ACCIDENT

Aircraft Type and Registration:	1) Mooney M20J, G-JAST 2) Vans RV-4, G-MARX
No & Type of Engines:	1) 1 Lycoming IO-360-A3B6D piston engine 2) 1 Lycoming O-320-E3D piston engine
Year of Manufacture:	1) 1980 2) 1996
Date & Time (UTC):	4 September 2010 at 1600 hrs
Location:	Near Ryde, Isle of Wight
Type of Flight:	1) Private 2) Private
Persons on Board:	1) Crew - 1 Passengers - 1 2) Crew - 1 Passengers - 1
Injuries:	1) Crew - 1 (Fatal) Passengers - 1 (Fatal) 2) Crew - 1 (Minor) Passengers - 1 (Minor)
Nature of Damage:	1) Destroyed 2) Extensive damage to landing gear and right wing
Commander's Licence:	1) ATPL(A) 2) CPL(A)
Commander's Age:	1) 73 years 2) 32 years
Commander's Flying Experience:	1) 17,500 hours (of which 100 were on type) Last 90 days - 28 hours Last 28 days - 8 hours 2) 2,000 hours (of which 126 were on type) Last 90 days - 57 hours Last 28 days - 25 hours
Information Source:	AAIB Field Investigation

Synopsis

The two aircraft, a Mooney M20J and a Vans RV-4, were participating in the Merlin Trophy Air Race, which started and finished at Bembridge Airport, on the Isle of Wight. The aircraft were closely matched on speed and after the last turn of the race the Mooney began to overtake the RV-4, shortly after which the two aircraft collided. The Mooney broke up in flight and fell to the ground. The pilot and his passenger were fatally injured. The RV-4 was badly damaged but the pilot managed to land at Bembridge Airport, both occupents having received minor injuries. The investigation determined that the pilot of the Mooney had probably been unable

to see the RV-4 for approximately the final 39 seconds before the collision.

History of the flight

The Merlin Trophy Air Race, with 20 participants, commenced at 1500 hrs when, in accordance with handicap racing procedures, the slowest aircraft started the race. At 1529:52 hrs the RV-4, G-MARX, was given its signal to start the race, as the sixteenth aircraft and at 1530:07 hrs the Mooney, G-JAST, was given the signal to start, as the seventeenth aircraft in the sequence. The crew of the Mooney were seen to be in good spirits as the race began. The final and fastest aircraft started the race at 1533:26 hrs.

The race progressed normally and the separation between the racing aircraft gradually reduced. On the final turn of the final lap of the race the RV-4 was overtaken by the aircraft that had started the race last. Shortly after this the crew of the RV-4 were aware that the Mooney was overtaking them from slightly behind and below on their right side. The Mooney was then seen, still below them but close in on their left side. The Mooney then moved back underneath them, to their right side, before it disappeared from view. The 'navigator'[1] in the RV-4 advised his pilot not to descend because he had lost sight of the Mooney which he believed was underneath them but slightly ahead. The RV-4 crew then felt a sudden and firm thump, after which the pilot of the RV-4 saw the Mooney passing down the right side of his aircraft and realised that there had been a midair collision. It was immediately apparent to the RV-4 pilot that the Mooney was in difficulty, as it was no longer pointing in its direction of travel. The RV-4 was now vibrating severely and the crew could see damage to their right wing.

The pilot of the RV-4 transmitted a MAYDAY call on 'Bembridge Radio', the frequency in use for the race. He considered landing in a nearby field but decided it would be safer to fly the remaining four miles to Bembridge Airport. The pilot, aware that his aircraft was damaged, attempted to call another of the racing pilots to ask for a visual inspection of his aircraft but the radio frequency was blocked by other pilots reporting what was happening to the Mooney.

The RV-4 pilot positioned his aircraft on final approach for the tarmac Runway 12 at Bembridge Airport. When he tried to lower the flaps, they did not go down symmetrically so he raised them immediately and decided that, given the uncertain state of his aircraft, the grass runway might be safer. The aircraft landed gently on the grass and the right main landing gear collapsed. The aircraft came to a halt, pitched forward onto its nose, and then the left main landing gear collapsed as the aircraft fell back onto its belly. The crew vacated the aircraft immediately but there was no fire. The fire crews were not in attendance because both fire tenders had deployed to the area where the Mooney was last seen.

After the collision, the Mooney was seen to descend and gyrate, breaking up into three main pieces and a considerable amount of smaller debris. The main wreckage fell into a wooded area, whilst the other larger items were seen to fall nearby. Paramedics were quickly on the scene of the main wreckage but it was immediately apparent that the occupants had not survived.

Witnesses

The pilot of a Bulldog aircraft competing in the race was at an altitude of 700 ft just after the final turn. He was

Footnote

[1] Aircraft with passenger seats normally carry a passenger to assist with navigation and to lookout for other race aircraft. This passenger is referred to as 'the navigator' and he is considered a member of the crew by the race officials.

slightly above and behind the RV-4 which was pulling away from him on his left side. Also on his left side was the Mooney, which had overtaken him at the same altitude. When the Mooney and the RV-4 were about 100 m ahead of him he saw the Mooney pitch nose down to about 15º and descend. This surprised the Bulldog pilot as that was not a normal manoeuvre to perform in the race and he could see no birds or other reason for the Mooney to perform such an abrupt manoeuvre. Also, the Mooney was still some distance from the point at which aircraft were allowed to descend and when they do descend they normally do so gradually. He then saw the Mooney pitch up, to what he estimated was around 15º, and climb through his level into the RV-4. There was a cloud of dust and it was obvious to the Bulldog pilot that the two aircraft had collided. The Mooney was then seen to pitch, roll and yaw, and its tail detached. The Bulldog pilot had to take action to avoid the resulting debris.

The Mooney broke up into three major components; the tailplane, the port wing and the main body of the aircraft. The Bulldog pilot flew orbits around the scene of the accident and, using his radio via ATC at Bembridge, tried to direct the emergency services to the accident site. When the emergency services arrived at the site, he returned to Bembridge Airport. The Bulldog pilot could not recall hearing any radio transmissions between the Mooney and the RV-4 in the minute prior to the accident.

Recorded data

The radio frequency in use for the race, 'Bembridge Radio', was not officially recorded. However, a video recording captured radio transmissions made during the last few minutes of the race.

Six portable GPS units were recovered from the Mooney and three more were recovered from the RV-4, together with a further GPS data source from the RV-4 pilot's Personal Digital Assistant (PDA). Two good quality data sources from both aircraft were used in the analysis of the accident. In each case, one source recorded pressure altitude and the other recorded GPS altitude, both in conjunction with GPS position and with frequent sampling.

The use of different altitude sources was important, as the recorded pressure altitudes were good indicators of vertical movement. However, the barometric sensors in the GPS units were not calibrated, so they were poor indicators of absolute altitude. In contrast, the GPS altitudes provided less robust motion information but good average absolute altitude values. Combining the data from the two sources provided a means of analysing the relative altitudes of the aircraft.

Radar data was not used in this case because of the aircrafts' low altitude, the multiple contacts in the race and the good quality of the data recovered from the GPS units.

The GPS tracks from the other racing aircraft, provided by the race organisers, helped to identify the location of the witnesses who were flying in the race at the time of the accident, and also established that no other aircraft was a factor in the accident.

The RV-4 started its takeoff roll at 1529:55 hrs and the Mooney followed 14 seconds later. The aircraft carried out four complete circuits of the race with the Mooney slowly catching up.

After the last turn on to the final straight of the fifth and final lap, the Mooney was below and to the rear and right of the RV-4. Figure 1 shows their relative positions and speeds. The RV-4 flew with a relatively stable speed and track, in a slow descent. Whilst

remaining below the RV-4, the Mooney tracked from the right side of the RV-4 to the left of its track. As it passed beneath the path of the RV-4, the Mooney started a descent, levelling off 70 ft lower. In doing so, it picked up speed and started to pass the RV-4 whilst below and to its left. The Mooney then started to climb and drifted to the right, losing speed, bringing it back to the right of the RV-4 but still beneath. This, in combination with a shallow descent and associated increase in the speed of the RV-4, resulted in a period of approximately seven seconds where the RV-4 was faster than the Mooney. The Mooney then drifted to the left of the RV-4, once more, while descending at a rate of approximately 900 ft/min, resulting in an increased speed and it pulling ahead of the RV-4. After losing 100 ft, it entered a climb, averaging about 800 ft/min, reduced speed again and climbed to the right closing on the RV-4 until the aircraft collided. The collision occurred at 1606:52 hrs at an altitude of about 675 ft amsl, over Rowlands Wood, approximately 3.7nm to the west of the Runway 12 threshold at Bembridge Airport.

The impact disrupted the still air environment inside the cockpits of both aircraft, making the pressure altitude readings unreliable, which explains the upward trace of the Mooney's altitude after the collision in Figure 1.

Obscuration of the pilot's view

The investigation modelled each pilot's ability to see the other aircraft during the moments before the collision. The RV-4 has a bubble canopy, providing good visibility in most horizontal directions and above the aircraft. However, its low wing configuration limits the pilot's view below the aircraft. The Mooney, as well as having a low wing obscuring part of the view below the aircraft, has a solid opaque roof limiting the ability of the pilot to see above the aircraft. This is exacerbated by the pilot's nominal head position being set well back from the windshield. The pilot sits in the left hand seat, well away from the right hand window, restricting his view above and to the right of the aircraft. Given that the Mooney was the overtaking aircraft, the view from this aircraft was analysed in more detail.

Data was gathered from both accident aircraft to show the relative positions of the aircraft leading up to the collision. Also, a similar Mooney was flown to gather data relating the aircraft's attitude to its motion. The data was used to derive the pitch and roll of the Mooney leading to the collision, based on the recorded motion. The positions of the window edges, relative to the pilot's nominal eye position, were also measured and used to create a model of the window apertures. Combining the relative paths of the aircraft with the model of the Mooney windows and the derived pitch and roll of the Mooney, enabled an assessment to be made of when the RV-4 was visible from the nominal view of the pilot in the Mooney.

The results indicate that the RV-4 would not have been visible from the nominal Mooney pilot's position for 39 seconds before the collision (see Figure 2). Varying the parameters to account for modelling errors changed this result to between 37 and 44 seconds.

The Mooney navigator was sitting in the right seat, which would have afforded a better view of the RV-4. However, the calculations showed that the view from the nominal right seat position of the Mooney would also have become obscured at about the same time as the pilot's view.

The view from just inside the right window would have been more favourable, losing sight of the RV-4 for approximately the last 14 seconds of flight. However,

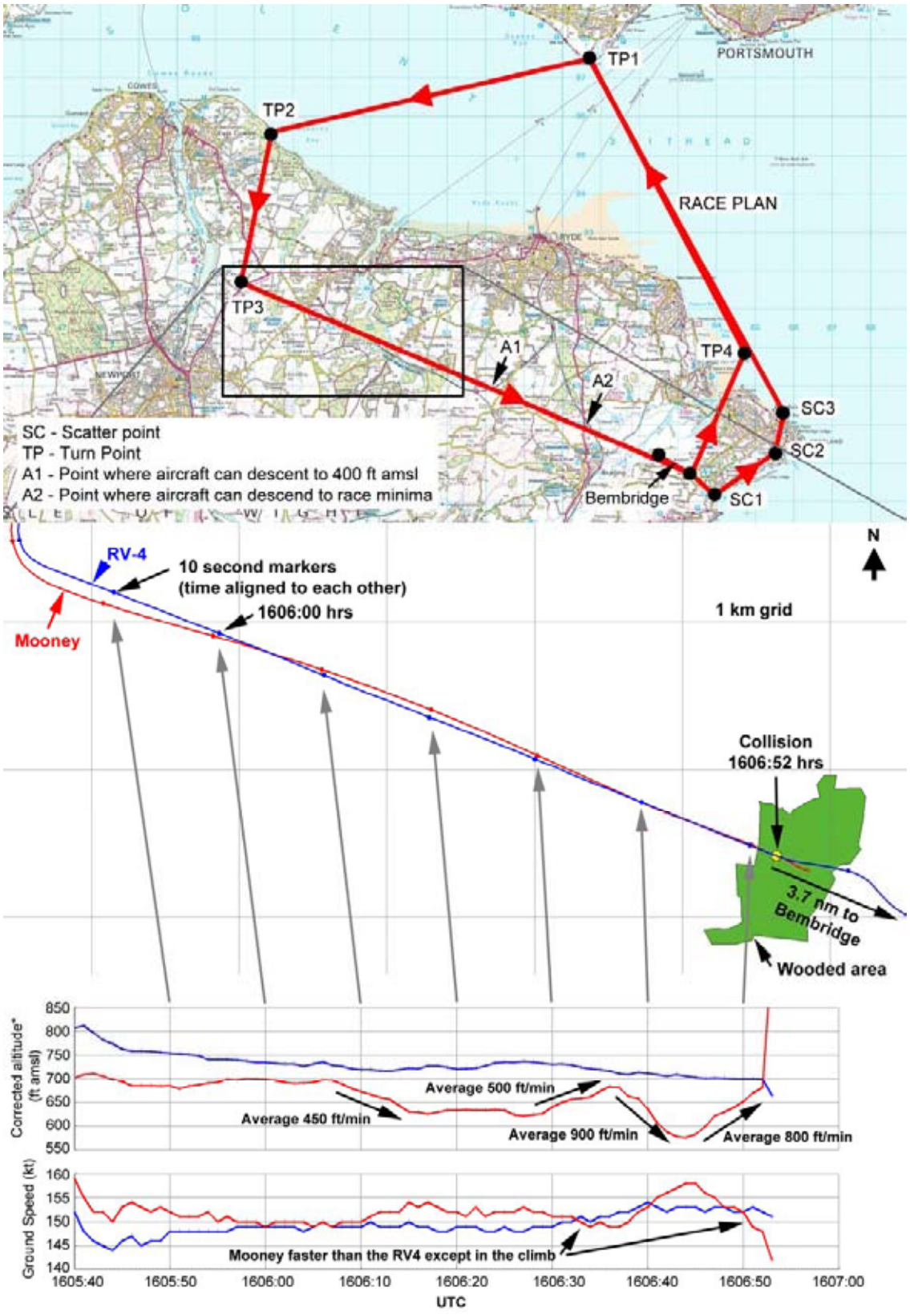

Figure 1

Relative motion of the two aircraft leading up to the impact

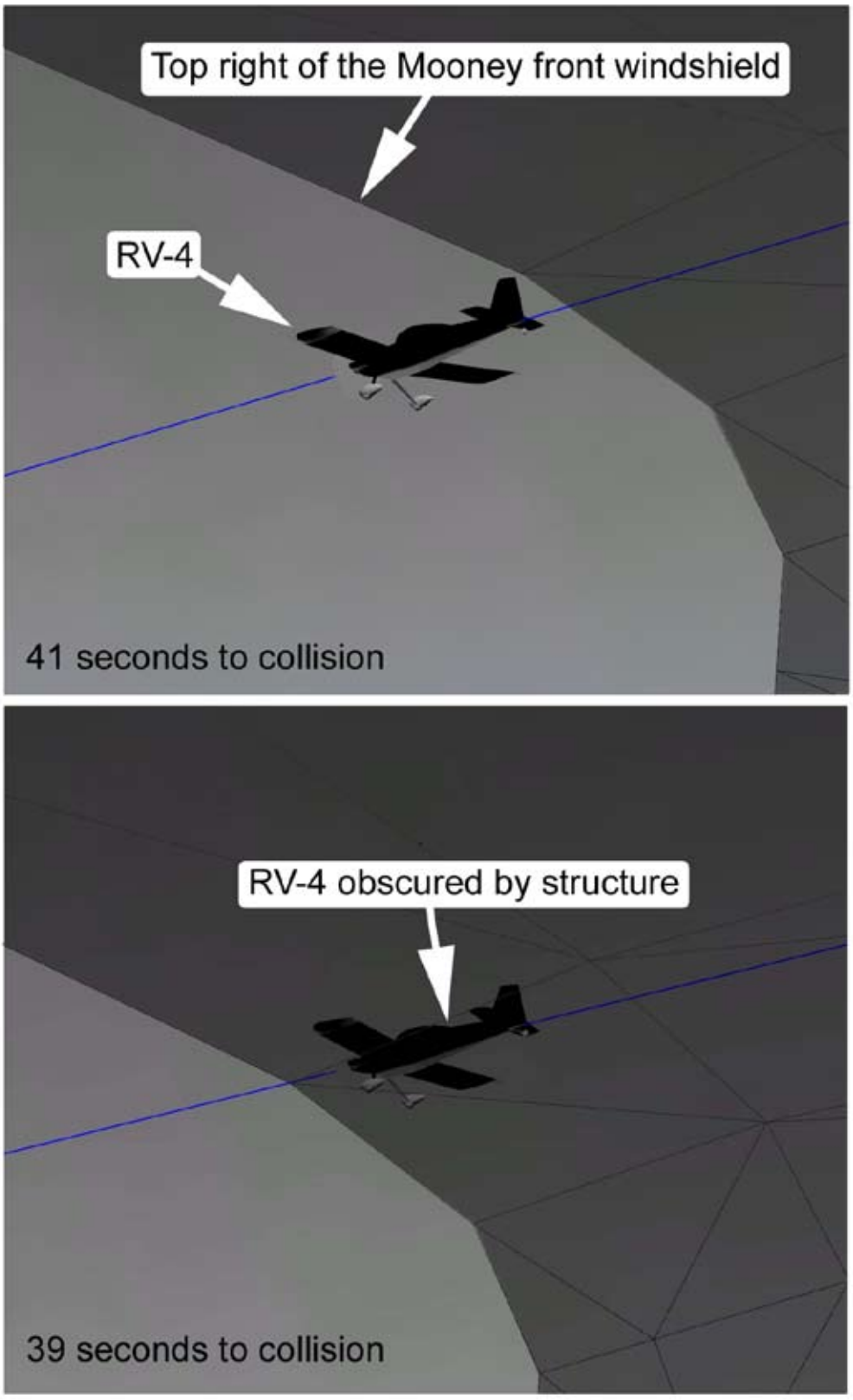

Figure 2

Illustration of the loss of line of sight of the RV-4 from the Mooney pilot's nominal eye position

the Mooney navigator would have had to move away from his normal sitting position in order to benefit from this view.

At the calculated point where visual contact would have been lost by the Mooney crew, the vertical and lateral separation of the aircraft was increasing and the Mooney was overtaking the RV-4. At this point it should have been possible for the RV-4 pilot to see the Mooney, albeit at an awkward location behind and below the RV-4.

The modelling indicates that shortly after the RV-4 became obscured from the view of the Mooney pilot, the RV-4 wing and then fuselage would have blocked the view of the Mooney from the RV-4 pilot's position. The RV-4's navigator, sitting behind the pilot, would have had a better view of the Mooney until it pulled further ahead.

Test flight in a Mooney M20J

The investigation conducted an exploratory flight in another Mooney M20J to establish the control inputs and aircraft attitudes required to make the aircraft describe the flightpath depicted by the recorded data. The control forces were found to be light and a descent rate of 900 ft/min was achieved using an attitude of approximately 1° nose down. A climb rate of 800 ft/min was achieved using a nose-up pitch of approximately 5°.

Meteorology

On the day of the accident an area of high pressure was centred over southern Norway maintaining a south-easterly flow over southern England. Visibility was generally more than 10 km and early morning haze had cleared by the time of the accident. There was a small amount of cloud at 3,000 ft. The surface wind was from the south-east at between 5 and 10 kt, with the temperature 18ºC. The weather conditions were described by other competitors as "good for air racing."

Aircraft descriptions

Mooney M20J

The Mooney M20J is a four-seat, low-wing monoplane powered by a single piston engine. The aircraft is equipped with a single piece forward windshield and two cabin windows on each side of the aircraft. The presence of the cabin roof structure limits the extent of the pilot's forward view, from the normal seated position, to approximately 19° upwards, in the vertical plane. The aircraft was painted in a white and green colour scheme.

Vans RV-4

The Vans RV-4 is a two-seat, tandem low-wing monoplane powered by a single piston engine. The aircraft has a tailwheel undercarriage configuration. A single piece bubble canopy is provided for the occupants, offering good visibility above the aircraft, although the engine cowling and low wing reduce the extent of the pilot's vision both ahead of and below the aircraft. The RV-4 was painted in a red and white colour scheme. The leading edges of both wings were painted red, with the exception of the fibreglass wingtip fairings. The RV-4's propeller was painted grey apart from the propeller tips, which were painted in three 2 inch wide coloured bands, alternating from white at the propeller tip, followed by a red band and an innermost white band.

Wreckage examination

Collision debris from both aircraft was distributed over a distance of approximately 470 m, on a heading of 118°M. This heading was aligned with the aircrafts' track to Bembridge Airport, some 3.7 nm distant. The debris field was also approximately aligned with the prevailing

wind conditions which, combined with the relatively low height of the collision, resulted in little off-axis drift of the lighter wreckage (Figure 3). The wreckage trail was composed of the Mooney, broken into three major sections and many smaller pieces, and fragments of the forward section of the RV-4's right mainwheel spat. The majority of the wreckage came to rest in woodland, with a small quantity of lightweight material from the cabin of the Mooney being blown downwind into open fields immediately to the west of the wooded area.

The Mooney wreckage

The Mooney had broken into three major sections:

- The right wing and fuselage, from the spinner rearwards to approximately 1.0 m behind the wing trailing edge and the inboard 0.9 m section of the left wing
- The empennage and rear fuselage section
- The left wing, which had separated at about 0.9 m outboard from the left fuselage side

The right wing and fuselage section had struck the ground in an inverted attitude, coming to rest on a heading of 176°M. It had fallen onto a track in between trees approximately 10 m tall, and the lack of visible damage to these trees indicated a near-vertical flight path immediately prior to ground impact. The cabin roof structure, from the windshield rearwards, was fully collapsed.

An impact depression, matching the size and shape of the RV-4's right wheel spat, was evident at the severed portion of the rear fuselage, 20 cm to the right of the aircraft's centreline. Paint transfer marks, matching those from the RV-4's wheel spats, were observed on the

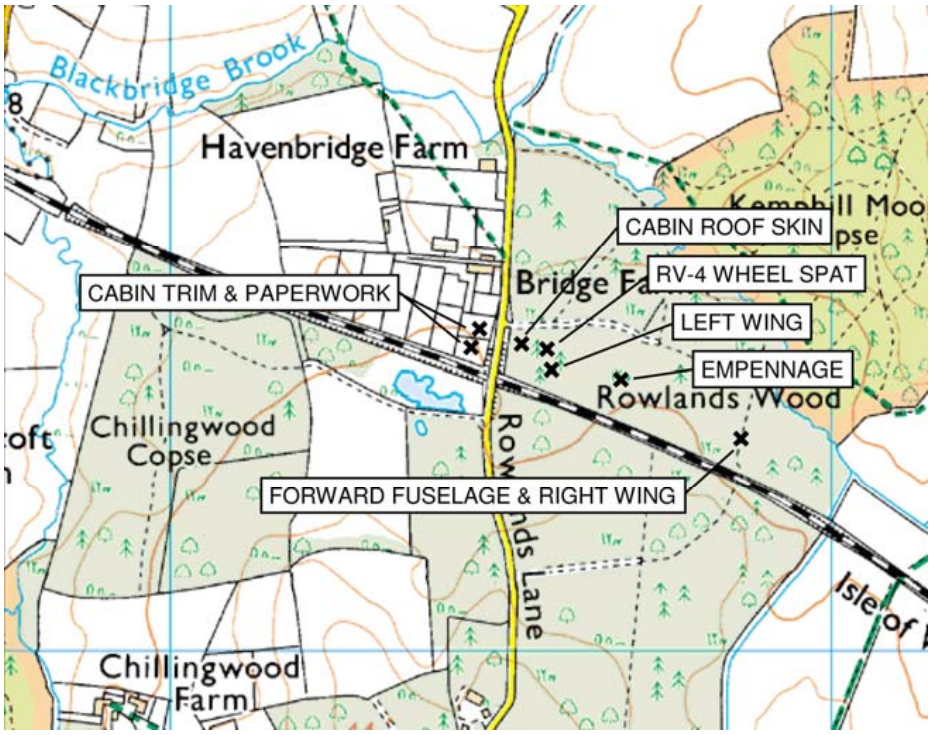

Figure 3

Wreckage plot

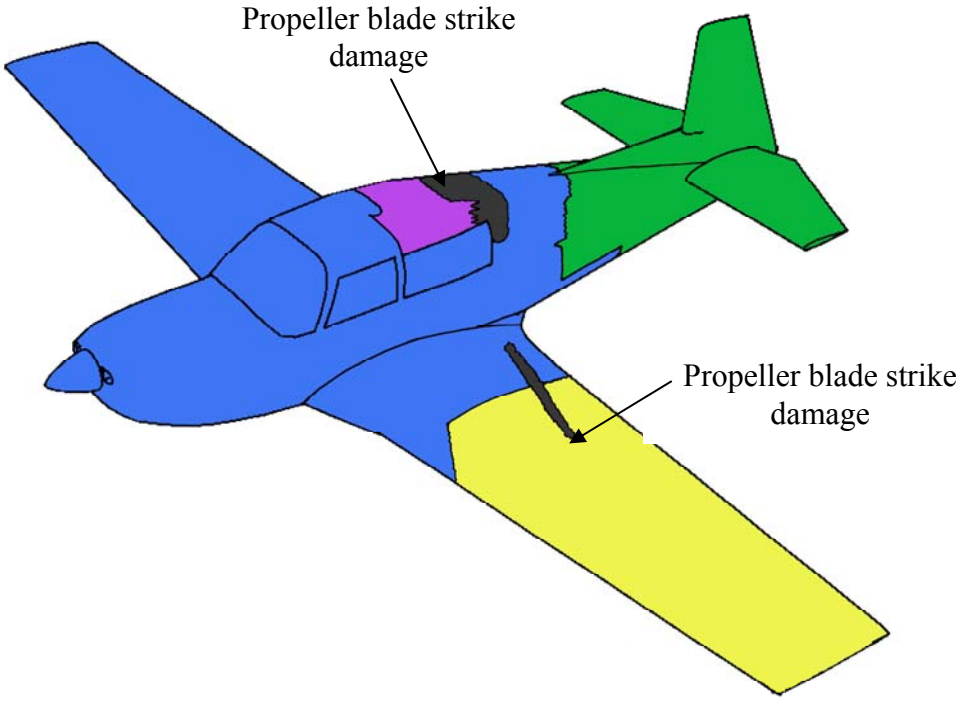

Figure 4

Main sections of Mooney wreckage

sides of this depression and an area of darker marking, made by the RV-4's right mainwheel tyre, was visible in the centre of the depression. Areas of red paint transfer, approximately 0.6 m in length, were visible on the upper left fuselage skin at the severed portion of the rear fuselage. The inboard section of the left wing exhibited damage consistent with downward moving propeller blade strikes in the region of the rear spar, behind the left main wheel well. No fire had occurred and 35 litres of fuel were recovered from the right wing's fuel tank.

The empennage and rear fuselage came to rest in dense woodland, 209 m from the forward fuselage section. Red paint transfer marks were evident on the forward edge of the severed rear fuselage, in a position adjacent to the red paint marks found on the matching forward fuselage section. The left tailplane was deformed upwards and did not show any signs of significant impact damage. The lower 0.5 m of fin leading edge skin was deformed to the left and two fragments of aluminium alloy skin, matching those from the RV-4's right aileron, were embedded in the deformed fin leading edge. The rudder and left elevator control surface mass balance weights had broken away from the empennage and were missing.

The rudder and elevator control pushrods' rod-end bearings had failed in a manner consistent with tensile overload at control connections located at the rear end of the main fuselage section. Three shallow depressions in the right tailplane's upper skin, consistent with propeller blade contacts, were evident close to the leading edge of the right tailplane. These contact marks exhibited red paint transfer and they indicated a propeller rotation direction from the tip to the root of the right tailplane.

The remaining section of the left wing, outboard of approximately 0.9 m from the left fuselage side, came to rest in woodland 331 m from the main fuselage wreckage.

The wing exhibited overload damage consistent with upward bending due to aerodynamic loads. Damage consistent with upward moving propeller blade strikes was visible over a distance of 0.5 m at the inboard end of the wing, in the vicinity of the rear spar and flap shroud. The rear spar itself had been severed by propeller blade strikes.

A section of cabin roof skin, measuring approximately 0.7 m long by 1.0 m wide, was found in the wreckage trail 393 m from the main fuselage section. It originated from the top of the cabin, above the rear cabin seats. Four propeller slash marks were visible on the left side of this piece of wreckage. Smaller fragments of cabin skin and interior trim from the area behind the roof skin section were found at the downwind end of the wreckage trail, and many of these also exhibited propeller blade strike damage.

The wreckage was recovered to the AAIB's facility at Farnborough for further detailed examination. The control runs were checked for continuity and range of movement, and no evidence of any pre-existing defects was found. The aircraft's maintenance records were reviewed. These showed that the aircraft had undergone an annual maintenance inspection on 16 April 2010 and that the Airworthiness Review Certificate was current at the time of the accident. The aircraft was last weighed on 12 June 2006 and, using these figures, the investigation calculated the aircraft was being operated within its permitted weight and centre of gravity limitations.

Longitudinal trim on the Mooney M20 series is accomplished by pivoting the entire empennage around a pivot located ahead of the tailplane main spar, and is actuated with a manually operated screw jack. Two threads were visible on the end of the screw jack, at its attachment to the trim linkage on the fin main spar. The screw jack mechanism is irreversible and did not show any evidence of damage incurred during the accident. The aircraft manufacturer confirmed that this empennage trim position was consistent with a trimmed speed of between 160 and 175 kt.

The RV-4 wreckage

The aircraft was examined at Bembridge Airport, where it had come to rest on a grassed area immediately to the south of Runway 12, on a heading of 127°M. The aircraft's two-bladed propeller had sustained extensive leading edge impact damage at the blade tips, consistent with contact with a metallic structure. One of the propeller blades had an 8.2 cm long section of its tip missing. The propeller spinner had detached from the spinner backplate and was also missing.

The leading edge of the right wing exhibited impact damage over a length of 0.6 m, with the damage centred at approximately mid wingspan (Figure 5). The right aileron was extensively damaged and the inboard 40 cm of aileron was missing aft of the aileron spar, which itself was bent forwards, consistent with being struck from behind. The right wing's lower skin was heavily scored with marks running in the outboard direction, towards the wing tip. The nature of these markings indicated that they had not occurred during the landing ground roll. The forward section of the right mainwheel spat had detached and photographs taken of the aircraft during landing showed that the right main landing gear leg was bent upwards, with the right wheel almost in contact with the right wing lower surface, immediately prior to touchdown.

Before the aircraft was moved from its resting position, its flying controls were checked and determined to be continuous, with no evidence of any pre-existing control restrictions.

Figure 5

Damage to the RV-4's right wing

Medical and pathology

An aviation pathologist conducted the autopsies. His report concluded that the pilot and passenger of G-JAST died of severe multiple injuries which were caused by the non-survivable crash of their aircraft following a mid-air collision. The pathology investigation revealed no evidence of medical factors which could be pertinent to the cause of the collision.

Handicapped Air Racing

Handicapped Air Racing has been in existence since the 1920's and is organised in the UK by the Royal Aero Club Records Racing and Rally Association (RRRA). Any propeller-driven aircraft, up to a maximum all-up mass of 5,700 kg, which is capable of maintaining a minimum of 100 mph in level flight, may compete. Turbine aircraft may also compete but they are subject to a maximum speed, straight and level, of 250 kt. Each aircraft is tested on the day of the first race for its maximum level in-flight speed. The time it should take to complete the race mileage at maximum speed is then calculated. The aircraft start times are staggered, with the slowest aircraft starting first, so that all aircraft should cross the finish line simultaneously. The race is normally flown at 500 ft above the highest obstacle on the race course until on the final straight, when, after crossing a predetermined point, normally marked on the map as "A", the aircraft can descend to the height that they cross the finish line, normally 100 ft agl. The idea is to give an exciting finish for the spectators and a race atmosphere for the competitors.

In order to compete in the race each pilot must

hold a Federation Aeronautique International (FAI) competitor's licence and each pilot who has not raced within the last three years is required to undertake a check flight with an air race check pilot.

Air races are conducted at seven or eight venues per year, typically over a weekend. A Chief Steward is appointed for each meeting and he appoints two other stewards. Stewards cannot be competitors in the race. Prior to each race and each practise session there is a briefing, conducted by a race official known as the Clerk of the Course. Attendance at these briefings is compulsory for all competitors. The Clerk of the Course is the sole person responsible to the Stewards for conducting the meeting, in accordance with the official programme. He is assisted by several other race officials.

After the first briefing of the race weekend, each aircraft's race speed is assessed by flying an octagon pattern at the aircraft's maximum speed, with a GPS track logger onboard. This octagon is normally supervised by race officials, and flown at a stated aircraft configuration and fuel quantity. From the GPS track logger, the average groundspeed for the aircraft around the octagon is calculated and the start times for the race are produced. The race is normally a lap distance of around 25 nm and the aircraft typically race for four or five laps of the circuit. After the octagon, there is a race practise session on the Saturday morning, where the competitors become familiar with the turning points (TPs). Then, after a briefing, the first race is held on the Saturday afternoon. The second race, around the same track, is normally held after a briefing on the Sunday.

In order for the air race to take place, the Civil Aviation Authority issued the RRRA with two exemptions from the Rules of the Air Regulations 2007. The first exemption permits aircraft participating in an air race to overtake on either side[2] during the race or practice air race and the second allows aircraft to land when the runway is not clear of aircraft.[3] The RRRA used to be given an exemption to Rule 5 of the air to permit them to allow aircraft to fly within 500 ft of persons, vehicles, vessels and structures, for the final part of the race, but in April 2008 the CAA wrote to the RRRA and explained that this exception was not required as Rule 6(f) allowed them to descend below 500ft when within 1,000 m of the finish line.

Races are conducted with all aircraft using a single common radio frequency and racers are encouraged to use the frequency for flight safety transmissions. This radio frequency is not normally recorded.

The Rolls Royce Merlin Trophy Air Race

The Rolls Royce Merlin Trophy Air Race is normally held every year on the Isle of Wight. Competing in the Merlin Trophy Air Race is a pre-requisite for entry into the Schneider Trophy Air Race, which is normally held the following day. The course is about 117 nm long and consists of five laps of an anticlockwise circuit, of approximately 23 nm, around the north of the Isle of Wright. On the first lap aircraft have to go past several additional waypoints, known as scatter-points. These additional points are intended to allow aircraft to achieve a safe speed prior to turning onto the initial race track.

For this race weekend all competitors were required to be present at Bembridge Airport before 0945 hrs and

Footnote

[2] Rule 11(1) of the Rules of the Air Regulations 2007 *'An aircraft which is being overtaken in the air shall have the right-of-way and the overtaking aircraft, whether climbing, descending or in horizontal flight, shall keep out of the way of the other aircraft by altering course to the right'.*

[3] Rule 14(2) of the Rules of the Air Regulations 2007 '*A flying machine or glider shall not land on a runway at an aerodrome if there are other aircraft on the runway'.*

the race officials checked all the paperwork for the competitors and their aircraft. Only competitors whose paperwork was correct were allowed to participate in the race. Competitors were, at this point, also required to sign an indemnity form, as either pilot or navigator, which contained the statement:

> *'I am aware of the risks inherent in aviation generally and air racing in particular and I am willing to accept those risks.'*

At 1000 hrs, the pre-practice briefing was held and, afterwards, the aircraft performed their octagons and the practise runs around the route. The pre-race brief was delayed from its planned time of 1330 hrs, as the refuelling of the aircraft to the race fuel states took longer than planned, and the race briefing commenced at 1400 hrs. The brief contained a reminder to the pilots that they were permitted to overtake on both the left and the right, but that it remained the responsibility of the overtaking aircraft to remain clear of the aircraft it was overtaking. The race commenced at 1500 hrs.

Previous mid-air collisions during air racing

In July 1983 a Cessna 182 Skylane and a Mooney collided during the practise for an air race. The pilot of the Cessna was fatally injured (AIB12/83). In August 1984 a Bolkow Monson B209 and a Piper Arrow PA-28R collided during an air race, the pilots of both aircraft being fatally injured (AIB 3/85). In

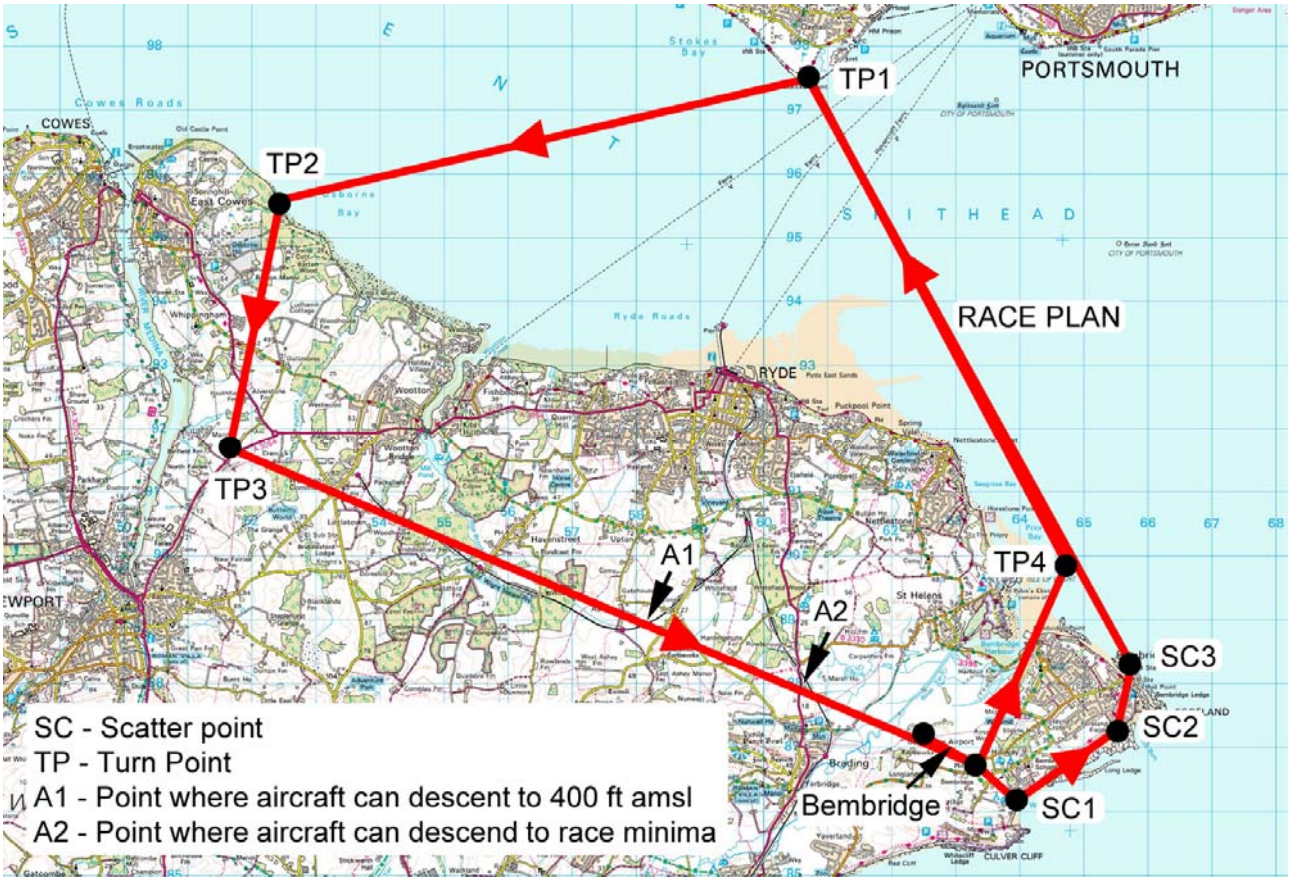

Figure 6

The Rolls Royce Trophy Air Race Course

August 1991 a Piper PA-28 Cherokee Arrow II and a Glos Airtourer 150 collided during the qualifying heat for the Schneider Trophy Air Race; both aircraft landed safely (AIB 10/91).

Analysis

General

The rules of handicapped air racing are designed to place multiple aircraft in close proximity to each other by the finish of the race. According to these rules it is the responsibility of the overtaking aircraft to remain clear of the aircraft being overtaken. In this situation the Mooney was slowly overtaking the RV-4. Analysis of the recorded data, however, shows that it is unlikely that the pilot of the Mooney was visual with the RV-4 for approximately the final 39 seconds before the collision. When the Mooney pilot had last been able to see the RV-4, the vertical and lateral separation of the two aircraft was increasing but, during the final 20 seconds, the average speed of the RV-4 increased by approximately 4 kt, such that for a period of approximately 7 seconds the RV-4 had the higher ground speed. With other aircraft ahead of the Mooney, and the finish line approaching, it is probable that the crew of the Mooney had lost spatial awareness of the RV-4.

The RV-4 navigator recalled seeing the Mooney to the right and below his position shortly before the impact; the recorded data indicates that this was approximately 15 seconds before impact. Thereafter, it was probable that, although the aircraft were in close proximity to each other, neither crew was able to see the other aircraft.

The pilot of the Bulldog recalled seeing the Mooney achieve attitudes of approximately 15º nose-up and nose-down; yet a flight conducted during the investigation found that the attitudes required to achieve the rates of climb and descent, derived from the Mooney's GPS, were 5º nose-up and 1º nose-down, respectively. Assessment of another aircraft's pitch attitude, whilst flying directly behind it, is difficult, especially when there is relative movement between that aircraft and the observer. Therefore, while the witness in the Bulldog saw the Mooney's change in the pitch attitude, it is likely that the attitude it achieved was similar to that recorded on the investigation flight.

The engineering investigation could find no technical fault which would explain the aircraft's divergence from straight and level flight. The flight test showed that the control forces for the Mooney were light. The control movements required to make it perform its last movements prior to the collision were very small, and, as such, the pilot might have made the control inputs inadvertently, whilst concentrating on something else.

Collision analysis

In order to correlate the pattern of damage sustained by both aircraft during the collision, simple three-dimensional Computer Aided Design (CAD) models of each aircraft were created. The pitch angles of both aircraft were set to be consistent with the airspeed and climb rates recorded on the GPS recorders carried on the aircraft immediately prior to the collision. The analysis showed that the initial contact between the aircraft was between the RV-4's right wheel spat and the top section of the Mooney's rear fuselage, at the forward end of the dorsal fin (Figure 7).

This initial contact was likely to have been followed almost immediately by contact between the RV-4's propeller and the left side of the Mooney's cabin roof skin, above the rear cabin seats (Figure 8). It is likely that the large section of cabin roof skin found in the wreckage trail detached from the aircraft at this point in the accident sequence.

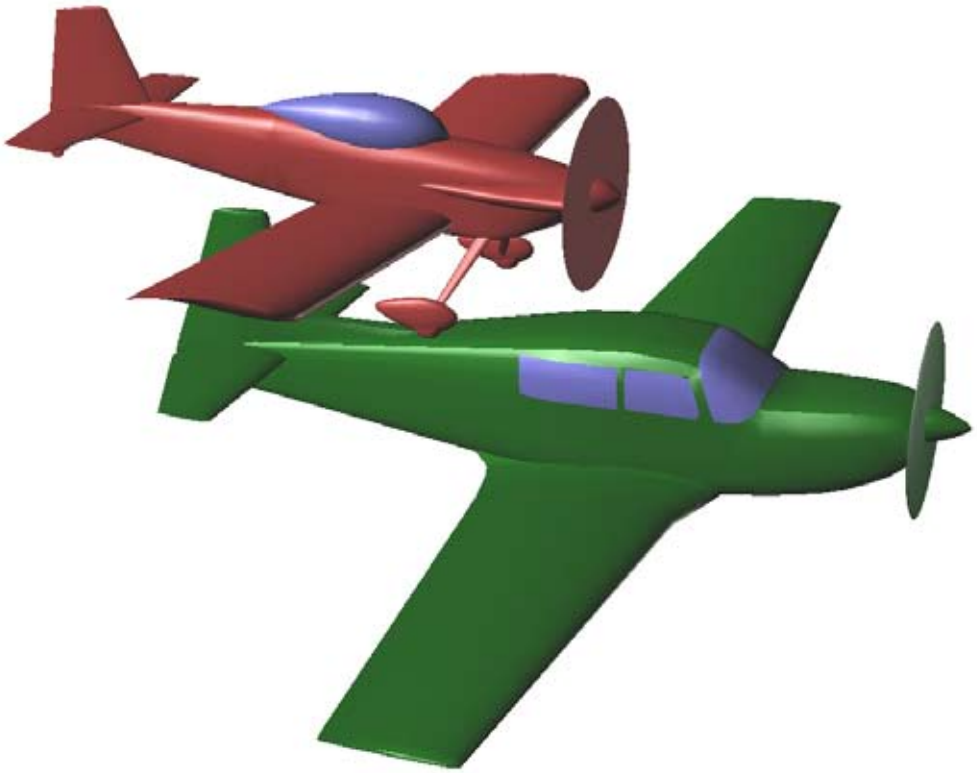

Figure 7

Initial contact

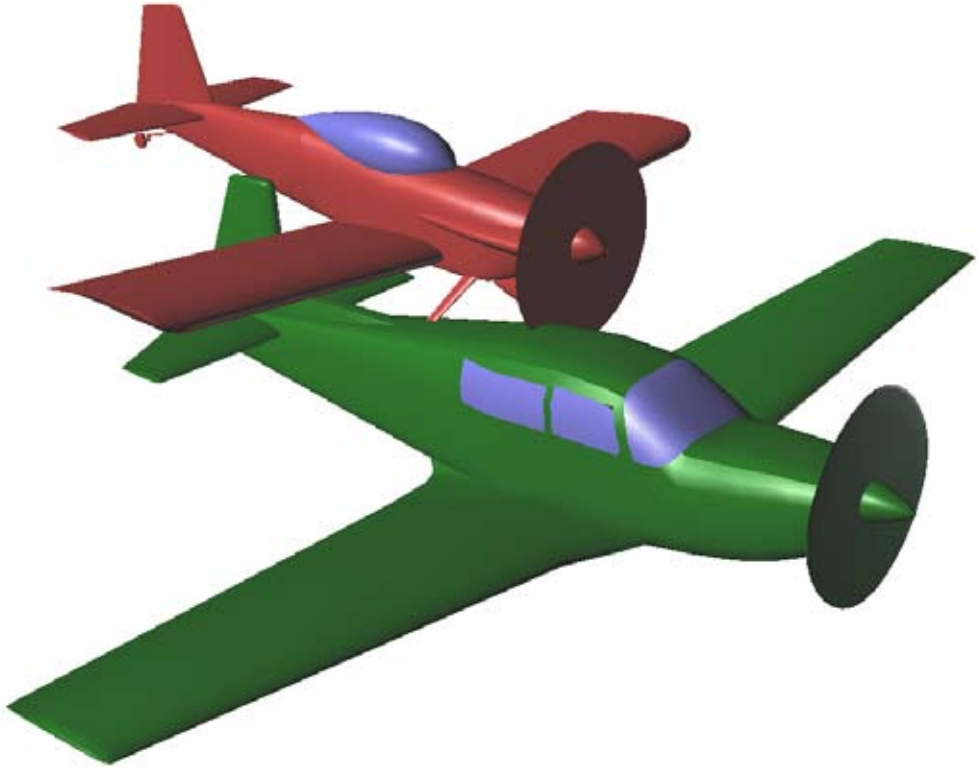

Figure 8

Propeller contact with Mooney's cabin roof

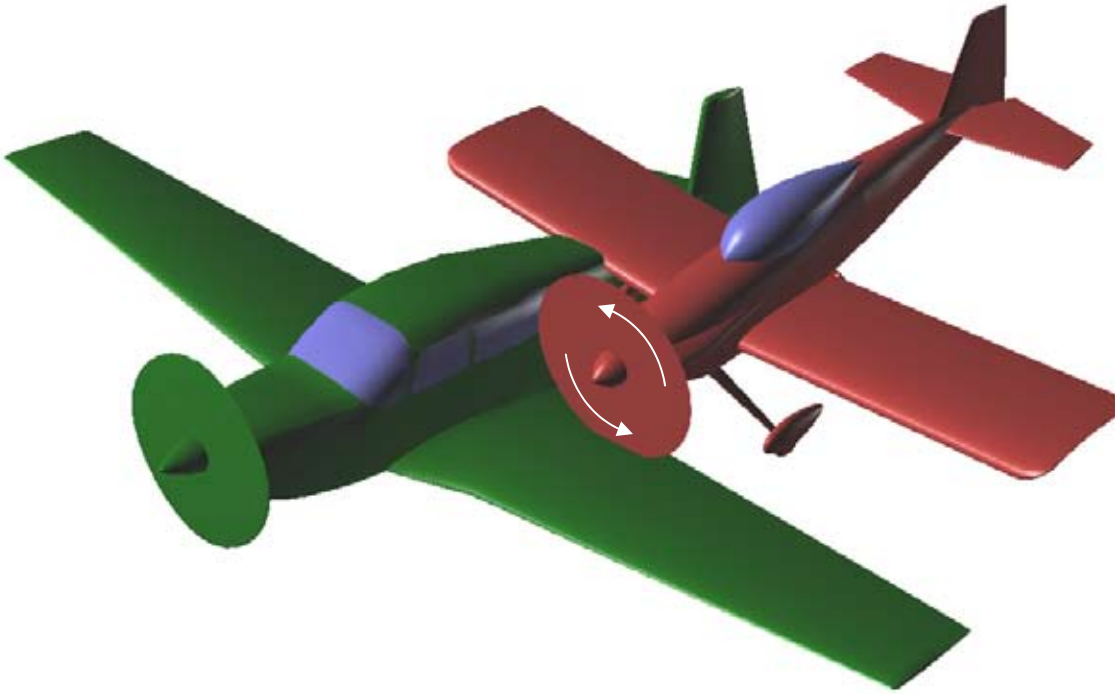

Figure 9

Propeller contact with the Mooney's left wing, showing the RV-4's propeller rotation direction

This was followed by contact between the RV-4's propeller and the inboard section of the Mooney's left wing, severing the wing's rear spar (Figure 9).

The vertical contact force between the RV-4's right mainwheel and the Mooney's rear fuselage, followed almost immediately by the RV-4's right wing, acted at a distance of approximately 3 m behind the Mooney's centre of gravity. This caused the Mooney to pitch nose-up, increasing the aircraft's angle of attack. It is likely that the combination of weakening of the Mooney's wing, due to the propeller damage at the rear spar, and the increased angle of attack at an airspeed of approximately 160 kt, generated an aerodynamic upload on the left wing that it was unable to withstand. The left wing failed in upward bending and subsequently detached from the aircraft.

The physical evidence of the wreckage shows that an impact occurred, in the fore-aft direction, between the lower section of the Mooney's fin leading edge and the inboard end of the RV-4's right aileron. This impact imposed a tensile load in the Mooney's rear fuselage. It is probable that this tensile load, in combination with the damage sustained during the initial contacts with the RV-4's right mainwheel and right wing leading edge, caused the tensile fracture and subsequent detachment of the Mooney's rear fuselage and empennage section.

As the empennage became displaced longitudinally from the forward fuselage section, the elevator and rudder control pushrods rapidly drove the elevators to full downward deflection and the rudder to the full right deflection position. The rapidity of these control surface accelerations caused the rudder and the left elevator mass balance weights to become detached due to inertial loads. The failure of the left tailplane in upload, combined with the absence of any obvious impact damage, indicates that the left tailplane, possibly in combination with full down elevator deflection,

experienced aerodynamic loads sufficiently high for it to fail in upward bending.

The shallow propeller depressions on the right tailplane upper surface were made at some point following the initial impact, because the red paint transfer left by the propeller must have been produced once the outer two inches of the propeller tips had been removed, during propeller strikes with the Mooney's structure.

Once the rudder and elevator pushrods reached their maximum travel positions, the rearward load acting on the empennage, due to contact with the RV-4, was sufficient to overload the rod-end bearings in tension at their connections with the control pushrods. Following this, the empennage detached completely from the forward fuselage section.

Safety action

As a result of this accident the Civil Aviation Authority and the RRRA are reviewing Air Race procedures and the risk air racing poses to third parties.

Conclusions

The accident occurred because the pilots of both aircraft lost sight of each other whilst engaged in air racing. Analysis of the geometry of the collision showed that the upward visibility from the overtaking aircraft, the Mooney, was very poor, with the pilot probably unable to see the RV-4 for approximately 39 seconds. When the Mooney was in the blind spot of the RV-4, and neither pilot could see the other aircraft, the Mooney pitched up into the RV-4 and a mid-air collision occurred. The investigation could not determine why the pilot made these control inputs, although the investigation considered they would have been small and the Mooney pilot was not aware of the close proximity of the RV-4.