Transportation Safety Board of Canada

Bureau de la sécurité des transports du Canada

AVIATION OCCURRENCE REPORT

MID-AIR COLLISION

BETWEEN
BEARSKIN AIRLINES
FAIRCHILD METRO 23 C-GYYB
AND
AIR SANDY INC.
REGISTRATION PA-31 NAVAJO C-GYPZ
SIOUX LOOKOUT, ONTARIO 12 nm NW
01 MAY 1995

REPORT NUMBER A95H0008

Canada

MANDATE OF THE TSB

The Canadian Transportation Accident Investigation and Safety Board Act provides the legal framework governing the TSB's activities. Basically, the TSB has a mandate to advance safety in the marine, pipeline, rail, and aviation modes of transportation by:

- conducting independent investigations and, if necessary, public inquiries into transportation occurrences in order to make findings as to their causes and contributing factors;
- reporting publicly on its investigations and public inquiries and on the related findings;
- identifying safety deficiencies as evidenced by transportation occurrences;
- making recommendations designed to eliminate or reduce any such safety deficiencies; and
- conducting special studies and special investigations on transportation safety matters.

It is not the function of the Board to assign fault or determine civil or criminal liability. However, the Board must not refrain from fully reporting on the causes and contributing factors merely because fault or liability might be inferred from the Board's findings.

INDEPENDENCE

To enable the public to have confidence in the transportation accident investigation process, it is essential that the investigating agency be, and be seen to be, independent and free from any conflicts of interest when it investigates accidents, identifies safety deficiencies, and makes safety recommendations. Independence is a key feature of the TSB. The Board reports to Parliament through the President of the Queen's Privy Council for Canada and is separate from other government agencies and departments. Its independence enables it to be fully objective in arriving at its conclusions and recommendations.

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Aviation Occurrence Report

Mid-Air Collision

Between
Bearskin Airlines
Fairchild Metro 23 C-GYYB
and
Air Sandy Inc.
Registration PA-31 Navajo C-GYPZ
Sioux Lookout, Ontario 12 nm NW
01 May 1995

Report Number A95H0008

Synopsis

Air Sandy flight 3101, a Piper PA-31 Navajo with one pilot and four passengers on board, had departed Sioux Lookout on a flight to Red Lake, Ontario. Bearskin Airlines flight 362, a Fairchild Swearingen Metro 23 with a crew of two and one passenger on board, was inbound to Sioux Lookout on a flight from Red Lake. The two aircraft collided at 4,500 feet above sea level, approximately 12 nautical miles northwest of Sioux Lookout. All eight occupants were fatally injured.

The Board determined that neither flight crew saw the other aircraft in time to avoid the collision. Contributing to the occurrence were the inherent limitations of the see-and-avoid concept which preclude the effective separation of aircraft with high closure rates, the fact that neither crew was directly alerted to the presence of the other aircraft by the Flight Service specialist or by onboard electronic equipment, and an apparent lack of pilot understanding of how to optimize avoidance manoeuvring.

Ce rapport est également disponible en français.

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1.0 Factual Information

1.1 History of the Flight

Bearskin flight 362, a Fairchild Swearingen Metro 23, departed Red Lake, Ontario, at 1300 central daylight saving time (CDT)[1], with two pilots and one passenger on board, en route to Sioux Lookout on an instrument flight rules (IFR)[2] flight plan. At approximately 30 nautical miles (nm)[3] north of Sioux Lookout, the flight was cleared by the Winnipeg area control centre (ACC) for an approach to the Sioux Lookout airport.

Air Sandy flight 3101, a Piper Navajo PA-31, departed Sioux Lookout at 1323 with one pilot and four passengers on board en route to Red Lake on a visual flight rules (VFR) flight. The pilot of Air Sandy 3101 reported clear of the Sioux Lookout control zone at 1326. No other communication was heard from the Air Sandy flight.

At 1315 the Winnipeg ACC controller advised the Sioux Lookout Flight Service specialist that Bearskin 362 was inbound from Red Lake, estimating Sioux Lookout at 1332. At 1327, Bearskin 362 called Sioux Lookout Flight Service Station (FSS) and advised them they had been cleared for an approach and that they were cancelling IFR at 14 nm from the airport. At 1328, as Sioux Lookout FSS was giving an airport advisory to Bearskin 362, the specialist heard an emergency locator transmitter (ELT) emit a signal on the emergency frequencies.

Moments later, the pilot of Bearskin 305, a Beechcraft B-99 in the vicinity of Sioux Lookout, advised the specialist that he had just seen a bright flare in the sky and that he was going to investigate. The pilot of Bearskin 305 stated that the flare had fallen to the ground and a fire was burning in a wooded area. A communications search was initiated to locate Bearskin 362, but the aircraft did not respond. A Search and Rescue aircraft from Trenton, Ontario, and an Ontario Ministry of Natural Resources (MNR) helicopter were dispatched to the site. The source of the fire was confirmed to be the Air Sandy aircraft. The MNR helicopter noticed debris and a fuel slick on a nearby lake, Lac Seul. It was later confirmed that Bearskin 362 had crashed into the lake. (See Appendix A.)

The two aircraft collided in mid-air at 1328 during the hours of daylight at latitude 50º14'N and longitude 92º07'W, in visual meteorological conditions (VMC). All three persons on board the Bearskin aircraft and all five persons on board the Air Sandy aircraft were fatally injured.

1.2 Injuries to Persons

1.2.1 Bearskin Swearingen Metro 23 C-GYYB

	Crew	Passengers	Others	Total

1 All times are CDT (Coordinated Universal Time [UTC] minus 5 hours) unless otherwise stated.

2 See Glossary for all abbreviations and acronyms.

3 Units are consistent with official manuals, documents, reports, and instructions used by or issued to the crew.

Fatal	2	1	-	3
Serious	-	-	-	-
Minor/None	-	-	-	-
Total	2	1	-	3

1.2.2 *Air Sandy Piper Navajo PA-31 C-GYPZ*

	Crew	Passengers	Others	Total
Fatal	1	4	-	5
Serious	-	-	-	-
Minor/None	-	-	-	-
Total	1	4	-	5

1.3 *Damage to Aircraft*

Both aircraft were destroyed.

1.4 *Other Damage*

There was localized environmental damage. The trees surrounding the Navajo were damaged or burnt, and the water surrounding the Metro 23 was contaminated by fuel and oil from the aircraft.

1.5 *Personnel Information*

1.5.1 *Bearskin Swearingen Metro 23 C-GYYB*

	Captain	First Officer
Age	27	30
Pilot Licence	ATPL	ATPL
Medical Expiry Date	01 Oct 95	01 May 96
Total Flying Hours	7,330	2,810
Hours on Type	580	355
Hours Last 90 Days	170	240
Hours on Type Last 90 Days	170	240
Hours on Duty Prior to Occurrence	7	6
Hours Off Duty Prior to Work Period	10	10

The captain and first officer were certified and qualified for the flight in accordance with existing regulations. Both crew members were trained in accordance with Transport Canada requirements.

1.5.2 Air Sandy Piper Navajo PA-31 C-GYPZ

	Captain
Age	29
Pilot Licence	CPL
Medical Expiry Date	01 June 95
Total Flying Hours	1,250
Hours on Type	1,000
Hours Last 90 Days	140
Hours on Type Last 90 Days	140
Hours on Duty Prior to Occurrence	5.5
Hours Off Duty Prior to Work Period	12.5

The captain was certified and qualified for the flight in accordance with existing regulations. The captain was trained in accordance with Transport Canada requirements.

1.5.3 Flight Service Specialist

Specialist Position	Air/Ground
Age	32
Licence	Not Required
Medical Expiry Date	14 June 1997
Experience - as a Specialist - in Present Unit	 7 years 21 months
Hours on Duty Prior to Occurrence	5.5
Hours Off Duty Prior to Work Period	12

The FSS was being staffed by two specialists; one was assigned to weather functions and the other to handling the air/ground communication duties. When the accident occurred, the specialist assigned to the air/ground duties was half-way through his final 12-hour shift of a three-day-on/three-day-off schedule. He was qualified, and there were no indications of any medical or physiological problems that would have had any bearing on his ability to perform the assigned functions. Flight Service specialists do not receive any formal training on the limitations of the see-and-avoid concept, nor are they required to by regulation.

1.6 Aircraft Information

1.6.1 Bearskin Metro 23 C-GYYB

Manufacturer	Fairchild Aircraft Incorporated
Type and Model	SA227-CC Metro 23
Year of Manufacture	1993
Serial Number	CC-827B
Certificate of Airworthiness (Flight Permit)	Valid
Total Airframe Time	3,200.8 hours
Engine Type (number of)	Garrett TPE331-11U-612G (2)
Propeller/Rotor Type (number of)	McCauley 4HFR34C652-F (2)
Maximum Allowable Take-off Weight	16,500 pounds
Recommended Fuel Type(s)	Jet A, Jet A1, Jet B
Fuel Type Used	Jet B

The aircraft was configured to carry 19 passengers. The aircraft's weight and centre of gravity on the occurrence flight were within the prescribed limits.

The aircraft was being maintained on a progressive phase inspection program and had undergone a No. 4 phase and service check on 27 April 1995, 15 flight hours prior to the occurrence. There were no recorded deferred unserviceabilities, and documentation indicates that the aircraft was certified, equipped, and maintained in accordance with existing regulations and approved procedures.

1.6.2 *Air Sandy Piper Navajo PA-31 C-GYPZ*

Manufacturer	Piper Aircraft Corporation
Type and Model	PA-31-350 Navajo
Year of Manufacture	1976
Serial Number	31-7652168
Certificate of Airworthiness (Flight Permit)	Valid
Total Airframe Time	6,784.4 hours
Engine Type (number of)	Lycoming TIO-540-J2BD (2)
Propeller/Rotor Type (number of)	Hartzell HC-E3YR-2ATF (2)
Maximum Allowable Take-off Weight	7,250 pounds
Recommended Fuel Type(s)	100 Low Lead
Fuel Type Used	100 Low Lead

The aircraft had been modified with a Boundary Layer Research vortex generator kit which increased the aircraft's maximum allowable take-off weight from 7,000 pounds to 7,250 pounds. The aircraft's weight and centre of gravity on the occurrence flight were within the prescribed limits.

On 26 April 1995, 17 flight hours prior to the occurrence, the aircraft's autopilot was repaired, both altimeters were recertified, and the aircraft's transponder was repaired and recertified. The work report indicated that the transponder unit still had a low power output and that a tube replacement was recommended in the near future. A check of the aircraft's pitot static system was carried out. The pilot's horizontal situation indicator (HSI) was removed on 21 September 1994 because of sluggishness and replaced with a directional gyro (DG).

The aircraft underwent a 100-hour inspection on 28 April 1995, 12 flight hours prior to the occurrence. Documentation indicates that the aircraft was certified, equipped, and maintained in accordance with existing regulations and approved procedures.

1.7 *Meteorological Information*

The area forecast for Sioux Lookout issued at 1230 on 01 May 1995 indicated a broken and locally scattered cumulus cloud layer based at 4,000 to 5,000 feet above sea level (asl) and topped at 8,000 feet asl. Other broken, variable scattered, cloud layers were forecast between 10,000 and 14,000 feet asl. Visibility was forecast greater than six miles. Isolated towering cumulus clouds, producing light rain showers, were anticipated with the tops of the cumulus cloud reaching up to 14,000 feet asl. The freezing level was forecast to be at 2,000 to 3,000 feet asl, and turbulence was predicted to be light to nil.

The terminal forecast for Sioux Lookout for the time of the occurrence indicated a scattered layer at 4,000 feet above ground level (agl) with a broken ceiling of 10,000 feet agl and visibilities in excess of six miles. The terminal forecast predicted occasional ceilings of 4,000 feet agl with visibilities greater than six miles in light rain showers.

The 1800Z weather reported at Sioux Lookout, about 28 minutes prior to the occurrence, was as follows: clouds 3,500 feet agl scattered, estimated 8,000 feet agl overcast; visibility, 15 miles; temperature, 9 degrees Celsius; dew point, -1 degree Celsius; wind, 210 degrees true at 6 knots. The 1851Z weather reported at Sioux Lookout, about 23 minutes after the collision, was as follows: clouds 4,000 feet agl scattered, estimated 8,000 feet agl overcast; visibility 15 miles.

The flight crew of the Bearskin Airlines Beech 99 that was flying in the area at the time of the occurrence indicated that they were in VMC at the time of the occurrence; they saw a brilliant flash, then saw debris and a fireball-type object fall to the ground. They stated that they were at an altitude of approximately 4,000 feet asl, 5 to 6 nm east of the explosion. The flight crew indicated that the visibility was unlimited beneath a solid overcast of approximately 6,500 feet asl, and that there was no direct sunlight breaking through the solid overcast.

1.8 *Aids to Navigation*

Each aircraft was equipped with a global positioning system (GPS) receiver. Bearskin aircraft have the GPS receiver connected directly to the HSI, and company procedures require the pilots to use GPS as an aid to primary navigation systems. Air Sandy company procedures also require the pilots to use GPS as an aid to navigation. The Canadian air navigation system is rapidly moving towards increased reliance on GPS as an inexpensive and accurate navigation system.

Airways are designed to be 8 nm wide (8.6 for non-directional beacon [NDB]) at their narrowest point. This width takes into account the inaccuracies of the ground transmitter and those of the aircraft receivers. GPS receivers, however, are considered accurate to within ± 300 feet and will show course deviations of 0.1 nm--in effect, the airway has become 600 feet wide. A large portion of the ± 300-foot accuracy error is deliberately introduced by the United States (U.S.) military on a random basis and is designed to deny high precision signals to unfriendly military aircraft.

When two aircraft using GPS are flying the same route and are in the same location, they could receive the same signal. Although they can be as much as 300 feet from their intended position relative to the ground, the distance between the two aircraft could be much less (see LP 95/95). Thus, GPS has greatly reduced the lateral displacement of aircraft flying along identical intended tracks.

Since the introduction of GPS, there have been no changes to procedures to take into account the increased risk of mid-air collisions for aircraft navigating by GPS. Transport Canada has acknowledged the problem and has promulgated a leaflet that discusses the use of GPS offset procedures to ensure separation en route. Although the information suggests using an offset track while navigating by GPS, there are no established procedures that would ensure that all pilots using GPS offset their tracks. If procedures for separating aircraft are not used, the probability of collision between aircraft using GPS is significantly higher than between aircraft using conventional navigation aids.

1.9 *Characteristics of the See-and-Avoid Concept*

1.9.1 *General*

Safe VFR flight is predicated on the see-and-avoid concept. The effectiveness of the see-and-avoid concept for collision avoidance is dependent on flight crew detecting other aircraft on collision courses in time to take evasive action. A pilot's ability to visually detect another aircraft is affected by many factors, including physiological limitations of the human visual and motor-response systems, the pilot's awareness of the presence of another aircraft, the pilot's available field of view, obstructions to that field of view, aircraft conspicuity, pilot scanning techniques, and pilot workload.

1.9.2 Physiological Factors

Physiological limitations in both the human visual and motor-response systems reduce the effectiveness of see-and-avoid as the relative closing speed of the aircraft increases.

The main physiological limiters are as follows:

a. when the threat is distant and sufficient time is available to react, the ability of the human optical system to perceive the required information is limited; however,

b. when the threat is close enough to allow the eye to perceive the required information, then the time available to allow for information processing and motor response may be insufficient.

1.9.3 Traffic Advisories

It is generally recognized that traffic advisories will improve a pilot's ability to visually acquire another aircraft. First, the advisory provides advance warning of a potential conflict and will tend to increase the time that the crew will devote to the visual search for the traffic. Second, the advisory will aid the pilot in concentrating the visual search in the proper direction.

Research conducted by the Lincoln Laboratory[4] during traffic alert and collision avoidance system (TCAS) flight testing showed that a pilot alerted to the presence of other aircraft visually acquired the other aircraft in 57 of 66 cases; the median range of visual acquisition was 1.4 nm. However, in cases where the pilot was not alerted to the presence of the other aircraft, visual acquisition of the other aircraft was achieved in only 36 of 64 encounters; in the successful encounters, the median acquisition range dropped to 0.99 nm.

These studies showed that verbal guidance as to where to look increased the acquisition probability for the pilots, and found that a pilot who had been alerted to the presence of another aircraft was eight times more likely to see the aircraft than was a pilot who had not been alerted.

1.9.4 Visibility from the Cockpit

Cockpit design affects the available view. In particular, obstructions such as window posts mask certain areas around the aircraft. Pilots are required to consciously alter their head position in order to look around these obstructions.

1.9.5 Conspicuity Of Aircraft On Collision Course

[4] J.W. Andrews, *Modeling of Air-to-Air Visual Acquisition*. The Lincoln Laboratory Journal, Volume 2, Number 3 (1989) p 478.

The human visual system has physical limitations which reduce effective visual performance. For example, people are particularly attuned to detecting movement, but are less effective at detecting stationary objects. Unfortunately, because of the geometry of collision flight paths, an aircraft on a collision course will appear to be a stationary object in the pilot's visual field.

The contrast between an aircraft and its background, and the apparent size of an aircraft are two of the factors that affect an aircraft's detectability. At the time of the occurrence, according to a report from pilots in another aircraft operating in the immediate area, the sky was overcast with a layer of cloud at about 6,500 feet asl. The pilots also indicated that there were no obstructions to flight visibility. The aircraft involved in this occurrence were white and light beige, and would have been relatively indistinguishable from their background or the clouds.

Most of the snow in the area had melted, including some of the snow in the woods. However, some of the lakes in the area of the occurrence were still ice covered and appeared white in colour from the air. The frozen surface of the lakes, as well as the snow and the topography of the area, made the detection of either aircraft more difficult.

1.9.6 Pilot Scanning Technique

A pilot's visual scanning technique is affected by the level and complexity of other pilot tasks and the pilot's level of concern about the threat of a collision.

The company procedure for the Navajo was to have the pilot climb the aircraft at a rate lower than the best-rate-of-climb in order to provide adequate airflow over the engine for cooling purposes. Assuming this rate-of-climb, the aircraft would have reached cruise altitude prior to the impact. The level-off checks for the Navajo require that the pilot momentarily look inside the cockpit at the flight and engine instruments in order to set cruise power.

The Metro pilots were preparing for a landing and talking to the Flight Service specialist. Analysis of the cockpit voice recorder (CVR) indicated that the crew also discussed the approach and landing, completed checks, and talked to company personnel on the radio.

1.9.7 Factors Affecting Visual Acquisition

For the see-and-avoid principle to be effective, it is necessary that a pilot be able to detect aircraft by visual means, recognize collision geometry based on visual cues, and react correctly, and in sufficient time, to avoid a mid-air collision.

In a potential mid-air collision situation, physiological limitations of the eye, pilot visual-scanning techniques, target characteristics, pilot reaction time, aircraft speed and design, and numerous other factors will influence a pilot's ability to acquire a target visually and avoid it. In general terms, assuming that a pilot is looking in the correct direction, the visual detection of a target is largely a function of target size. A pilot will only see an aircraft when the size of the target becomes large enough to meet the minimum resolution capability of the eye. Commercial or charter aircraft similar to the ones involved in this occurrence should, under good conditions, be detectable at an approximate range of 1 to 1.5 nm. Contrast with the background, aircraft attitude, and relative flight path of an aircraft can affect this detection range, often reducing it significantly.

1.9.8 Human Response Limitations

Simple detection of another aircraft in flight is not the only problem with the see-and-avoid concept. Studies[5] indicate that minimum times required for a human to process information and then react will range from six to nine seconds. Additionally, in a flying situation, there will be a further delay due to the inertia of the aircraft. As a result, the total reaction time necessary for a pilot to recognize and analyze visual information and then effect a change to an aircraft's flight path could be as high as 12 seconds[6], assuming that the pilot is alert, attentive, and doing visual scanning.

With closing speeds in the range of 410 knots, a pilot would have to see the approaching target at a minimum range of approximately 1.4 nm (12 seconds) in order to have sufficient time to take effective evasive action. Using data from a study conducted at the Massachusetts Institute of Technology (MIT) (see LP 86/95), it was determined that the probability of the Air Sandy pilot detecting the Bearskin flight 12 seconds before impact was about 13%. The probability of his detecting the Bearskin aircraft 20 seconds (2.3 nm) prior to impact was only 6%.

As the two aircraft approach each other, the probability of detection increases. Using the same MIT study data, it was determined that, at 20 seconds prior to impact, the Bearskin pilots had a 7% chance of detecting the Air Sandy aircraft. At 12 seconds (1.4 nm) to impact, they had a 16% chance of detecting the Air Sandy aircraft. At a time of 4.4 seconds (0.5 nm) prior to impact, the Bearskin pilots would have had a 53% chance of detecting the Air Sandy aircraft. At a time of 3.5 seconds (0.4 nm) prior to impact, the Air Sandy pilot would have had a 52% chance of detecting the Bearskin aircraft. These probabilities were determined using optimum flight conditions with no restriction to the visibility field of the pilots. Restrictions to a pilot's visibility field could come from the aircraft's attitude, the aircraft airframe, a windshield post, windshield size, or from dirt, scratches, or bugs on the windshield.

1.9.9 Pilot Avoidance Techniques

Assuming that a pilot will be capable of visually detecting another aircraft in flight and determining that the closing geometry represents a mid-air threat, then the final stage in the see-and-avoid sequence is to initiate an effective avoidance response. The aim of that response will be to increase the miss distance between the aircraft. The effectiveness of that response is dependent on a number of factors; in general, either pilot can alter the geometry of a collision by changing some combination of aircraft speed, altitude, and heading. Because each of these actions will affect the geometry differently, it is essential that the pilot choose an appropriate combination of actions that will merge to achieve a corresponding effect.[7]

The optimum avoidance response will differ depending on the time to impact. There is research evidence[8] to indicate that, outside 10 seconds to the point of closest approach, the pilot should use compatible manoeuvres combining speed, altitude, and heading change. However, once the aircraft are inside the range of approximately 10 seconds to impact, the pilot should employ an altitude change

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5 Anchard F Zeller, *Human Reaction Time*. ISASI Forum, October, 1981 pp 12-13.

6 Harold F. Marthinsen, *Another Look at the See-and-Avoid Concept* ISASI Forum December 1989, pp 82-103.

7 J.L. Harris, Sr., "*Avoid", The Unanalyzed Partner of "See*". ISASI Forum #2, 1983 pp 12-17.

8 J.L. Harris, Sr., p 16.

only. This conclusion is based on an argument that, when two aircraft are confined in close quarters, the essential action is to minimize the relative cross-sectional areas of each aircraft. Under these circumstances, it has been generally found that any application of bank will increase the relative cross-sectional area and thereby increase the probability of impact.[9]

As an example, a Piper Navajo aircraft similar to the one involved in this occurrence will have a vertical cross-section of approximately 13 feet when in level flight. At bank angles in the range of 45 to 60 degrees, the vertical cross-section will be in the range of 28 to 34 feet. The final value of the vertical cross-section will be dependent on the aircraft's wing span and on the applied bank angle.

Formal training on how to recognize in-flight collision geometry and on how to optimize avoidance manoeuvring is not part of the required syllabus for any level of civilian pilot licence in Canada.

1.10 *Aerodrome Information*

1.10.1 *General*

Sioux Lookout airport, located at 50º06'N and 91º54'W, is a certified aerodrome operated by the town of Sioux Lookout. The field point elevation is 1,280 feet asl. The main runway, which is oriented 160/340 degrees magnetic, is paved and measures 4,500 feet by 100 feet. An NDB and a distance measuring equipment (DME) transmitter are located at the airport. The control zone extends around the airport for a 5 nm radius from the surface of the earth to an altitude of 4,300 feet asl. A pie-shaped corridor in the western section of the control zone is exempted from the mandatory frequency (MF) at an altitude below 700 feet agl. This corridor is designed to permit float-equipped aircraft access to the lake and townsite without having to enter the control zone. A flight service station is located at the airport and provides traffic advisories, among other things, to aircraft flying in the area. IFR traffic operating in and out of Sioux Lookout is controlled by Winnipeg ACC.

1.10.2 *FSS Facilities/Operation*

The Sioux Lookout FSS is normally busy, in that the airport supports scheduled flights for Bearskin Airlines, Air Sandy, charter flights for a number of commercial carriers, and local traffic. Additionally, the Sioux Lookout area encompasses float bases and an MNR base, both of which are within several miles of the airfield.

FSS duties and functions are governed by a *Flight Service Manual of Operations (MANOPS)* which stipulates the priority of duties and establishes specific procedures to govern how the FSS support functions will be accomplished.

1.10.3 *Flight Service Specialist Equipment*

The specialist is responsible for providing airport advisory information to aircraft operating to or from a location within the MF area. In accordance with MANOPS, when giving the advisory, the specialist must provide a summary of known pertinent aircraft traffic that may affect the aircraft's flight safety. While operating in visual meteorological conditions, pilots have the sole responsibility for seeing and avoiding other aircraft. The specialist did not directly advise Air Sandy of the Bearskin 362 flight inbound from Red Lake; however, he did advise two other aircraft on the MF of the approaching Bearskin 362 flight while Air Sandy 3101 was on the same frequency. Pilots are also responsible for maintaining a listening watch on the MF.

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9 J.L. Harris, Sr., p 16.

The Flight Service specialist can contact Winnipeg ACC via landline for IFR traffic information; however, the tools available to the specialist to facilitate traffic recognition and determine the traffic location are limited. The Sioux Lookout specialist had a plotting board on which he would make a strip that would identify the traffic in his area. He would also be able to rely on position reports provided on 122.0 (the MF) and 126.7 megahertz (MHz) frequency. Taking this type of traffic information and processing a mental picture of the various aircraft and their positions in relation to one another is more difficult without adequate visual references.

Most air traffic controllers in area control centres are able to view a radar screen for traffic information. The information on the radar screen allows the controller to identify traffic and have a pictorial display of the traffic in his or her area of control. Some air traffic control towers that are located near radar sites have personal-computer-based radar displays of the traffic in their area. Although the tower controllers do not use the radar information for traffic separation, they do use this information to provide traffic information with respect to their location. The Sioux Lookout FSS is equipped with very high frequency (VHF) direction finding (VDF) equipment. Information is displayed by a numerical readout which gives an indication of the bearing of an aircraft from the VDF site. This is based on a radio signal from the aircraft; however, no distance information is provided.

1.10.4 Air Carrier Radio Frequency Procedures

On a VFR departure from Sioux Lookout, the Air Sandy company procedure is for the pilot to communicate on the MF until clear of the control zone and then change to an en route frequency of 122.8 MHz. The second radio in the aircraft would be tuned to either 126.7 MHz or 122.0 MHz. The switch to 122.8 MHz would be made prior to reaching a distance of 10 nm from the airport.

Bearskin 362 was on the Winnipeg ACC frequency en route to Sioux Lookout. Once cleared for the approach by Winnipeg ACC and instructed to contact the Sioux Lookout FSS, the Bearskin crew delayed contacting the FSS for about 70 seconds. This delay was intentional because the crew wanted to wait until they were clear of cloud so that they could cancel their IFR clearance and proceed VFR. Had they contacted Sioux Lookout FSS immediately after being instructed, they still would not have heard the Air Sandy flight clearing the zone; however, the specialist would have had more time to relay vital traffic information to the Bearskin crew.

1.11 Flight Recorders

The Metro 23 wreckage was in about 30 feet of water; a tuneable hydrophone receiver was used to locate the underwater locating beacons of the flight data recorder (FDR) and the cockpit voice recorder (CVR). Investigators experienced difficulty locating the underwater beacons of the recorders because impact damage to the transducer ring on both beacons degraded the signal output beyond the manufacturer's specification.

Information from the FDR and CVR of the Metro 23 proved invaluable to the investigation. A review of the FDR information shows that the Bearskin aircraft took no evasive manoeuvres prior to impact, and that the mid-air collision occurred at 4,500 feet asl. There was no indication of mechanical problems that would have contributed to the occurrence. The airspeed of the Bearskin aircraft during the descent was about 250 knots, slowing to about 230 knots prior to the collision. There were no indications on the CVR that the Bearskin crew saw the Air Sandy aircraft. The CVR also indicated that the Bearskin crew turned on the aircraft's recognition lights during the descent into Sioux Lookout, in accordance with company procedures.

The Air Sandy aircraft was not equipped with an FDR or CVR, nor was either required by regulation.

1.12 Wreckage and Impact Information

The wreckage from both aircraft was scattered over an area measuring approximately 1 1/2 by 1/2 miles. The major portions of the Bearskin Metro were located in water (designated Site 1). The high-speed impact with the water resulted in the destruction of the aircraft. Evidence showed that the aircraft was on fire prior to impact with the water. The major portions of the Air Sandy Navajo wreckage were located on land (designated Site 2), where the majority of the aircraft was burned in a post-crash fire.

1.12.1 Site 1 - Metro Wreckage and Impact Information

The major portion of the Bearskin Metro wreckage was located in about 30 feet of water, approximately 200 feet south of an island directly west of Devil's Elbow in Lac Seul. The tight wreckage pattern at the bottom of the lake indicates that the aircraft struck the water in a near vertical attitude. Numerous pieces of aircraft debris were discovered floating downstream into the channels on either side of the Devil's Elbow point. Bubbles and a noticeable oil/fuel slick were noted emanating from the underwater location.

The left engine, left landing gear assembly, and wheel well structure were recovered from the water in one section. The landing gear was extended upon recovery; however, damage to the uplock roller casting on the main gear housing and damage to the gear door uplock roller bearing indicates that the landing gear was retracted prior to impact and forced out of the wheel well during the crash sequence. Portions of the left propeller hub were attached to the engine flange--the remaining pieces of the propeller hub and propeller blades were not located. The right engine and propeller were not located.

The right landing gear assembly and wheel well structure were recovered from the water as one section. The landing gear was retracted and both tires were deflated and driven off the rims. The landing gear housing was split open vertically along its length from being driven rearwards at an angle, and a piece of Navajo wing skin was found jammed between the wheel brake assemblies. The wing structure, outboard of the nacelle, was cut through at an approximately 45-degree angle.

The cockpit floor section through to the tail section was pulled out of the water in one crumpled section approximately 1/5 of its original length. The roof and side wall structures were blown open, crumpled, and fragmented. Fire sooting was evident on pieces of the right fuselage structure and on the upper and lower surfaces of the right horizontal stabilizer and elevator. The cockpit instrument and radio panel section was broken apart and scattered in small pieces along the bottom of the lake; only one altimeter was recovered.

The right wing of the Bearskin Metro, outboard of the right engine nacelle, and pieces of one of the Metro's propeller spinner and engine exhaust duct housing wrap were located on land in an area approximately midway between the two wreckage sites. The wing was cut through at about a 45-degree angle, consistent with the damage to the wing located at the Metro site. In this same area were numerous pieces of the Navajo's right wing and right aileron.

1.12.2 Site 2 - Navajo Wreckage and Impact Information

The major portion of the Navajo was located on land approximately 1.2 nm northwest of Site 1. The aircraft came through the trees on a heading of approximately 320 degrees magnetic and in an approximately 65 degrees nose-down left-wing-low attitude. The nose of the aircraft struck the ground and deflected forward while the remainder of the aircraft buried itself into the partially frozen ground. A post-crash fire consumed most of the cabin structure. Both engines were located in the crater.

The tail section and left wing structure through to the right engine nacelle were removed from the crater and partially reconstructed. The reconstruction showed that most of the right wing structure outboard of the engine nacelle was missing. The remainder of the aircraft appeared to be present. All three landing gear were located, and it was noted that the right landing gear was retracted in the wheel well.

1.12.3 System Examination

Due to the near complete destruction of both aircraft, a complete physical examination of all the aircraft systems was not possible. The aircraft flight profiles, however, coupled with CVR and FDR information from the Bearskin Metro 23, indicate that the aircraft were likely not experiencing any mechanical or flight system control difficulties prior to the collision.

1.12.4 Wreckage Reconstruction

The partial wreckage reconstruction of both aircraft indicates that the aircraft collided nearly head on, at a sharp bank angle. Because the Metro FDR and CVR information does not show a sudden roll input, it is likely that the Air Sandy Navajo was in a sharp left turn at the point of initial contact. Examination of the wreckage indicates that the right wing of the Navajo struck the nose of the Metro before contacting the Metro's right propeller. The Metro's right propeller was fragmented at this point and the engine sheared outboard off its mount. Portions of the Navajo's right wing continued on to drive the Metro's right main landing gear rearwards and outboard and slice off the Metro's right wing at a 45-degree angle, outboard of the engine nacelle. The Navajo's right wing, outboard of the engine nacelle, was completely fragmented at this point and both aircraft, minus one wing, descended nearly vertically into the ground.

1.13 Fire

Witnesses observed a brilliant flash in the sky, followed by an arcing streak leading to an explosion, which was thought to be fireworks. Following the explosion, an object was observed falling to the ground, and smoke was later observed emanating from the area of ground impact. This area of impact was later determined to be the Air Sandy Navajo site.

Both aircraft lost their right wings during the mid-air collision, and both wings contained fuel cells which ruptured upon impact. Sooting on the tail of the Bearskin Metro indicates that the aircraft was on fire prior to striking the water. The Air Sandy Navajo was burned by a post-crash fire after impact with the ground.

1.14 Survival Aspects

The in-flight collision took place at an approximate closing speed of more than 400 knots and at an altitude of approximately 3,200 feet agl. Both aircraft were damaged structurally by that collision. In each case, portions of one wing were destroyed by the in-flight collision and both aircraft commenced an immediate and uncontrolled descent. The collision and the impact with the ground or water would have resulted in "g" forces beyond the range of human tolerance.

1.15 Communications

The inbound Bearskin (IFR) changed from Winnipeg ACC to the MF frequency, and the outbound Air Sandy (VFR) normally changes from the MF frequency to 122.8 MHz. The only common frequency for the two aircraft would have been the MF, and, when the collision occurred, both aircraft were well outside the 5 nm MF zone.

Many aircraft operating in northwestern Ontario use the 122.8 MHz frequency for en route communication instead of 126.7 MHz. The 122.8 MHz frequency is not published in the *Canada Flight Supplement* for the Sioux Lookout area. Any pilot using the published frequency of 126.7 MHz or the MF will not be able to hear local traffic that is on 122.8 MHz and may be deprived of relevant traffic information. Similarly, the traffic operating on 122.8 MHz will not receive traffic information provided by aircraft on 126.7 MHz or on the MF.

1.16 Traffic Alert and Collision Avoidance System (TCAS)

TCAS is designed to operate independently of air traffic control and is designed to provide pilots with traffic information to assist them in the visual acquisition of other aircraft. TCAS I is a less sophisticated system which will provide a warning of proximate traffic (traffic advisories, or TAs) without providing guidance to avoid potential collisions. TCAS II is capable of providing TAs and resolution advisories (RAs) in the form of recommended vertical escape manoeuvres to avoid conflicting traffic. TCAS makes use of the radar beacon transponders installed on other aircraft; specifically, basic transponder returns are used to provide azimuth and range information; Mode C information, the aircraft altitude to the nearest 100-foot level, and Mode S intent-to-manoeuvre information are used to interpret the vertical geometry required for the generation of RAs. Once a target is tracked and displayed, the TCAS processor will update the associated displays and advisories as long as transponder signals are received and until the target no longer constitutes a threat or goes beyond the display parameters. Aircraft without transponders are invisible to TCAS.

TCAS was developed in the U.S. by the Federal Aviation Administration (FAA). The U.S. is the only state in the world which mandates the use of TCAS. As of 31 December 1995, it is mandatory that all aircraft flying in U.S. airspace with 10 to 30 passenger seats be equipped with TCAS I. All aircraft with more than 30 passenger seats have been required to be equipped with TCAS II since 30 December 1993. There is no requirement for aircraft in Canada to be TCAS equipped, and neither of the two accident aircraft was so equipped.

2.0 Analysis

2.1 General

The pilots of both aircraft were certified and qualified, and there was no evidence that any physiological factors affected their ability to conduct the flights safely. There were no mechanical discrepancies found with either aircraft that would have contributed to the occurrence. The only apparent evasive action to avoid the collision was taken by the Air Sandy pilot; however, it was taken in insufficient time to avoid the collision.

Although this was a typical VFR situation in that two aircraft were flying under visual conditions, a number of factors combined to create a high risk of collision. Therefore, this analysis will examine the pilots' ability to see the other aircraft, the limitations of the see-and-avoid concept, the lateral precision of GPS, why the pilots were not alerted, the effects of high closing speeds, the apparent lack of pilot understanding of how to optimize avoidance manoeuvring, and other factors that could have contributed to the occurrence.

2.2 Limitations of the See-and-Avoid Concept

See-and-avoid is used as the primary means of separating aircraft in visual flight conditions; however, due to the physiological limitations on the human visual and motor-response systems, it may be impractical to rely on this system as the primary means of separation. This is particulary true in situations that involve head-on geometry with high closing speeds; the risks involved in relying on see-and-avoid increase as the relative closing speed of the aircraft increases.

In this occurrence, the Bearskin Metro had been descending at approximately 250 knots and was decelerating to approximately 230 knots. The departing Navajo would have just levelled off from an en route climb and would have been accelerating to a flight planned cruise speed of approximately 180 knots. At a closing speed of about 410 knots and with 12 seconds before impact, the Bearskin pilots had less than a 16% probability of detecting the Air Sandy aircraft, and the Air Sandy pilot had less than a 13% chance of detecting the Bearskin aircraft. Not until the Bearskin pilots were within 4.4 seconds of impact and the Air Sandy pilot was within 3.5 seconds of impact did the pilots of either aircraft have at least a 50% chance of detecting the other aircraft. It is likely that the Air Sandy pilot saw the Metro and attempted an evasive manoeuvre.

With 12 seconds required to see and avoid another aircraft, it is doubtful that a pilot could effectively avoid another aircraft on a head-on collision course at a high closure rate.

Advisory communications by Air Traffic Services and flight crew monitoring of frequencies are crucial in helping prevent collisions. It is, therefore, considered important that Flight Service specialists have a level of understanding comparable to that of pilots on the limitations of see-and-avoid.

2.3 Avoidance Manoeuvre

Based on the aircrafts' relative attitudes at impact, it appears that the Air Sandy pilot had detected the approaching Bearskin Metro, and had begun an evasive manoeuvre by initiating a steep left-turn which had reached approximately 45 degrees to 60 degrees of bank. As the bank angle increased, the aircraft's cross-section would have increased correspondingly from a minimum value of approximately 13 feet to some final value in the range of 28 to 34 feet; the net result of the evasive roll would have been to inadvertently increase the Navajo's cross-sectional area and, thus, increase the risk of colliding with the oncoming Metro aircraft.

A vertical manoeuvre, consistent with that demanded by TCAS-equipped aircraft, is normally more effective in close-range, head-on collision scenarios. However, formalized training on how to recognize in-flight collision geometry and on how to optimize avoidance manoeuvring is not part of the required syllabus for any level of civilian pilot licence in Canada. Without appropriate training, it is possible that a pilot who sees a target in sufficient time to react may react by turning, thereby increasing the cross-sectional area of the aircraft and increasing the risk of collision.

2.4 FSS Advisory Communications

In this occurrence, it is unlikely that the involved aircraft were on the same radio frequency at the point where the collision occurred. Since the collision occurred approximately 12 nm from the airport, outside of the MF zone, it is likely that the Air Sandy aircraft would have been on 122.8 MHz and would not have heard any of the radio transmissions between the FSS and the Bearskin aircraft. The inbound Bearskin flight was operating under IFR control and had been directed to change from Winnipeg ACC to the Sioux Lookout MF. It is therefore unlikely that either aircraft would have heard transmissions generated by the conflicting flight. The only common frequency for the two aircraft would have been the MF, but, when the collision occurred, both aircraft were well outside the 5 nm control zone. If the flight crew of either aircraft had been alerted to the presence of the other, the likelihood of seeing the other aircraft would have increased by about a factor of eight. This increased likelihood of detection might have given the crew of either aircraft the opportunity to initiate a collision avoidance manoeuvre in time to prevent the collision.

Unlike air traffic controllers, Flight Service specialists do not have radar equipment. The specialist at Sioux Lookout was provided with VDF equipment, which has some capability to display potential collision information; however, VDF does not provide distance information.

The specialist had to rely on voice reports from aircraft, and, aided by a plotting board, his own ability to keep mental track of traffic in the area to visualize potential conflicts. He did not have additional equipment that would have helped alert him to the presence of the Bearskin flight and the conflict between it and the Air Sandy flight.

2.5 Control Zone

The use of the MF is only required while in the control zone. The edge of the control zone in Sioux Lookout is 5 nm from the airport. High performance, multi-engine aircraft that frequent the airport can have closing speeds of up to 400 knots (one departing, one landing), which is equivalent to more than 6 nm per minute. If the control zone radius is 5 nm, it is likely that these aircraft will have less than one minute before their paths cross within the control zone. At such a speed, there is little time for the Flight Service specialist to convey traffic information, especially if he is tasked with other duties such as talking to other traffic or to the ACC on the telephone. If the MF area were larger, or if the aircraft were approaching and departing at lower speeds, there would be more time for aircraft to be made aware of each other.

2.6 Lateral Precision of GPS

Although all indications are that the pilots of both aircraft were navigating with the use of GPS, it was not possible to determine this with certainty. However, the use of GPS makes it possible to navigate with great precision. Navigating with an accuracy of ± 300 feet laterally does not leave much space when aircraft are converging at high speeds and are climbing or descending. Transport Canada has recognized this problem and has promulgated leaflets which discuss this issue. The leaflets suggest that pilots use laterally offset navigation tracks. However, there is no established procedure to ensure that all pilots navigating by GPS are using lateral separation. If one aircraft uses an offset track and another does not, the risk of collision will be reduced, but not by as much as it would be if both aircraft used offset tracks.

2.7 TCAS and Transponder Use

Modern TCAS equipment depends on transponder operation. Neither of the aircraft involved in this occurrence was TCAS equipped; however, if one of the aircraft had been equipped with TCAS and both had had operating transponders, the collision would likely not have occurred. TCAS, if installed and operable, would have provided constant warnings and cues to the crew of their proximity to the other aircraft. The warning likely would have provided the crew with adequate time to take appropriate actions to avoid the collision.

3.0 Conclusions

3.1 Findings

1. The two aircraft collided at 4,500 feet above sea level, approximately 12 nautical miles northwest of Sioux Lookout.

2. The aircraft flight profiles, coupled with CVR and FDR information from the Bearskin Metro 23, indicate that the aircraft were likely not affected by any mechanical or flight system control malfunctions prior to the collision.

3. Neither aircraft was equipped with TCAS, nor was either required to be by regulation.

4. In the United States, it is mandatory that all aircraft with 10 or more passenger seats be equipped with TCAS. There is no corresponding requirement for aircraft in Canada to be TCAS equipped.

5. The Flight Service specialist did not directly advise Air Sandy 3101 of the Bearskin 362 flight inbound from Red Lake; however, he did advise two other aircraft on the MF of the approaching Bearskin 362 flight while Air Sandy 3101 was on the same frequency.

6. The specialist had to rely on voice reports from aircraft, VDF equipment, and his own ability to keep mental track of traffic in the area to visualize potential conflicts. He did not have additional equipment that would have helped alert him to the presence of the Bearskin flight and the conflict between it and the Air Sandy flight.

7. There was no direct communication, TCAS, or radar information available to alert either aircraft crew to the presence of the other aircraft. A pilot who has been alerted to the presence of another aircraft is eight times more likely to see the aircraft than is a pilot who has not been alerted.

8. The probability of a collision between aircraft using GPS on established air routes is significantly higher than between aircraft using conventional navigation aids because of the greater accuracy of navigation using a GPS.

9. Various procedures have been established for IFR and VFR aircraft to reduce the risk of mid-air collisions; however, there have been no prescribed changes to procedures as a result of the introduction of GPS.

10. Neither flight crew saw the other aircraft in time to avoid the collision.

11. Physiological limitations in both the human visual and motor-response systems reduce the effectiveness of the see-and-avoid concept as the relative closing speed of the two aircraft increases.

12. Formal training on how to recognize in-flight collision geometry, and on how to optimize avoidance manoeuvring is not part of the required syllabus for any level of civilian pilot licence in Canada.

13. Many aircraft operating in northwestern Ontario use the 122.8 MHz frequency for en route communication instead of 126.7 MHz. Consequently, the traffic operating on 122.8 MHz will not receive traffic information provided by aircraft on 126.7 MHz or on the MF.

3.2 Causes

Neither flight crew saw the other aircraft in time to avoid the collision. Contributing to the occurrence were the inherent limitations of the see-and-avoid concept which preclude the effective separation of aircraft with high closure rates, the fact that neither crew was directly alerted to the presence of the other aircraft by the Flight Service specialist or by onboard electronic equipment, and an apparent lack of pilot understanding of how to optimize avoidance manoeuvring.

4.0 Safety Action

4.1 Action Taken

4.1.1 Operator Action

Subsequent to the accident, Bearskin Airlines developed procedures to reduce the risk of mid-air collisions in the busy Sioux Lookout area. These procedures include a requirement that all Bearskin aircraft be flown at a speed of less than 150 knots when operating within 5 nm of the Sioux Lookout airport. This reduction in airspeed should decrease the probability of mid-air collision by increasing both the likelihood of detecting conflicting traffic and the time available to take evasive action once conflicting traffic has been detected.

4.1.2 Transport Canada Action

Transport Canada has taken action to increase pilot awareness of procedures to reduce the likelihood of mid-air collisions. An Aviation Notice entitled "Mid-Air Collision Alert Bulletin" was issued in July 1995. The notice informs pilots of the increased potential for collision when using GPS and stresses the benefits of using arrival, departure, and position reports in order to be alerted to potential conflicting traffic. The notice also included an enhanced version of the Mid-Air Collision Avoidance Guidelines.

Two posters have been produced: the first, entitled "MF/ATF Communications Requirements," reviews applicable pilot reporting/communication requirements; the second, entitled "GPS-Traffic Separation," suggests flying one or two miles right of the centre line of the track when navigating with GPS in order to avoid conflict with opposite direction traffic.

In addition, Transport Canada has published four articles about collision avoidance in issue 2/96 of the Aviation Safety Newsletter.

Furthermore, Transport Canada (Central Region) has established a Mandatory Frequency Working Group. In July 1995, the group solicited input from the aviation community concerning the adequacy of procedures associated with mandatory frequency areas. Various procedural and structural solutions to problems related to MF areas are being evaluated in light of the responses received.

4.1.3 MF Area Procedures

The new Canadian Aviation Regulations, which are expected to come into force in 1996, change the reporting procedures for aircraft approaching an MF area. The pilot-in-command of a VFR aircraft will now be required, where circumstances permit, to call at least five minutes before entering the MF area. This change will give both arriving and departing aircraft more warning of conflicting traffic, and will effectively expand the radius of the MF area in accordance with an aircraft's speed; under these procedures, given the radius of the MF area and the ground speed of the Metro, the Bearskin flight would have been required to contact Sioux Lookout FSS at least 25 nm back from the airport.

4.1.4 FSS Traffic Awareness

Flight Service specialists are required to provide airport advisory information to aircraft operating to or from locations within an MF area. A summary of known pertinent aircraft traffic that may affect the aircraft's safety must be provided, and must be updated if the specialist becomes aware of potential conflicts. Pilots use traffic advisories to assist in seeing and avoiding conflicting traffic. The resources available to specialists to provide these advisories, however, are scant.

The quality of traffic advisories can be adversely affected by inaccurate aircraft position reports, communication errors, and frequency congestion. Further inaccuracies can be introduced when specialists rely primarily on radio to determine the position and intentions of aircraft in their area, then attempt to recognize potential conflicts by extrapolating from their mental picture of the current traffic situation. As traffic densities and aircraft speeds increase, a specialist's ability to integrate available information and provide credible and timely traffic advisories is adversely affected, thereby increasing the risk of collision.

The Board understands that relatively low cost equipment is now available which can provide a pictorial display of aircraft traffic. If used by specialists, such systems could reduce the potential for cognitive errors, reduce frequency congestion, and facilitate remote monitoring. In light of the reduced risk of collision which might accrue through the use of such systems, the TSB forwarded a Safety Advisory to Transport Canada (TC) suggesting that TC evaluate the use of systems which provide pictorial displays of aircraft position (such as ground-based TCAS systems and Personal Computer systems displaying radar data via land line) to assist Flight Service specialists in identifying potential conflicts and in providing accurate and timely traffic advisories.

Although the specialist at Sioux Lookout advised two aircraft on the MF of the approaching Bearskin 362 flight while Air Sandy 3101 was on the same frequency, it is not known if the Air Sandy pilot heard the traffic advisory concerning the Bearskin flight. The TSB is not aware of the extent to which specialists are ensuring that aircraft are aware of conflicting traffic and has suggested in a Safety Advisory that Transport Canada consider placing increased emphasis in this area during quality assurance reviews.

4.2 Action Required

4.2.1 Separation Procedures for Aircraft Navigating with GPS

GPS has been approved for use under VFR and as a backup aid to navigation under IFR; approval as a primary IFR navigation aid is imminent. The Canadian Air Navigation System is rapidly moving toward increased reliance on this inexpensive and accurate navigation system.

In 1995, the Board made two recommendations to TC aimed at reducing the potential for GPS-related occurrences resulting from the use of unapproved equipment, inadequate understanding of the system, or lack of approved approaches. Transport Canada agreed with the recommendations and outlined several initiatives to expedite the implementation of GPS standards and raise the aviation community's awareness of the limitations and safe use of GPS.

The correct use of GPS decreases the average displacement of an aircraft from the centre line of its desired track; consequently, if separation procedures fail, the probability of a mid-air collision will increase (see LP 95/95). This increased risk of collision applies to both IFR and VFR aircraft in all types of operations.

The probability of collision for aircraft using GPS could be reduced if pilots used the area navigation (RNAV) capabilities of GPS to avoid high traffic routes, either by flying at an off-set distance from the centre line of these routes or by creating their own routes. Although TC has taken some action in this regard (see 4.1.2), the action is limited in scope and short term in nature. Given the increasing use of GPS, and the increased potential for mid-air collision associated with its use, the TSB recommends that:

> The Department of Transport expedite the development and implementation of safe separation procedures for the use of GPS in navigation.

A96-04

4.2.2 Collision Avoidance

Procedures to separate aircraft are not always followed (as evidenced by IFR loss-of-separation incidents) and are not always effective (for example, during VFR climb/descent). There have been eight mid-air collisions in Canada since 1991, and 142 reported occurrences where aircraft safety was compromised due to a loss of separation. Where procedures to separate aircraft fail, pilots may have to rely on the see-and-avoid method to avoid a mid-air collision. This method, however, becomes less effective as aircraft airspeeds increase.

The estimated closing speed of the accident aircraft was 410 knots. At this speed, the probability of the pilots of one aircraft acquiring the other aircraft in time to take effective evasive action was only about 20 per cent (LP 086/95 and LP 001/96 refer). This probability would have been doubled if the closing speed had been reduced to about 300 knots. In light of the increased probability of acquiring conflicting traffic at reduced airspeeds, the TSB recommends that:

> The Department of Transport ensure that aircraft are flown at reduced airspeeds, consistent with safe manoeuvring, in the vicinity of aerodromes where separation relies primarily on the see-and-avoid concept.

A96-05

Even if aircraft are flown at reduced airspeeds, pilots must be able to recognize a collision threat and take appropriate action if a collision is to be avoided. Transport Canada's Flight Instructor's Guide advocates the use of a steep turn to avoid collisions; however, this manoeuvre may actually increase the probability of impact if it is initiated when the aircraft are inside the range of approximately 10 seconds to impact[10] (evidence indicates that the Navajo was steeply banked at the time of the collision).

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10 J.L. Harris, Sr., "*Avoid*", *The Unanalyzed Partner of* "*See*". ISASI Forum #2, 1983 p 16.

Since inappropriate responses to a risk of collision situation may increase the risk of a mid-air collision, the TSB recommends that:

> The Department of Transport take both long- and short-term action to increase the ability of pilots to recognize in-flight collision geometry and optimize avoidance manoeuvring.

A96-06

4.2.3 TCAS

The see-and-avoid method of traffic separation can be much more effective if pilots are alerted to the existence and relative location of conflicting traffic. TCAS I provides such proximate traffic alerts (TAs).

Although United States Federal Aviation Regulations would have required the Metro to be TCAS equipped, and many other countries are instituting TCAS requirements, no such requirements exist or are planned in Canada.

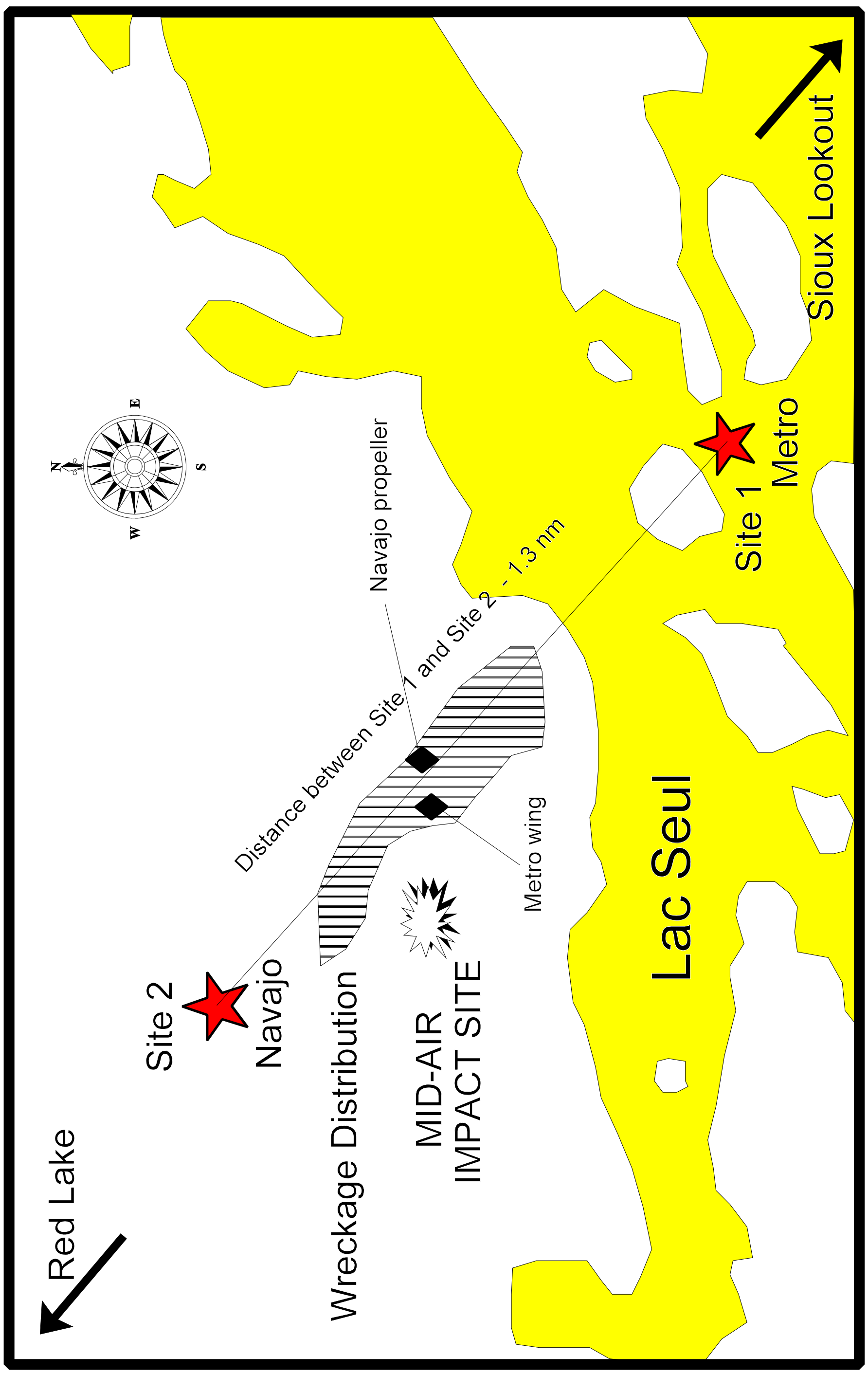
In view of the demonstrated capabilities of TCAS, and the increasing risk of collision due to improved navigational accuracy, increasing aircraft speeds, and mixed VFR/IFR traffic at uncontrolled airports such as Sioux Lookout, the Board recommends that:

> The Department of Transport conduct an analysis of the benefits of requiring commercial passenger-carrying aircraft to be equipped with TCAS versus the risks associated with operating aircraft without TCAS.

A96-07

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson John W. Stants, and members Zita Brunet and Maurice Harquail, authorized the release of this report on 04 April 1996.

Appendix A - Wreckage Distribution



Appendix B - List of Supporting Reports

The following TSB Engineering Branch reports were completed:

LP 71/95 - Preservation of Documents;
LP 72/95 - Underwater Acoustic Beacons Analyses;
LP 73/95 - Instruments Examination;
LP 74/95 - Structures Examination;
LP 75/95 - Site Survey;
LP 86/95 - Visibility Study; and
LP 95/95 - Probability of Mid-Air Collision, Effects of Navigation System, GPS vs VOR and NDB/ADF.

These reports are available upon request from the Transportation Safety Board of Canada.

Appendix C - Glossary

ACC	Area Control Centre
ADF	automatic direction finder
agl	above ground level
AIP	Aeronautical Information Publication
asl	above sea level
ATC	air traffic control
ATF	aerodrome traffic frequency
ATPL	Airline Transport Pilot Licence
ATS	Air Traffic Services
CDT	central daylight saving time
CPL	Commercial Pilot Licence
CVR	cockpit voice recorder
DG	directional gyro
DME	distance measuring equipment
ELT	emergency locator transmitter
FAA	Federal Aviation Administration
FDR	flight data recorder
FSS	Flight Service Station
GPS	global positioning system
HSI	horizontal situation indicator
IFR	instrument flight rules
MANOPS	Flight Service Manual of Operations
MF	mandatory frequency
MHz	megahertz
MIT	Massachusetts Institute of Technology
MNR	Ministry of Natural Resources
NDB	non-directional beacon
nm	nautical miles
RAs	resolution advisories
RNAV	area navigation
TAs	traffic advisories
TC	Transport Canada
TCAS	traffic collision avoidance system
TSB	Transportation Safety Board of Canada
U.S.	United States
UTC	Coordinated Universal Time
VDF	VHF direction finding equipment
VFR	visual flight rules
VHF	very high frequency
VMC	visual meteorological conditions
VOR	VHF omni-directional range
'	minute(s)
°	degree(s)

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