37 ± 0.54 nm. The difference between the two distances was highly significant (22 d.f., $t = 5.2$, $p = 0.0001$).

Conclusions

In the simulated thermalling condition, the MG with the 3M Black Film on the underside of the wings was detected at a significantly greater distance than the clean MG. The visibility during the trials was very good, and whilst the trials were commenced at 6 nm, it became apparent that the MG with the black underside was being detected almost immediately, so the distance from which the run began was increased to 8 nm. Even then, the MG with the black underside was detected at 7.5 nm on one occasion. Thus, it can be stated with reasonable confidence that the black underside made the thermalling MG considerably more conspicuous.

The crews noted that there was a clear difference between the underside and the top of the wings being presented. The crew in the thermalling MG observed which surface was being presented to the detector MG at the time of contact, and it was almost exclusively the black underside.

The temperature of the underside of the wing was not measured accurately, but was cool to the touch once the MG had landed. However, the trials were carried out in October, so temperatures were not high. Evaluation of the temperatures during the summer months would need to be carried out before making the underside of wings black on any fleet of gliders.

Black has once more proven to be a successful colour with which to increase the conspicuity of aircraft. With thermalling gliders in summer months, the problems of solar heading may be problematic. Therefore some monitoring of the surface temperature of the black underside would be essential before any widespread changes to gliders.

Overall summary

Overall, the trials have supported the use of a reflective mirror film on the leading edges and control surfaces as an aid to motor glider conspicuity. Furthermore, this has been demonstrated with thermalling motor gliders and in detecting an aircraft from behind whilst in a simulated circuit pattern. The black colouring to the underside of the wings also significantly increased the conspicuity of a thermalling motor glider. The average increase in the distance at which each was detected was between 1 and 1.2 nm. This increase allows a greater period of time in which there is opportunity to detect another MG, glider or aircraft, and must present a useful aid to safety and specifically to collision avoidance.

The second key point that has arisen from the trials in 2000 and 2002, is that, even when crews are hyper vigilant and are searching for an aircraft which they know is on a potential collision course, occasionally they will not see the other aircraft. This finding emphasizes the importance of increasing conspicuity wherever possible, and of a good lookout strategy.

The third key point is that movement is important to detection. The difference between the detection distances in the thermalling trials, the simulated circuits and the converging paths highlights the requirement for frequent turns if one is to be more easily detected. The thermalling MG was detected at a mean distance of approximately 7 nm when visibility was good. Even when the weather was less than ideal, a thermalling MG was detected at a mean distance of 4.1 nm. This may be compared to the 1.7 nm mean detection distance when the MG was on a converging path in poor weather and 2.7 nm in good weather. Thus, movement helps detection. One can imagine that a combination of movement, reflective mirror film (leading edges and control surfaces) and black underside would make any turning aircraft considerably more conspicuous in many different weather conditions.

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