AVIATION INVESTIGATION REPORT
A99P0168

IN-FLIGHT COLLISION

BETWEEN
ERCO AIRCOUPE 415C C-GHFB
AND
PACIFIC FLYING CLUB
CESSNA 152 C-GPFE
CLOVERDALE, BRITISH COLUMBIA
20 NOVEMBER 1999

Aviation Investigation Report

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Between
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and
Pacific Flying Club
Cessna 152 C-GPFE
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Synopsis

At 1552 Pacific daylight time, the Aircoupe, serial number 451, departed the Langley, British Columbia, airport. The pilot and one passenger flew to the Pitt Meadows airport to carry out a series of touch-and-go landings. After spending about 15 minutes in the circuit at Pitt Meadows, the Aircoupe departed the circuit at 1621 and flew southwest into a local training area, CYA 125 (T). At 1619, the Cessna 152, serial number 15279941, departed the Boundary Bay airport. The instructor and the student pilot flew northeast into CYA 125 (T) to carry out basic flight instruction. At 1627, in daylight and visual meteorological conditions, the two aircraft collided on nearly opposing headings at 1300 feet above sea level. The accident occurred close to the centre of CYA 125 (T). Both aircraft suffered catastrophic damage, broke up in flight, and plunged to the ground. The aircraft were destroyed, and the four occupants were fatally injured. There was no fire.

Ce rapport est également disponible en français.

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5.0 Appendices

1.0 Factual Information

1.1 History of Flight

The Aircoupe departed the Langley airport and flew to the Pitt Meadows airport, where the pilot requested low-level touch-and-go circuits. He was then cleared by air traffic control (ATC) tower personnel for a straight-in approach to runway 26. After completing one circuit at 600 feet above ground level (agl), the Aircoupe continued low-level for another touch-and-go. The pilot turned onto the base leg prematurely. Shortly after, the tower controller instructed the pilot to overshoot because of insufficient spacing behind the aircraft already on final. The Aircoupe continued as directed and carried out a second approach without further event. The pilot then departed the circuit at 1621 Pacific daylight time (PDT)[1] and flew into training area CYA 125 (T), a distance of four nautical miles (nm). The specific reason for this segment of the flight could not be determined. The flight was apparently a recreational flight in the local area.

ATC radar does not record the entire flight path of the Aircoupe before the collision; however, the last two minutes of flight are captured. The Aircoupe's flight path from Pitt Meadows to CYA 125 (T) was reconstructed from information gathered from ground witnesses, ultralight aircraft pilots airborne in the area at the time, ATC radar and communication records, and flight performance data of the two accident aircraft. This reconstruction

[1] All times are PDT (Coordinated Universal Time [UTC] minus seven hours).

shows that the Aircoupe's flight path was direct from the circuit at Pitt Meadows, south into the northeast corner of CYA 125 (T), where the Aircoupe met an ultralight aircraft at 1624:30 and carried out an orbiting manoeuvre around it. The manoeuvre took about 1 minute 15 seconds. During the next 60 seconds before the collision occurred, radar data show that the Aircoupe continued on a southwesterly track for about 40 seconds after orbiting the ultralight. The Aircoupe then turned right to the northwest, rapidly closing on the Cessna's flight path. The Aircoupe appears to have then turned to the left, nearly into a head-on situation with the Cessna, and about 10 seconds later the two aircraft collided. During the last five or so seconds before impact, the Aircoupe was reportedly in a nearly straight and level flight attitude.

Collision damage patterns suggest that the Aircoupe was in a slight climbing, right-bank attitude at impact, consistent with a turn away from the Cessna. It was reported that the Aircoupe may have initiated evasive action immediately before impact with the Cessna; however, this action could not be conclusively identified from ATC radar data or confirmed from wreckage evidence.

The instructor and the student in the Cessna 152 began taxiing from the Pacific Flying Club ramp at Boundary Bay airport at 1601. This flight was to give the student pilot flight time currency and to review basic flying exercises (such as slow flight, precautionary forced landings, and steep turns) in preparation for his Canadian Recreational Pilot Permit—Aeroplane. After an 18-minute delay on the ground, caused by circuit traffic congestion at Boundary Bay, the Cessna took off from runway 12 and tracked east to penetrate CYA 125 (T) near the midpoint of the western boundary. From there, the aircraft turned north about 45 degrees (°) and tracked a straight-line course to the northeast into the centre of the training area. ATC radar data show that the Cessna maintained a track of about 025° magnetic (M), a groundspeed of about 110 knots, and an altitude of 1300 feet above sea level (asl). The Cessna was not seen to deviate from its flight path or take evasive action before the collision.

Two pilots of a Spectrum Beaver RX550 ultralight aircraft observed the events and circumstances that led up to the collision, although they did not see the two aircraft collide. At about 1615, the ultralight took off from a grass strip near Fort Langley, 6 nm northeast of the accident site. It flew southwest into CYA 125 (T) at an altitude of about 1100 feet asl, en route to the King George Airpark in Surrey, on the western edge of the training area. The Sea Island ATC radar recorded that the ultralight tracked directly southwest from Fort Langley at about 50 knots groundspeed; the midair collision would have been out of their sight, behind them.

About three minutes before the collision, the ultralight pilots first noted a bright light ahead on the horizon, coming toward them from about 8 nm away. They then recognized the light as the landing light of an approaching aircraft, which they later identified as a Cessna. About a minute later, the pilots observed the Cessna alter course slightly to the north. They judged that the Cessna's path was not in conflict with their own and that they would pass comfortably to the south of the Cessna. The pilots recall that the landing light was on for the entire time the Cessna was visible to them.

About the same time, they watched the Aircoupe pass their ultralight on the left, from behind, on a parallel track and similar heading of about 225°M, about 200 feet higher. The Aircoupe then made a steep right turn ahead of them to cross their flight path, then passed down their right-hand side, and disappeared from their view, behind them. The ultralight pilots did not see the Aircoupe's landing light on. They do recall that the red rotating beacon on the Aircoupe's belly was on and that the Aircoupe's two occupants were looking at the ultralight during the turn around it. The ultralight pilots continued on to the airpark and landed, unaware of the collision behind them. The ultralight was not equipped with a radio or a transponder, nor was it required to have been by regulation.

1.2 Injuries to Persons

1.2.1 Aircoupe 415C

	Crew	Passengers	Total
Fatal	1	1	2
Serious	-	-	-
Minor/None	-	-	-
Total	1	1	2

1.2.2 Cessna 152

	Crew	Passengers	Total
Fatal	2	-	2
Serious	-	-	-
Minor/None	-	-	-
Total	2	-	2

1.3 Damage to Aircraft

Both aircraft were destroyed by the impact forces of the midair collision and the subsequent collisions with the ground.

The Aircoupe completely disintegrated in-flight as a result of the collision. The aircraft broke into five major pieces: the nose section, the cockpit and main fuselage section, the empennage section, and the two wings.

In comparison, the Cessna suffered less extensive damage from the collision. Nonetheless, the damage was catastrophic and rendered the aircraft completely uncontrollable. At impact with the Aircoupe, the left wing was torn off at the root, and the empennage was severed but remained attached by the control cables.

1.4 Other Damage

There was no other damage.

1.5 Personnel Information

1.5.1 Aircoupe 415C

	Pilot-in-command
Age	57
Pilot Licence	Private
Medical Expiry Date	01 January 2000
Total Flying Hours	2210

The 57-year-old pilot had been flying recreationally for more than 30 years. He held a valid medical certificate and a Canadian Private Pilot Licence—Aeroplane endorsed for all single-pilot, single-engine, land and sea planes, day or night. The pilot was a local aviation enthusiast and had owned and flown the Aircoupe for the last five years. On this flight, he was accompanied by a lifelong friend who had at least 40 years of flying experience and who had owned more than 45 small aircraft over the years.

1.5.2 Cessna 152

	Instructor	Student
Age	25	15
Pilot Licence	Commercial	Student Permit
Medical Expiry Date	01 April 2000	01 August 2001
Total Flying Hours	550	26
Hours on Type	280	26
Hours Last 90 Days	180	15
Hours on Type Last 90 Days	105	15

1.5.2.1 Instructor Pilot

The instructor pilot had been employed as a flight instructor by the Pacific Flying Club since July 1999. His supervisors and his peers regarded him as a capable, safe professional. He held a Canadian Commercial Pilot Licence—Aeroplane with a Group 1 instrument rating valid until March 2001. His medical certificate was valid until April 2000. He had received his Class 4 instructor rating on 30 June 1999; since then he had flown about 250 hours as an instructor. His personal logbook shows that he had started flying in July 1997. He had flown a total of about 550 hours, of which about 280 hours were in Cessna 152's. He was seated in the Cessna's right pilot seat, which is the traditional seat for an instructor providing flight instruction.

1.5.2.2 Student Pilot

The 15-year-old student pilot began his flying lessons with the Pacific Flying Club in July 1999. Other pilots and his schoolmates regarded him as a capable, eager, and cheerful young man. He held a valid Student Pilot

Permit and medical document and had accumulated about 26 hours of flight time. His flight training progress had been normal. He was seated in the Cessna's left pilot seat, which is the traditional seat for a pilot-in-command or a student receiving flight instruction.

1.6 Aircraft Information

1.6.1 Aircoupe 415C

Manufacturer	Engineering and Research Company (ERCO)
Type and Model	Aircoupe 415C
Year of Manufacture	1946
Serial Number	451
Certificate of Airworthiness	17 March 1980
Total Airframe Time	2022 hours
Engine Type	Continental C-85-12
Propeller Type	McCauley 1B90-CM
Maximum Take-off Weight	1260 pounds
Recommended Fuel Type(s)	Avgas 100 LL

The yellow ERCO Aircoupe 415C was a single-engine, two-place, low-wing monoplane of metal and fabric construction. Standard equipment includes one fixed landing light mounted in the leading edge of the left wing. Witnesses revealed that the Aircoupe did not have its landing light on immediately before the midair collision, but the red, belly rotating beacon was on.

According to documents recovered after the accident, the weight and balance of the Aircoupe at take-off from Langley were estimated to have been within certificated limits. An examination of the aircraft and engine maintenance records and other documentation revealed nothing remarkable. Records showed that the aircraft was certificated, equipped, and maintained in accordance with existing regulations and approved procedures.

1.6.2 Cessna 152

Manufacturer	Cessna Aircraft Company
Type and Model	152
Year of Manufacture	1977
Serial Number	15279941

Certificate of Airworthiness	23 August 1989
Total Airframe Time	8280 hours
Engine Type	Lycoming O-235-L2C
Propeller Type	McCauley 1A103/TCM
Maximum Take-off Weight	1670 pounds
Recommended Fuel Type(s)	Avgas 100 / 100 LL
Fuel Type Used	Avgas 100 LL

The white Cessna 152 was a two-place, single-engine aircraft with a cantilevered high-wing and fixed tricycle landing gear. Standard equipment includes one fixed landing light mounted in the nose. Some witnesses confirmed that the Cessna had its landing light on before the midair collision.

According to documents recovered after the accident, the weight and balance of the aircraft at take-off from Boundary Bay were estimated to have been within certificated limits. An examination of the aircraft and engine maintenance records and other documentation revealed nothing remarkable. Records showed that the aircraft was certificated, equipped, and maintained in accordance with existing regulations and approved procedures.

1.7 Meteorological Information

The weather was consistent with visual meteorological conditions and suitable for visual flight rules (VFR) flight. In CYA 125 (T) at the time of the accident, the sky was reported to have been generally overcast, with some low, thin cloud in the northwestern sector. The aviation weather reports for Vancouver International Airport, 15 nm west of the accident site, and for the Abbotsford airport, 15 nm east, show no significant weather condition that would have contributed to the accident circumstances. Weather is not considered to have contributed to this accident.

The fading lighting conditions were not ideal for effective aircraft detection or identification. The setting sun was partly obscured by cloud on the western horizon, and glare was not a factor. Official sunset occurred at 1626, coincidentally about the time of the accident; official evening twilight was at 1701. The western sky was backlit by the sunset and still allowed reasonable definition of aircraft on the horizon, as was reported by the ultralight pilots. In contrast, the eastern sky was described as confused, with complicated and cluttered cloud patterns of varying shades. The ground foliage in the surrounding greenbelt areas and the many open parklands adjacent to the accident site were also variegated, creating a camouflage effect in the setting sun.

1.8 Aids to Navigation

Navigational aids did not contribute to this accident. The Cessna had an altitude-encoding transponder unit installed and had been transmitting code 1200 on Mode C until the accident. ATC radar data show that the Cessna was level at 1300 feet asl. The Aircoupe was not equipped with a transponder, nor was it required to have been by regulation. A transponder is not required for aircraft operating in CYA 125 (T).

The Sea Island radar coverage in the area of CYA 125 (T) had a low-level limit (floor) of about 600 feet asl, likely because of terrain shielding. Because of the floor, the radar did not reliably detect aircraft flying below 600 feet. For example, the radar did not capture aircraft conducting low-level circuits at Pitt Meadows. The radar did not capture the Aircoupe's flight path from Pitt Meadows until the aircraft climbed above the radar floor shortly before the collision.

1.9 Communications

The Aircoupe's radio was found set to 119.0 megahertz (MHz), which is the frequency for Langley Tower. The Cessna's radio was found tuned to 123.0 MHz, which is the frequency often used by Pacific Flying Club aircraft for internal company communication. Two-way radio communication is not mandatory for aircraft operating in CYA 125 (T). A safety promotion brochure, *Take Five* (TP 2228 E), produced in April 1999 by Transport Canada (TC) System Safety, recommends that pilots flying in CYA 125 (T) monitor a common frequency of 123.5 MHz to avoid traffic conflicts in this congested area.

1.10 Aerodrome and Airspace Information

Although both aircraft departed from licensed aerodromes, the aerodromes themselves were not directly involved in this accident.

The accident occurred in Class F airspace, an area where aviation activities must be confined because of their nature. Limitations may be imposed upon aircraft that are not participating in those activities. Most importantly, aircraft operations are not directed by ATC services and rely solely on pilots detecting and avoiding other aircraft. Pilots rely on the unalerted "see-and-avoid" principle to maintain separation from other aircraft; that is, pilots have to maintain a continuous and vigilant lookout for other aircraft.

CYA 125 (T) is an uncontrolled advisory area of Class F airspace where flight training generally occurs. It is a well-known and constantly used training and recreational area used by local pilots from at least three surrounding airports—Langley, Pitt Meadows, and Boundary Bay. This VFR training area underlies Class C airspace controlled by the Vancouver Terminal ATC unit. A buffer of at least 500 feet exists between the two airspaces: the upper limit of CYA 125 (T) is set at 2000 feet asl; the floor of the Terminal airspace is 2500 feet asl. Reportedly, VFR aircraft overflying CYA 125 (T) often transit at a midway altitude, such as 2200 feet, to avoid both areas. The physical dimensions of the airspace are clearly marked on several aeronautical charts available to pilots.

1.11 Flight Recorders

Neither aircraft was equipped with a flight data recorder or a cockpit voice recorder, nor was either required by regulation.

1.12 Wreckage and Impact Information

1.12.1 Aircoupe 415C

The Aircoupe broke up completely in flight because of the collision. The main wreckage sections fell into a vacant field within an area about 400 feet by 300 feet. The wind carried smaller debris and littered the adjacent fields for several hundred feet. A detailed examination of the wreckage revealed damage patterns that were consistent with in-flight break-up characteristics. No evidence of mechanical malfunction or pre-existing defect was found. An emergency locator transmitter was fitted on board the Aircoupe, but it was destroyed by the in-flight impact forces and likely did not activate.

In summary, all flight control surfaces and control cables/tubes were accounted for, and control continuity was verified. Collision damage signatures show that the Cessna's propeller struck the nose wheel tire and the belly of the Aircoupe on the right side of the wing spar attachment box. The propeller severed the spar and separated the two wings and the nose section at about the cockpit floor. The red battery box, installed in this area, was found several metres away from the main Cessna wreckage. A panel of sheet metal from the belly area at the wing spar was found jammed between the propeller and the engine block of the Cessna.

1.12.2 Cessna 152

After impact with the Aircoupe, the Cessna spiralled down into the same vacant field. The left wing was found 200 feet from the main impact point. A detailed examination of the wreckage also revealed damage patterns that were consistent with in-flight break-up characteristics. No evidence of mechanical malfunction or pre-existing defect was found. The Cessna's emergency locator transmitter activated at the time of impact.

In summary, all flight control surfaces and control cables were accounted for, and control continuity was verified. Examination revealed that the flaps were retracted at the time of in-flight collision. Collision damage signatures show that the Aircoupe struck the rear right side of the fuselage, probably severing the empennage. Damage to both wings shows heavy impact with the Aircoupe, and the right side of the Cessna nose section has red paint transfer marks, likely from the Aircoupe battery box. The Cessna propeller has the same paint transfer. The Cessna propeller might have carried the battery and battery box with it to ground impact. Since the propeller jammed the sheet metal panel against the engine block, the engine would have stopped when the propeller struck the Aircoupe belly.

1.13 Medical Information

The pilots' medical records, the autopsy findings, and the toxicology results revealed no indication that the performance of any of the pilots was degraded by physiological factors or incapacitation.

1.14 Fire

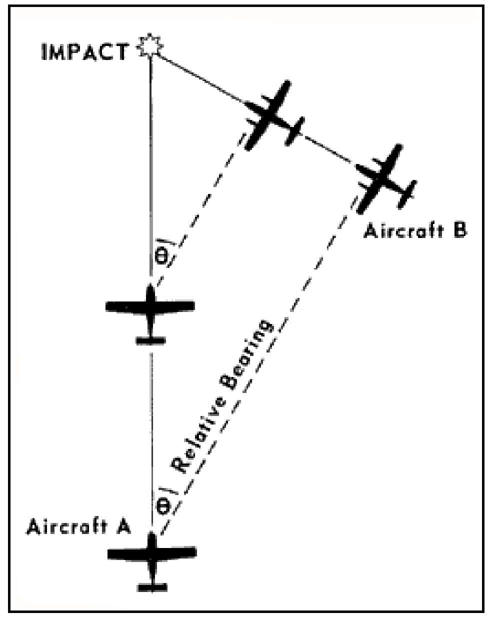
There was no fire.

1.15 Survival Aspects

The impact forces associated with the midair collision and break-up, and the subsequent impact with the terrain, were severe and beyond the extremes of normal human tolerance. The accident was not survivable.

1.16 Tests and Research

1.16.1 Constant Relative Bearing



When two aircraft are on a collision course with constant headings and constant speed, they have a constant relative bearing to each other.[2] Each aircraft, if detected, would appear to be motionless to the other pilot. This illusion increases the difficulty for each pilot to visually acquire the other aircraft. Even if one aircraft is travelling faster than the other, as long as their relative bearings remain constant, the aircraft will collide. From a pilot's perspective, if the approaching aircraft has no apparent relative motion and stays at the same point on the windscreen, a collision will likely occur unless evasive action is taken.

1.16.2 Physiological Limitations of the Human Eye

Under certain circumstances, the eye's physiological limitations may also adversely affect a pilot's ability to see other aircraft. Appendix A has been included to indicate research information on the human eye and on some of the limitations that may affect a pilot's ability to see other aircraft. While this information may provide the reader with a better understanding of physiological limitations, it has not been determined whether any of these limitations were causal in this occurrence.

1.16.3 Vision Limitations of Aircraft Design

When a pilot conducts a right turn in a low-wing aircraft, the pilot's view to the left is largely blocked by the rising left wing. The pilot of an Aircoupe would therefore have increased difficulty seeing conflicting traffic to the left. The view to the right, however, would be unobstructed, although the pilot would have to conduct a search across the cockpit and around any passenger in the right seat. The reverse is true for a left turn.

Conversely, when a pilot conducts a right turn in a high-wing aircraft, the pilot's view to the right is largely blocked by the right wing. The pilot of a Cessna 152 would therefore have increased difficulty seeing conflicting traffic to the right. In addition, the pilot would have to conduct a search across the cockpit and around any passenger in the right seat. The pilot would, however, have an unobstructed view of traffic to the left.

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[2] For more information, see Richard H. Woods and Robert W. Sweginnis, *Aircraft Accident Investigation*, Casper, Wyoming: Endeavor Books, 1995 and Bureau of Air Safety Investigation, "Relative Motion", *See and Avoid*, Australia, 1998. Figure 4 is from the former.

1.16.4 Design Eye-Reference Point

Some aircraft manufacturers provide visual reference markers in the cockpit to enable the pilot to select the best personal seat position. This design feature is a result of human factors engineering in aircraft design (ergonomics). The markers are usually fixed, coloured balls near the instrument panel or the glareshield that the pilot lines up when making seat adjustments. The pilot can thereby achieve the optimum position for visibility inside and outside the cockpit and for access to cockpit switches and controls. This optimum position, termed the design eye-reference point (DERP), is a static position based on the cockpit design.

Smaller aircraft, such as the Aircoupe and the Cessna, also have a DERP, but it is unlikely to be obviously marked. Information on the DERP is often available from the specific airframe manufacturer on request. When such information is not available, the pilot usually makes seat adjustments in height and fore-and-aft position to optimize the following factors:

a. full and free flight controls;
b. access to critical controls;
c. unobstructed view of all instruments and warning lights;
d. outside forward visibility; and
e. pilot comfort.

Pilots can ensure a consistent view outside the cockpit by adjusting their seats in this manner. They can also recognize and overcome the vulnerable areas in their visual scan for conflicting traffic.

1.16.5 The See-and-Avoid Principle

In Canada, several types of airspace require pilots to employ the see-and-avoid technique when flying under VFR or instrument flight rules. Separation relies solely on pilots' abilities to sight other aircraft and to manoeuvre their aircraft in sufficient time to avoid a conflict. In the dynamic operational environment, developing a situational awareness of all potential conflicting aircraft is not an easy task. Training areas are inherently riskier, and pilots have to assiduously scan for other aircraft.

Research indicates that a pilot is eight times more likely to acquire a target if alerted to its presence.[3] An alert may come in the form of radio communication, on-board technology such as TCAS (traffic alert and collision-avoidance systems), or simple passive equipment such as strobe lighting.

In mandatory broadcast zones and areas of high traffic density, radio calls from all aircraft in the area assist pilots to maintain an alerted see-and-avoid environment. Such advisories provide advance warning of potential conflicts and generally increase the time that pilots devote to visually searching for traffic. Advisories also aid pilots in concentrating their visual search in the proper direction. The absence of radio reports places an over-reliance on the unalerted see-and-avoid principle to maintain separation from other aircraft. The final level of protection is provided by pilots being able to see potentially conflicting traffic in time to take avoidance action.

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[3] Canada, Transportation Safety Board of Canada, *Aviation Occurrence Report A95H0008*, sections 1.9.3 and 1.9.8.

Aeronautical Information Publication[4] (AIP), section RAC (Rules of the Air and Air Traffic Services) 2.5.1—Use of Controlled Airspace by VFR Flights, states: "because of air traffic density at certain locations, the 'see and be seen' principle [*sic* see-and-avoid principle] of VFR separation cannot always provide positive separation." Further, AIP, section AIR (Airmanship) 3.7—Vision, notes that good visual scan practices are required for the see-and-avoid principle to be effective. Pilots need to identify conflicting traffic while there is still time to take avoiding action. This section also points out that good visual scan practices are an acquired not an inherent skill. Research by the Australian Bureau of Air Safety Investigation concluded "the see-and-avoid principle in the absence of traffic alerts is subject to serious limitations" and that unalerted see-and-avoid has a "limited place as a last resort means of traffic separation at low closing speeds."[5]

1.16.6 Recognition and Reaction Times

Simply detecting another aircraft in flight is not the only criterion of the see-and-avoid principle. Compounding the problem is the finite time required for a human to process the information and then to react to it, coupled with the delay in overcoming in-flight aircraft inertia. The US Naval Aviation Safety Center released data concerning typical recognition and reaction times (in seconds) for pilots confronted with a potential midair collision. The data are duplicated in the following table.[6]

Process / Task	Response (seconds)	Cumulative (seconds)
See an object ahead	0.1	0.1
Recognize that object is an aircraft	1.0	1.1
Become aware that a collision course exists	5.0	6.1
Make a decision to turn left or right	4.0	10.1
Muscular reaction	0.4	10.5
Aircraft lag in response to flight control input	2.0	12.5
Total time before aircraft begins to move	**12.5**	

Typically, at least 12 seconds are required to begin to move an aircraft away from a collision course after the pilot first sees conflicting air traffic. However, when a target aircraft is ½ nm away, its image is only 1° wide. At this size, the pilot is unlikely to see it, especially if the target is on a line of constant relative bearing, unless the image falls directly on the fovea.

1.16.7 Midair Collision Defences

[4] Canada, Department of Transport, *Aeronautical Information Publication,* TP2800E.

[5] Australia, Bureau of Air Safety Investigation, *Limitations of the See-and-Avoid Principle*, 1991.

[6] United States, Federal Aviation Administration, "How to Avoid a Midair Collision", FAA-P-8740-51 AFS-800-0687.

Safety in aviation is based on the concept of defences built into the system. Three main principles of defence keep aircraft apart from each other in VFR flight in uncontrolled airspace: procedures, technology, and the see-and-avoid principle. These elements provide redundancy to reduce the likelihood of a single-factor failure leading to a catastrophic event.

Assuming that a pilot is looking in the correct direction, the success of visually detecting a target is largely a function of target size. Under certain circumstances, however, physiological limitations of the eye, angular size of the approaching traffic, cockpit distractions, workload, and numerous other factors may adversely affect a pilot's ability to see approaching traffic. Consequently, the see-and-avoid principle is the weakest defence by far, particularly when it is unalerted.

Recommended or mandatory procedures provide the most effective element of defence and redundancy. These procedures are published to ensure commonality of operations, but if pilots do not use these procedures or do not communicate that they are not using them, other users of the airspace may not be aware of actions being taken, and a conflict may occur.

Radio communication provides another facet of defence and redundancy when all pilots within a defined area are required to communicate on a prescribed frequency. This procedure allows pilots to provide their own separation from each other and to organize themselves in a safe and orderly manner. Other examples of technology-based alerting defences include altitude-encoding transponders, aircraft collision-avoidance systems (ACAS/TCAS), and recent advances into automatic dependent surveillance broadcast (ADS–B) and traffic information services broadcast (TIS–B). These systems are principally targeted at enhancing the see-and-avoid defences of the larger air carriers. Continuing research enables the development of less sophisticated yet affordable systems for the general aviation community. For example, advances in aircraft anti-collision strobe lighting have led to effective and affordable lighting units that are superior to conventional equipment for small aircraft.

In short, improved aircraft conspicuousness reduces the risk of collision in high traffic-density areas. Strobe lighting, pulsing landing lights, and electronic surveillance technology help pilots search for and detect conflicting traffic in a timely manner. Increased pilot awareness of the factors that can reduce their effective visual fields and encouragement to adopt proven aircraft traffic scanning techniques can also mitigate the see-and-avoid limitations.

1.17 Additional Information

1.17.1 Post-accident Air Traffic Conflict

In the 15 minutes after the accident, ATC radar captured five other light aircraft flying low-level over the accident site. These aircraft were in perilous proximity to each other at least three separate times. A real risk of collision existed on each occasion. ATC radar data reveal that these aircraft entered CYA 125 (T) after the accident had occurred and flew towards and over the wreckage on the ground, using irregular and circuitous flight paths that frequently overlapped. None of the overflying aircraft were involved in the formal response to the accident, and after their accident-sightseeing activities, they returned to Boundary Bay airport.

1.17.2 Collision Avoidance—Use of Landing Lights

According to AIP, AIR 4.5—Collision Avoidance—Use of Landing Lights: “Pilots have confirmed that the use of the landing light(s) greatly enhances the probability of the aircraft being seen.” AIR 4.5 also recommends “that all aircraft show a landing light(s) ... when flying below 2000 feet agl within terminal areas and aerodrome traffic zones.” It would be prudent and reasonable to adopt a similar procedure for high traffic-density areas, such as CYA 125 (T).

1.17.3 Statistics

Between 1989 and 1999, 17 civilian midair collision accidents occurred in Canada. Eight of these accidents involved formation flight. Of the remaining nine accidents, three occurred in practice training areas, and six occurred near uncontrolled airports between aircraft that were not associated with each other. Research conducted by the Federal Aviation Administration shows “nearly all midair collisions occur during daylight hours and in VFR conditions.”[7]

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[7] United States, Federal Aviation Administration, “How to Avoid a Midair Collision”, FAA-P-8740-51 AFS-800-0687.

2.0 Analysis

2.1 General

This accident was a non-associated midair collision,[8] that is, the pilots involved were not intentionally flying in each other's vicinity, and neither knew that the other was there. Although regulations and procedures address right of way issues, they do not apply to non-associated collisions. A pilot cannot be expected to give way to another if he/she is not aware of the other.

No evidence of mechanical defect with either aircraft was found. Accordingly, this analysis focuses on the operational issues of flight in a confined training area and the inherent limitations of the see-and-avoid principle.

2.2 Operational Circumstances

In Canada, the see-and-avoid principle is used as the primary means of maintaining spacing between aircraft in visual meteorological conditions. Research shows that this principle is the least effective of the available mechanisms to keep aircraft apart because of the physiological limitations of the human eye and the motor-response systems. Accordingly, reliance on the see-and-avoid principle as the primary means of separation may be inadequate, particularly where the aircraft are close to head-on with high closure speeds.

The flight profiles of both accident aircraft indicate that neither pilot saw the other aircraft in sufficient time to initiate effective and timely evasive action. The cockpit circumstances at the time of the accident are not entirely known. The Aircoupe pilot's attention was probably focused on orbiting and manoeuvring around the ultralight, whereas the attention of the Cessna pilots was likely focused on the training environment. Although this cannot be proven, it is a scenario to which most pilots can relate and underlines why constant vigilance is so important, especially in uncontrolled airspace. Consequently, the pilots' respective tasks limited their opportunity to detect each other.

Research indicates that a pilot is eight times more likely to visually acquire another aircraft when alerted to its presence. Traffic advisories greatly assist pilots develop and maintain situational awareness (a mental picture of relevant traffic). Missing, incomplete, or inaccurate position reports from pilots, communication problems, frequency congestion, and pilot workload can introduce further inaccuracies when a pilot tries to use this information to recognize or resolve potential conflict.

The Aircoupe is a low-wing aircraft with the pilot's seat over the wing. During the right bank in the turn, the left wing would have restricted the pilot's field of view to his left, the direction from which the Cessna approached. It may therefore have been physically impossible for the occupants of the Aircoupe to see the Cessna until just before the aircraft collided.

From the perspective of the Cessna pilots, the Aircoupe would have been approaching from the front, right quadrant. The target image would have been a small profile view. The yellow Aircoupe may have blended with the variegated background, and no indication was found that the Aircoupe's landing light was on. Without a

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8 Richard H. Woods and Robert W. Sweginnis, *Aircraft Accident Investigation*, Casper, Wyoming: Endeavor Books, 1995.

warning, the Cessna pilots may not have detected the Aircoupe. The Aircoupe would have appeared motionless to them for about 10 seconds because of their constant relative bearing, which commenced when the aircraft speeds and headings combined to establish the collision course.

Canadian regulations require all pilots to maintain separation from other aircraft in flight so as not to create a risk of collision. To maintain this separation effectively, pilots must vigilantly scan for other air traffic. All pilots need to maintain a more assiduous lookout in training areas because training aircraft generally follow erratic flight paths and perform unpredictable manoeuvres. Effective lookout is degraded by the high workload and focus on training in the cockpit.

The TC safety promotion pamphlet *Take Five* recommends that all pilots operating in the training area CYA 125 (T) monitor the aerodrome radio frequency of 123.5 MHz. The pamphlet also encourages pilots to provide position advisories. Had they followed these recommended communication procedures, the accident pilots would likely have improved their situational awareness and reduced the level of risk of collision.

3.0 Conclusions

3.1 Findings as to Causes and Contributing Factors

1. Neither pilot saw the other aircraft in time to avoid the collision.

2. The pilots were not in communication with each other and did not monitor the recommended frequency for CYA 125 (T).

3.2 Findings as to Risk

1. Fading light conditions at sunset, background camouflage, aircraft design, and the inherent limitations of the human eye may preclude effective see-and-avoid separation of aircraft on a collision course.

2. Neither accident aircraft had any additional technological equipment to detect conflicting aircraft, nor was such equipment required by existing regulation.

3.3 Other Findings

1. The Cessna had its landing light on leading up to the accident. This light was an effective visual detection aid.

2. The ultralight's flight path was consistent with normal operations and procedures in uncontrolled airspace.

3. The Aircoupe's flight path was unusual in that it flew an orbit around the ultralight.

4. The Cessna's flight path was consistent with normal operations and procedures in uncontrolled airspace.

5. The Cessna's heading, speed, and attitude at collision indicate that the pilots did not see the Aircoupe before impact.

6. It could not be determined if the occupants of the Aircoupe saw the Cessna immediately before impact.

7. Nav Canada does not provide traffic conflict resolution in CYA 125 (T), nor is it required to by regulation or agreement.

4.0 Safety Action

4.1 Action Taken

4.1.1 Nav Canada

Nav Canada provides all air traffic services in Canada. As a result of this accident and unrelated operational air traffic control incidents, Nav Canada identified a timely opportunity to present situational awareness and procedural education to local general aviation pilots, flying schools, and pleasure flyers. Nav Canada embarked on a series of situational awareness workshops in concert with Transport Canada (TC) System Safety and the TSB Pacific regional office. These workshops were open to all general aviation pilots in the lower mainland in British Columbia. Over three months, speakers from the three agencies presented several operational issues and situational awareness techniques at six workshops. Attendance at the workshops was high, with pilots of diverse background and experience.

4.1.2 Transport Canada

In April 1999, before this occurrence, TC System Safety issued the *Take Five* safety promotion pamphlet in an attempt to reduce the risk of in-flight collision in CYA 125 (T). The pamphlet identifies traffic congestion in this area as a serious problem because of the dense mixture of ultralight, training, and transiting aircraft. The pamphlet highlights the requirement for a vigilant lookout in this area but also identifies that other precautions are necessary. The first counsel is that aircraft not participating in flight training operations avoid the area whenever possible. Secondly, the pamphlet advises that, since the training area contains an active ultralight field, all pilots operating in the area should monitor the aerodrome radio frequency of 123.5 MHz. In addition, the pamphlet encourages pilots to provide position advisories.

Following this accident, TC System Safety participated in several of the situational awareness workshops conducted by Nav Canada. TC System Safety is planning to conduct similar workshops on a more regular basis.

4.1.3 Pacific Flying Club

Shortly after the accident, the Pacific Flying Club fitted pulsing landing lights on all its aircraft to improve the conspicuity of their aircraft. The Pacific Flying Club also sponsored two Nav Canada situational awareness workshops.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 03 July 2001.

Appendix A—Physiological Limitations of the Human Eye

General

The human eye receives information about the movement, shape, and colour of the objects we see. That information falls onto the retina (the inner layer at the back of the eye), which contains millions of light-sensitive receptor cells, mainly cones and rods. Cones are stimulated by bright light, provide colour perception, and are concentrated in the fovea (the highly sensitive central area of the retina), which is about two degrees (°) wide. Rods respond to darkness, faint light, shape, and movement and are more numerous than cones.

Light entering the eye focuses directly on the fovea, making the fovea the site of greatest visual acuity and providing the ability to distinguish fine details. The optic nerve then relays this visual information, in the form of electrical impulses, to the brain, which processes the impulses into images.

Blind Spot

The optic nerve contains no light-sensitive receptor cells. A blind spot therefore occurs where the optic nerve attaches to the retina. This blind spot is about 5° to 10° wide and is normally compensated for by the other eye. Even when we look at an object with one eye closed, the image appears to be complete because the brain fills in a background of colour and texture to hide the blind spot. However, an object the size of a small aeroplane at a distance of 600 feet could be completely eliminated by this blind spot.

Blind spots can lead to serious consequences for pilots, including collisions. For example, if one eye were to be shielded by an obstruction, such as a windshield pillar, while the image of the potential conflict falls into the blind spot of the eye seeing past the obstruction, the pilot would not see the potential conflict and might divert attention elsewhere. The problem can be resolved by the pilot moving his or her head, but because of the constant relative bearing effect, the pilot still may not see the other aircraft.

Visual Acuity

Relative motion is important for detecting other aircraft because the retina, in particular, the fovea, is especially sensitive to small movements. The retina is not equally sensitive over its whole surface; even at small angular departures from the fovea, visual acuity diminishes significantly. For example, the acuity at 5° to the fovea is only one-quarter that at the fovea.[9] Consequently, a pilot visually searching for a small target is unlikely to see it if the target does not fall on the fovea, especially if the target has no relative movement.

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[9] Australia, Bureau of Air Safety Investigation, "Visual Acuity", *See and Avoid*, 1998.

For aircraft on a collision course, the apparent size of the oncoming aircraft roughly doubles with each halving of the distance apart.[10] For example, with a closing speed of 180 knots, two general aviation light aircraft, 40 seconds away from impact, will be two nautical miles apart; to the pilot, the target size is only ¼° wide. At 10 seconds to impact, the distance between the aircraft is now one-half nautical mile, and the target size is only 1° wide. In other words, the image size of the oncoming aircraft remains extremely small and almost impossible to detect until about 5 seconds to impact, when the image is about 2° wide.

Empty-Field Myopia

In the absence of a visual stimulus, such as empty airspace, the eye muscles relax, preventing the lens from focusing. This presents a problem for a pilot who is attempting to scan for traffic in clear, featureless sky. Because the eye cannot properly focus on empty space, vision becomes unfocused or blurred. This phenomenon hinders effective search and detection.[11]

Saccadic Eye Movements

When the eyes are not tracking a moving target, they shift in saccades (a series of jerky movements). As a result, aircrew cannot make voluntary, smooth eye movements while scanning featureless airspace. Research shows that saccadic eye movements decrease visual acuity significantly, leaving large gaps in the distant field of vision.[12]

Binocular Vision

The effectiveness of target detection depends, in part, on restrictions in the visual field. In an aircraft, the most common restriction is the visual boundary created by the overall structure of the cockpit. The visual field of each eye overlaps with that of the other eye, providing us with binocular vision and enabling depth perception.[13]

The restricted visual field of the cockpit can interfere with a pilot's ability to detect targets. The cockpit layout creates monocular visual borders (areas where an object can only be seen with one eye), thereby diluting visual acuity and inducing the pilot to concentrate searching near the centre of the binocular field (directly ahead).[14] A typical windshield, for example, is divided by support posts, which create monocular visual borders. Coupled with the natural blind spot limitation of the eye, obstructions such as cockpit windshields, supports, posts, and passengers' heads represent serious challenges for the pilot to visually detect conflicting traffic.

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10 Australia, Bureau of Air Safety Investigation, "Time, Distance and Size", *See and Avoid*, 1998.

11 Shari Stamford Krause, "Collision Avoidance Must Go Beyond 'See and Avoid' to 'Search and Detect'", *Flight Safety Digest*, 16, 5 (May 1997), p. 3.

12 Krause, p. 3.

13 Krause, p. 4.

14 Krause, p. 5.

Appendix B—Glossary

ACAS	aircraft collision-avoidance systems
ADS–B	automatic dependent surveillance broadcast
agl	above ground level
AIP	*Aeronautical Information Publication* (TP 2800E)
AIR	Airmanship
asl	above sea level
ATC	air traffic control
DERP	design eye-reference point
M	magnetic
MHz	megahertz
nm	nautical mile(s)
PDT	Pacific daylight time
RAC	Rules of the Air and Air Traffic Services
TC	Transport Canada
TCAS	traffic alert and collision-avoidance system
TIS–B	traffic information services broadcast
TSB	Transportation Safety Board of Canada
UTC	Coordinated Universal Time
VFR	visual flight rules
°	degree(s)