Midair Collision over George Inlet de Havilland DHC-2, N952DB, and de Havilland DHC-3, N959PA Ketchikan, Alaska May 13, 2019

Accident Report

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Aircraft Accident Report

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National
Transportation
Safety Board

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National Transportation Safety Board. 2021. ***Midair Collision over George Inlet, de Havilland DHC-2, N952DB, and de Havilland DHC-3, N959PA, Ketchikan, Alaska, May 13, 2019*****. Aircraft Accident Report NTSB/AAR-21/04. Washington, DC: NTSB.**

Abstract: This report discusses the May 13, 2019, accident involving a de Havilland DHC-2 (Beaver) airplane, N952DB, and a de Havilland DHC-3 (Otter) airplane, N959PA, which collided in midair about 8 miles northeast of Ketchikan, Alaska. The DHC-2 pilot and four passengers sustained fatal injuries. The DHC-3 pilot sustained minor injuries, nine passengers sustained serious injuries, and one passenger sustained fatal injuries. The DHC-2 was destroyed and the DHC-3 sustained substantial damage. The National Transportation Safety Board (NTSB) identified seven safety issue areas in this report: (1) the inherent limitations of the see-and-avoid collision avoidance concept, (2) the benefit of automatic dependent surveillance-broadcast (ADS-B) Out- and In-supported traffic advisory systems in high-traffic tour areas, (3) the lack of an ADS-B In requirement for Title 14 *Code of Federal Regulations* (*CFR*) Part 135 operations, (4) the lack of cockpit display of traffic information alerting on both aircraft, (5) the loss of alerting capabilities with ADS-B systems installed as part of the Federal Aviation Administration's (FAA) post-Capstone upgrade program, (6) an inadequate checklist used in Taquan Air's operation, and (7) the lack of a requirement for safety management systems in Part 135 operations. As a result of this investigation, the NTSB makes six new safety recommendations to the FAA and one recommendation each to ForeFlight, Taquan Air, aviation industry groups, and aviation educator groups. The NTSB also reiterates one safety recommendation to the FAA.

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Figures

Abbreviations

5KE	Ketchikan Harbor Seaplane Base
AC	advisory circular
ADS-B	automatic dependent surveillance-broadcast
AIM	*Aeronautical Information Manual*
ATAS	ADS-B traffic advisory system
ATC	air traffic control
CDTI	cockpit display of traffic information
CFR	*Code of Federal Regulations*
CSA	conflict situational awareness
EFIS	electronic flight instrument system
FAA	Federal Aviation Administration
FIS-B	flight information service-broadcast
GOM	general operations manual
GPS	global positioning system
IFR	instrument flight rules
kts	knots
LOA	letter of agreement
MFD	multi-function display
MOPS	minimum operational performance standards
msl	mean sea level
NAS	National Airspace System
nm	nautical miles
NPRM	notice of proposed rulemaking
OpsSpecs	operations specifications
PFD	primary flight display
PIC	pilot-in-command
RFP	request for proposal
SFAR	special federal aviation regulation
SFRA	special flight rules area

SMS	safety management system
STC	supplemental type certificate
STOL	short takeoff and landing
TIS-B	traffic information service-broadcast
TSO	technical standard order
UAT	universal access transceiver
USCG	United States Coast Guard
VFR	visual flight rules

Executive Summary

On May 13, 2019, about 1221 Alaska daylight time, a float-equipped de Havilland DHC-2 (Beaver) airplane, N952DB, and a float-equipped de Havilland DHC-3 (Otter) airplane, N959PA, collided in midair about 8 miles northeast of Ketchikan, Alaska. The DHC-2 pilot and four passengers sustained fatal injuries. The DHC-3 pilot sustained minor injuries, nine passengers sustained serious injuries, and one passenger sustained fatal injuries. The DHC-2 was destroyed and the DHC-3 sustained substantial damage. The DHC-2 was registered to and operated by Mountain Air Service LLC, Ketchikan, Alaska, under the provisions of Title 14 *Code of Federal Regulations* (*CFR*) Part 135 as an on-demand sightseeing flight. The DHC-3 was registered to Pantechnicon Aviation LTD, Minden, Nevada, and operated by Venture Travel, LLC, dba Taquan Air, Ketchikan, Alaska, under the provisions of Part 135 as an on-demand sightseeing flight. Visual meteorological conditions prevailed in the area at the time of the accident.

According to information provided by the operators, both airplanes had been conducting sightseeing flights and were both converging on a scenic waterfall before returning to the Ketchikan Harbor Seaplane Base (5KE), Ketchikan, Alaska, when the accident occurred. Automatic dependent surveillance-broadcast (ADS-B) tracking data for both airplanes revealed that, at 1217:15, the DHC-3 was about level at 4,000 ft mean sea level (msl) on a track of 225°, and the DHC-2 was 4.2 nautical miles (nm) south of the DHC-3, climbing through 2,800 ft msl, on a track of 255°.[1] About 1219, the DHC-3 started a descent from 4,000 ft, and the DHC-2 was at 3,175 ft and climbing. During the next 1 minute 21 seconds, the DHC-3 continued to descend on a track between 224° and 237°, and the DHC-2 leveled out at 3,350 ft on a track of about 255°. The airplanes collided at 1221:14 at an altitude of 3,350 ft, 7.4 nm northeast of 5KE.

Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was the inherent limitations of the see-and-avoid concept, which prevented the two pilots from seeing the other airplane before the collision, and the absence of visual and aural alerts from both airplanes' traffic display systems, while operating in a geographic area with a high concentration of air tour activity. Contributing to the accident were (1) the Federal Aviation Administration's provision of new transceivers that lacked alerting capability to Capstone Program operators without adequately mitigating the increased risk associated with the consequent loss of the previously available alerting capability and (2) the absence of a requirement for airborne traffic advisory systems with aural alerting among operators who carry passengers for hire.

Safety Issues

The NTSB identified the following safety issues as a result of this accident investigation:

- **The inherent limitations of the see-and-avoid collision avoidance concept.** Pilots' ability to visually acquire other aircraft is often compromised due to their limited field

[1] All altitudes in the report are reported as msl unless otherwise noted.

of view from the cockpit as well as the limitations of human attention and visual performance. An effective visual scan combined with a cockpit display of traffic information (CDTI) can assist pilots in scanning for airborne traffic.

- **The benefit of ADS-B Out- and In-supported traffic advisory systems in high-traffic tour areas.** Because of the increased number of aircraft operating in popular air tour areas, the risk of collision is greater than in the general National Airspace System. The use of ADS-B Out- and In-supported traffic advisory systems with aural and visual alerts can help mitigate this risk by supplementing pilots' traffic scans and alerting them to other nearby aircraft.
- **The lack of an ADS-B In requirement for 14 *CFR* Part 135 operations.** The FAA requires ADS-B Out only in certain airspace. There is currently no requirement for ADS-B In. Although this technology is currently available, many operators conducting passenger-carrying flights under Part 135 are not using it because there is no nationwide requirement to use it.
- **The lack of CDTI alerting on both aircraft.** Although both aircraft were equipped with CDTIs, limitations in their alerting capabilities resulted in neither pilot being alerted to the impending collision. Had these limitations not existed, aural traffic alerts in each airplane would have occurred early enough for the pilots to have prevented the collision.
- **The loss of alerting capabilities with ADS-B systems installed as part of the FAA's post-Capstone upgrade program.** The DHC-3 was originally equipped with ADS-B components that were provided by the FAA as part of the Capstone Program and contained aural alerting capabilities. Seven years after the original installation, the FAA upgraded the ADS-B components with new components that did not maintain the existing alerting capability.
- **An inadequate checklist used in Taquan Air's operation.** The DHC-3 was not transmitting pressure altitude data on the day of the accident because its Garmin GSL 71 control head selector knob was in the OFF position; this information was necessary for the DHC-2 pilot's traffic alerting system to produce visual and aural alerts. The checklist found in the DHC-3 (which listed the name of a different operator) did not contain a checklist item to ensure the GSL 71 control head selector knob was in the ON position and in the ALT mode before takeoff. Leaving the GSL 71 in the OFF position constituted an unacceptable hazard that could have been mitigated through a procedural safeguard, such as a checklist item.
- **Lack of a requirement for safety management systems (SMS) in Part 135 operations.** SMS is currently not required for Part 135 operators despite its utility in identifying and mitigating hazards. Had an SMS been established at Taquan Air at the time of the accident, it would have provided the operator better opportunities to identify and mitigate the increased risk of an airborne collision posed by the loss of alerting in the upgraded ADS-B components provided by the FAA and the absence of pressure altitude data resulting from the GSL 71 being turned off.

Findings

- None of the following safety issues were identified for the accident flight: (1) pilot qualification deficiencies; (2) pilot impairment; or (3) a malfunction or failure on either airplane.
- The circumstances of this accident underscore the inherent limitations of the see-and-avoid collision avoidance concept, including how collision geometry, obscuration by aircraft structures, and limitations of human performance can make it difficult to see nearby aircraft.
- Aural and visual alerts that draw the pilots' attention to conflicting traffic presented on the cockpit display of traffic information can greatly increase the pilots' awareness of potentially conflicting traffic and avoid a collision.
- Because of the high concentration of traffic in popular air tour areas, the risk of collision is higher than in the general National Airspace System and technology that supplements pilots' traffic scans by providing aural and visual alerts can mitigate this risk.
- Although existing automatic dependent surveillance-broadcast traffic alerting applications can help draw pilots' attention to conflicting traffic, these applications are currently not required.
- Requiring automatic dependent surveillance-broadcast–supported airborne traffic advisory systems with aural alerting in high-traffic air tour areas, through a special federal aviation regulation or other means, would mitigate the risk of midair collisions.
- The manner in which the ForeFlight application currently handles missing altitude data from traffic targets precludes the application from providing visual and aural alerts concerning these targets and, in certain configurations of the application, removes the targets from the moving map entirely, which degrades the ability of the application to call attention to potential collision threats.
- Because the Garmin GSL 71 can be manually turned off without any obvious indication on the Chelton display that pressure altitude is not being reported with the automatic dependent surveillance-broadcast data, there is a potential for the GSL 71 to be inadvertently left in the OFF position, which can lead to other pilots not receiving appropriate visual and aural alerts of traffic.
- The combination of automatic dependent surveillance-broadcast (ADS-B) components in the de Havilland DHC-3 did not have the same conflict detection capability that was present in systems installed as part of the Capstone Program, which provided visual and aural alerting; this reduction in capability was a result of the Federal Aviation Administration's upgrade of ADS-B equipment for aircraft participating in the Capstone Program with components that did not maintain the existing alerting functions.

- A procedural safeguard, such as a checklist item that addresses the position of the Garmin GSL 71 control head selector knob, can mitigate the hazard of the selector knob being inadvertently and indefinitely placed in the OFF position.

- Increasing pilots' awareness of the inherent limitations of the see-and-avoid collision avoidance concept and the benefits of cockpit displays of traffic information with traffic alerting can mitigate the risk of midair collisions.

- If Taquan Air had been required to have a safety management system (SMS) at the time of the accident, the activities required by the safety risk management element would have provided better opportunities for Taquan Air to discover and mitigate the increased risk of airborne collision posed by changes to the Capstone-affiliated avionics installed in its aircraft, which provides another example of the value of SMS for all Title 14 *Code of Federal Regulations* Part 135 operators.

Recommendations

New Recommendations

To the Federal Aviation Administration:

Identify high-traffic air tour areas and require, through a special federal aviation regulation or other means, that Title 14 *Code of Federal Regulations* Parts 91 and 135 air tour operators that operate within those areas be equipped with an Automatic Dependent Surveillance-Broadcast Out- and In-supported traffic advisory system that 1) includes both visual and aural alerts, 2) is driven by an algorithm designed to minimize nuisance alerts, and 3) is operational during all flight operations. (A-21-15)

In the high-traffic air tour areas identified in Safety Recommendation A-21-15, require that all non–air tour aircraft operating within the airspace be equipped with Automatic Dependent Surveillance-Broadcast Out. (A-21-16)

Require the installation of Automatic Dependent Surveillance-Broadcast Out- and In-supported airborne traffic advisory systems that include aural and visual alerting functions in all aircraft conducting operations under Title 14 *Code of Federal Regulations* Part 135. (A-21-17)

Review current and future supplemental type certificate installation instructions and flight manual supplements to ensure they provide provisions to prevent the inadvertent disabling of the broadcast of pressure altitude data, by design, where practicable. (A-21-18)

Ensure that checklists for all Capstone Program (phase 2) aircraft include verification that the Garmin GSL 71 control head selector knob is in the ON position and that the unit is in ALT mode before takeoff. (A-21-19)

Update the *Aeronautical Information Manual* and the *Pilot's Handbook of Aeronautical Knowledge* to include the limitations inherent in visual scans for traffic and the benefits and best practices of using cockpit displays of traffic information to supplement visual scans to help overcome these limitations. (A-21-20)

To ForeFlight:

Update your traffic alerting algorithms so that traffic targets for which there is no altitude information are assumed to be at the same altitude as the ownship (that is, the aircraft receiving the target data). (A-21-21)

To Taquan Air:

Revise the checklists for your fleet of aircraft to ensure they include verification that the Garmin GSL 71 control head selector knob is in the ON position and that the unit is in ALT mode before takeoff. (A-21-22)

To aviation industry groups (Aircraft Owners and Pilots Association, Experimental Aircraft Association, National Business Aviation Association, Tour Operators Program of Safety, Tongass Aircraft Pilots Association, and Helicopter Association International):

Inform your members about the circumstances of this accident and encourage them to take the following actions: (1) become familiar with the traffic display equipment installed in their aircraft; (2) if their equipment does not provide an aural alert concerning proximate targets that might pose a collision threat, encourage pilots/operators to supplement the equipment with devices that provide both an aural and visual alert; and (3) remind pilots to include the traffic display when scanning for traffic through the aircraft's windows. (A-21-23)

To the National Association of Flight Instructors and the Society of Aviation and Flight Educators:

Inform your members of the circumstances of this accident and incorporate instruction on including the traffic display when scanning for traffic through an aircraft's windows in both initial and recurrent pilot training. (A-21-24)

Previously Issued Recommendation Reiterated in This Report

To the Federal Aviation Administration:

Require all 14 *Code of Federal Regulations* Part 135 operators to establish safety management system programs (A-16-36).

1. Factual Information

1.1 History of Flight

On May 13, 2019, about 1221 Alaska daylight time, a float-equipped de Havilland DHC-2 (Beaver) airplane, N952DB, and a float-equipped de Havilland DHC-3 (Otter) airplane, N959PA, collided in midair about 8 miles northeast of Ketchikan, Alaska.[1] The DHC-2 pilot and four passengers sustained fatal injuries. The DHC-3 pilot sustained minor injuries, nine passengers sustained serious injuries, and one passenger sustained fatal injuries. The DHC-2 was destroyed, and the DHC-3 sustained substantial damage. The DHC-2 was registered to and operated by Mountain Air Service LLC, Ketchikan, Alaska, under the provisions of Title 14 *Code of Federal Regulations* (*CFR*) Part 135 as an on-demand sightseeing flight. The DHC-3 was registered to Pantechnicon Aviation LTD, Minden, Nevada, and operated by Venture Travel, LLC, dba Taquan Air, Ketchikan, Alaska, under the provisions of Part 135 as an on-demand sightseeing flight. Visual meteorological conditions prevailed in the area at the time of the accident.

According to information provided by the operators, both airplanes had been conducting sightseeing flights to the Misty Fjords National Monument area. They were both converging on a scenic waterfall in the Mahoney Lakes area on Revillagigedo Island before returning to the Ketchikan Harbor Seaplane Base (5KE), Ketchikan, Alaska, when the accident occurred.[2]

According to recorded avionics data recovered from the DHC-3, it departed from an inlet (Rudyerd Bay) in the Misty Fjords National Monument area about 1203 and followed the inlet westward toward Point Eva and Manzanita Island.[3] At 1209, at an altitude between 1,900 and 2,200 ft, the DHC-3 crossed the Behm Canal then turned to the southwest about 1212 in the vicinity of Lake Grace (see figure 1).

[1] (a) All times in this report are Alaska daylight time unless otherwise indicated. (b) Supporting documentation for information referenced in this report can be found in the public docket for this accident, which can be accessed from the National Transportation Safety Board's (NTSB's) Case Analysis and Reporting Online query tool by searching CEN19MA141. Other NTSB documents referenced in this report, including reports and summarized safety recommendation correspondence, can also be found using the query tool.

[2] Misty Fjords National Monument area was located about 30 nautical miles northeast of Ketchikan. Additionally, both operators were based at 5KE.

[3] The recorded avionics data were retrieved from the primary flight display installed as part of the Chelton electronic flight Information system on the DHC-3. There were no recorded avionics data for the DHC-2.

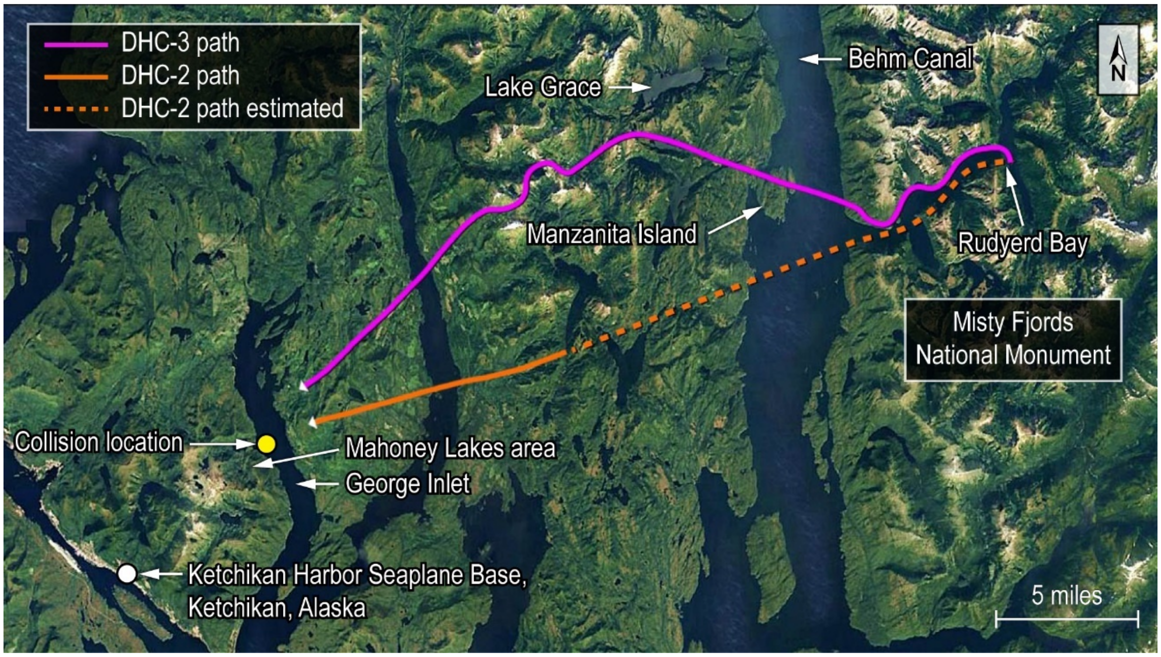

Figure 1. Map showing departure area, flightpaths, and collision location.

Automatic dependent surveillance-broadcast (ADS-B) tracking data for both airplanes, which were provided by the Federal Aviation Administration (FAA), began at 1213:08 for the DHC-3, and at 1213:55 for the DHC-2.[4] At 1217:15, the DHC-3 was about level at 4,000 ft mean sea level (msl) over Carroll Inlet on a track of 225°.[5] The DHC-2 was 4.2 nautical miles (nm) south of the DHC-3, climbing through 2,800 ft, on a track of 255°. The DHC-3 pilot stated that, about this time, he checked his traffic display and "there were two groups of blue triangles, but not on my line.[6] They were to the left of where I was going." He stated that he did not observe the DHC-2 on his traffic display before the collision.[7]

The ADS-B data indicated that, about 1219, the DHC-3 started a descent from 4,000 ft, and the DHC-2 was climbing from 3,175 ft. During the next 1 minute 21 seconds, the DHC-3 continued to descend on a track between 224° and 237°, and the DHC-2 leveled out at 3,350 ft on a track of about 255°. Between 1220:21 and 1221:14, the DHC-3 made a shallow left turn to a track of 210°, then a shallow right turn back to a track of 226°. The airplanes collided at 1221:14 at an altitude of 3,350 ft, 7.4 nm northeast of 5KE (see figure 2).

[4] According to the FAA, ADS-B uses GPS satellite signals to provide air traffic controllers and pilots with accurate information that will help keep aircraft safely separated in the sky and on runways. Aircraft transceivers receive GPS signals and use them to determine the aircraft's precise position in the sky, which is combined with other data and broadcast out to other aircraft and air traffic control (ATC) facilities. More information can be found at: Fact Sheet – NextGen (archive.org).

[5] All altitudes in the report are reported as msl unless otherwise noted.

[6] The blue triangles the pilot referred to were two groups of traffic targets to the left and ahead of the DHC-3. The traffic display will be discussed further in section 1.9.3.

[7] The area of the collision was not covered by ATC.

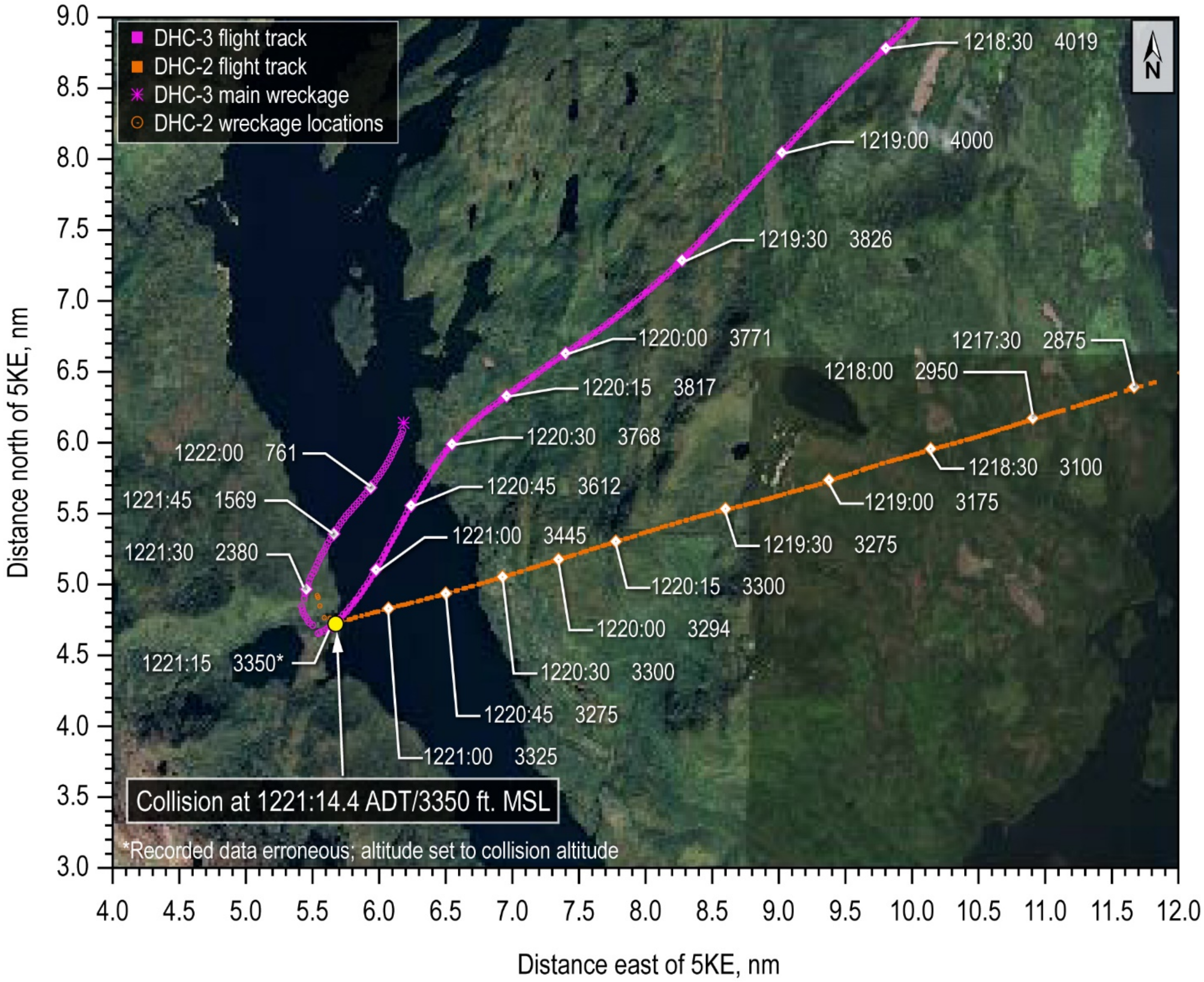

Figure 2. Map showing flight tracks for both airplanes and collision location. Times and altitudes are depicted along the flight tracks.

The ADS-B data for both airplanes end about the time of the collision. The DHC-2 was fractured into multiple pieces and impacted the water and terrain northeast of Mahoney Lake. Recorded avionics data for the DHC-3 indicate that at 1221:14, the DHC-3 experienced a brief upset in vertical load factor and soon after entered a right bank, reaching an attitude about 50° right wing down at 1221:19 and 27° nose down at 1221:22. The DHC-3 began descending and completed a 180° turn before impacting George Inlet at 1222:15 along a northeast track.[8]

[8] In a postaccident interview, the DHC-3 pilot described the impact as "…a tremendous collision. The airplane lurched to the right, 180 degrees, like a snap roll…and before I knew it, the airplane was heading back toward, away from the mountains."

1.2 Personnel Information

1.2.1 DHC-2 Pilot Information

The pilot, age 46, held a commercial pilot certificate with ratings for airplane single-engine land and sea, multiengine land and sea, and instrument airplane. He also held a flight instructor certificate with ratings for airplane single-engine land and instrument airplane. The pilot's most recent FAA second-class medical certificate was dated April 29, 2019, with no limitations.

The pilot was the owner of and sole pilot for Mountain Air Service, the DHC-2's operator. According to the pilot's wife, before starting Mountain Air Service the pilot flew for several other seaplane operators in Alaska. Although the pilot's personal flight records were not located, the pilot's application for his FAA medical certificate, dated April 29, 2019, indicated that his total aeronautical experience was about 11,000 hours. Additionally, Mountain Air Service provided flight and duty records that indicated the pilot was off duty in February and March. In April, he was on duty for 2 days and off duty for 28 days. In the 30 days, 12 days, and 24 hours before the accident, he flew 18.6 hours, 15 hours, and 1.2 hours, respectively. During each of the 3 days before the accident, the pilot was on duty from 0700 to 1700.

According to Mountain Air Service records, the pilot successfully passed his initial competency check in the DHC-2 on May 17, 2012.[9] He also completed an airman competency check and a pilot-in-command (PIC) line check in the DHC-2 on May 2, 2019.[10]

According to his wife, the pilot had a consistent sleep schedule in the 72 hours before the accident, sleeping about 8.5 to 9 hours per night. On the night before the accident, the pilot spent the evening at home and went to bed about 2200. He woke up about 0630, and he planned to depart on the tour flight at 1000.[11]

1.2.2 DHC-3 Pilot Information

The pilot, age 60, held an airline transport pilot certificate with a rating for airplane multiengine land and commercial privileges for airplane single-engine land and airplane single-engine sea. He also held a flight instructor certificate with ratings for single- and multiengine land and instrument airplane. The pilot's most recent FAA first-class medical certificate was dated

[9] Title 14 *CFR* 135.293 stated, in part, "(a) No certificate holder may use a pilot, nor may any person serve as a pilot, unless, since the beginning of the 12th calendar month before that service, that pilot has passed a written or oral test, given by the Administrator or an authorized check pilot."

[10] Title 14 *CFR* 135.299 stated, in part, "(a) No certificate holder may use a pilot, nor may any person serve, as a pilot in command of a flight unless, since the beginning of the 12th calendar month before that service, that pilot has passed a flight check in one of the types of aircraft which that pilot is to fly."

[11] According to the pilot's sister, who was also the director of operations for Mountain Air Service, she contacted the pilot on the morning of the accident around 0800 when she thought she may have sold an earlier tour flight; however, she later informed the pilot she was unsuccessful in selling the earlier flight. She also stated that he was at the airplane when she arrived with the passengers for the 1000 scheduled flight.

November 28, 2018, and included a limitation to wear corrective lenses and possess glasses for near or intermediate vision.[12]

The pilot was hired by Taquan Air in 2018 and flew primarily during the summer months.[13] According to records provided by Taquan Air, the pilot successfully completed his airman competency check and PIC line check in the DHC-3 on April 25, 2019, and was subsequently assigned for duty as PIC in the DHC-3.[14] According to records provided by Taquan Air, the pilot had about 25,000 hours of total flight experience, 15,000 of which were as PIC.

Flight and duty records provided by Taquan Air revealed the pilot was on duty April 25, April 27, and April 29. Between May 1 and May 12, the pilot was on duty 8 days and accumulated 33.6 hours of flight time. On the 2 days before the accident, he woke up at 0500 and went to bed at 2100. On the day of the accident, he woke up at 0500. He stated that he felt adequately rested on the morning of the accident and that he was "very alert" during the accident flight.

1.3 Aircraft Information

1.3.1 DHC-2

The DHC-2 is a single-engine, propeller-driven, high-wing, short takeoff and landing (STOL) airplane (see figure 3). The accident airplane (N952DB) was powered by a single reciprocating, radial Pratt & Whitney R-985 engine and was configured with Edo 58-4580 floats. It was equipped with position lights, landing lights, wingtip strobe lights, and an anti-collision beacon, as well as one pilot seat and six passenger seats.

[12] In a postaccident interview, the pilot reported he was wearing contacts during the accident flight.

[13] The pilot was a permanent resident of Eden, Utah, and resided in Ketchikan during the summer.

[14] The pilot's Taquan Air single line entry record of checks and training indicated that all his prerequisite ground training had been completed by April 25, 2019; however, Taquan Air ground training records indicated April 30, 2019, for the required transition and recurrent ground training subjects.

Source: Mr. John Leach

Figure 3. Photo of accident DHC-2 airplane (N952DB).

The DHC-2 airplane was manufactured in 1951 and purchased by Mountain Air Service in September 2012. It was maintained under the provisions of 14 *CFR* Parts 43 and 91, which required 100-hour and annual inspections. The airplane's most recent 100-hour inspection was completed on August 24, 2018, at a total airframe time of 16,375 hours, and its most recent annual inspection was completed on April 16, 2019, at a total airframe time of 16,452 hours.

Avionics installed on the DHC-2 included ADS-B Out and In.[15] The ADS-B system was comprised of FreeFlight Systems components: an FDL-978-XVR transceiver (commonly referred to as a RANGR 978 transceiver), a TC-978 controller, and a Wi-Fi controller. The RANGR 978 transceiver was used to send and receive ADS-B position reports.[16] The TC-978 controller provided the interface between the pilot and the RANGR 978 transceiver and controlled the output (and input) of ADS-B messages. The Wi-Fi controller provided a Wi-Fi hotspot that enabled compatible portable devices to connect to and receive the traffic information (ADS-B In data) from the RANGR 978 transceiver. An iPad, which was connected to the Wi-Fi controller (through a Bluetooth connection) and mounted in the center of the instrument panel, had a ForeFlight mobile application that could display the traffic information (see figure 4).

[15] ADS-B Out enables an aircraft to broadcast its three-dimensional position (latitude, longitude, and altitude) to other ADS-B-equipped aircraft and to ADS-B ground stations. ADS-B In enables an aircraft to receive traffic messages from ADS-B Out-equipped aircraft and from ADS-B ground stations. ADS-B will be discussed further in section 1.5.

[16] A RANGR 978 transceiver may also receive flight information service-broadcast (FIS-B) and traffic information service-broadcast (TIS-B) information. FIS-B provides weather and other aeronautical information (such as airspace restrictions and notices to airmen) to aircraft in areas serviced by ground-based infrastructure. TIS-B provides position reports for aircraft that are not equipped with ADS-B based on ATC radar data in areas serviced by ground-based infrastructure.

Figure 4. Photo of DHC-2 cockpit

At the time of the accident, the ForeFlight application generated a visual and aural traffic alert if the "Traffic Alerts" setting is enabled when a target approaches within 1.8 nm horizontally and ±1,200 ft vertically of the "ownship."[17] The ForeFlight application depicted all traffic targets that do not have a traffic alert as filled cyan (blue) arrowheads, and those that are in "alert status" are depicted as filled yellow arrowheads. The ForeFlight visual traffic alert includes a traffic pop-up that contains the target's clock position, distance, and relative altitude from the ownship (see figure 5). The aural alert contains the same information and can be transmitted to the pilot's headset via Bluetooth if the headset is so equipped, or through the tablet speaker.[18] If the ForeFlight "Hide Distant Traffic" setting is enabled, traffic more than 15 nm from or more than 3,500 ft above or below the ownship will not be displayed.

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[17] Ownship refers to the aircraft in which the cockpit display of traffic information is installed. In January 2021 the traffic alerting feature in the ForeFlight application was revised to include a predictive algorithm that used both speed and direction of aircraft targets projected to come within 1,200 ft vertically of the ownship. Targets either currently, or predicted to be in the next 45 seconds, within 2 miles horizontally and 1,200 ft vertically of the ownship are depicted in yellow; targets either currently, or predicted to be in the next 25 seconds, within 1.3 miles horizontally and 1,200 ft vertically are depicted in red accompanied by a corresponding visual and aural alert.

[18] The DHC-2 pilot's headset was equipped with Bluetooth.

Figure 5. Example of a ForeFlight visual traffic alert with a traffic pop-up display.

1.3.2 DHC-3

The DHC-3 is a single-engine, propeller-driven, high-wing, STOL airplane with a cruciform tail (see figure 6). The accident airplane (N959PA) was powered by a single turboprop Pratt & Whitney PT6A engine and was configured with Edo 7490 floats. It was equipped with position lights, landing lights, and an anti-collision beacon, as well as 1 pilot seat and 10 passenger seats.

Source: Mr. Kelly Thomas

Figure 6. Photo of accident DHC-3 airplane (N959PA).

The DHC-3 airplane was manufactured in 1956 and registered to Pantechnicon Aviation LTD in 1997. Taquan Air began operating the airplane in 2016. The DHC-3 airplane was maintained under the provisions of 14 *CFR* 91.409, which requires annual and 100-hour inspections. The most recent annual inspection was completed on March 28, 2019. Additionally, a monthly inspection was completed on April 30, 2019, at an airframe total time of 30,296.7 hours.[19]

The DHC-3 was equipped with ADS-B Out and In through a RANGR 978 transceiver. A Garmin GSL 71 control panel provided pressure altitude and mode 3A "squawk" code to the RANGR 978 transceiver datalink for transmission.[20] The Garmin GSL 71 control head selector knob must be placed in the ON position and the ALT mode selected for the unit to provide pressure altitude to the RANGR 978 transceiver (see figure 7).

Figure 7. Photo of an exemplar GSL 71 that is transmitting pressure altitude.

The airplane had two Chelton FlightLogic electronic flight instrument system (EFIS) integrated display units that were configured to operate as a primary flight display (PFD) or a multi-function display (MFD).[21] The PFD showed aircraft parameter data, including altitude, airspeed, attitude, vertical speed, and heading. The MFD showed navigational information using a moving map. Additionally, the DHC-3 Chelton EFIS units could display traffic information received by the RANGR 978 transceiver. Figure 8 shows the location of the Chelton EFIS units and the GSL 71 in the cockpit.

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[19] The items checked during the monthly inspection were similar to the 100-hour inspection; the monthly inspection was performed to prepare the airplane for the tour season.

[20] a) Pressure altitude is the altitude indicated on the altimeter when the barometric pressure is set to 29.92 inches of mercury. b) Mode 3A provides a four-digit octal identification code for the aircraft that is set in the cockpit but assigned by an air traffic controller. Mode 3A is often combined with mode C to provide altitude information as well.

[21] Genesys Aerosystems acquired Chelton Flight Systems and S-TEC Corporation in April 2014; however, the integrated display units are commonly referred to as Chelton EFIS units.

Figure 8. Photo of the DHC-3 cockpit.

The Chelton EFIS display could generate aural and visual alerts for particular traffic targets if the traffic messages associated with those targets were received from a device that formats and provides traffic messages in an "alert status." The RANGR 978 transceiver was not designed to send "alert status" messages; therefore, the DHC-3 did not have the capability to generate aural or visual traffic alerts.[22]

1.4 Meteorological Information

Automated surface observations were recorded at Ketchikan International Airport, Ketchikan, Alaska, 8.5 miles west-southwest of the accident location. At 1153, the reported wind was from 130° at 11 knots (kts) with gusts up to 17 kts, visibility of 10 miles or greater, clear sky below 12,000 ft, temperature of 16°C, dew point temperature of 3°C, and an altimeter setting of 29.91 inches of mercury. At 1253, the reported wind was from 140° at 8 kts, visibility of 10 miles

[22] The requirements to send "alert status" messages are defined in FAA Technical Standard Order (TSO) C195b and will be discussed further in section 1.5.

or greater, clear sky below 12,000 ft, temperature of 15°C, dew point temperature of 4°C, and an altimeter setting of 29.92 inches of mercury.

Satellite imagery recorded at 1220 identified mostly clear conditions across the region with a few clouds. Additionally, weather cameras closest to the accident site confirmed clear conditions with a few clouds.

At the accident time, the sun was at an azimuth from true north (clockwise) of 171.6° and an elevation from the horizon of 52.8°.

1.5 Automatic Dependent Surveillance-Broadcast

1.5.1 ADS-B Overview

ADS-B uses global navigation satellite system position reports from appropriately equipped aircraft to track aircraft movements. ADS-B Out-equipped aircraft broadcast aircraft position (latitude, longitude, and altitude) and velocity to ADS-B In-equipped aircraft and to ADS-B ground stations once per second. ADS-B ground stations record and re-broadcast this data along with additional traffic data collected using legacy radar technology (see figure 9). ADS-B In-equipped aircraft can receive this information, process it through onboard transceivers, and display it on a cockpit display of traffic information (CDTI) screen, as was accomplished on the accident airplanes using the Chelton and ForeFlight systems.

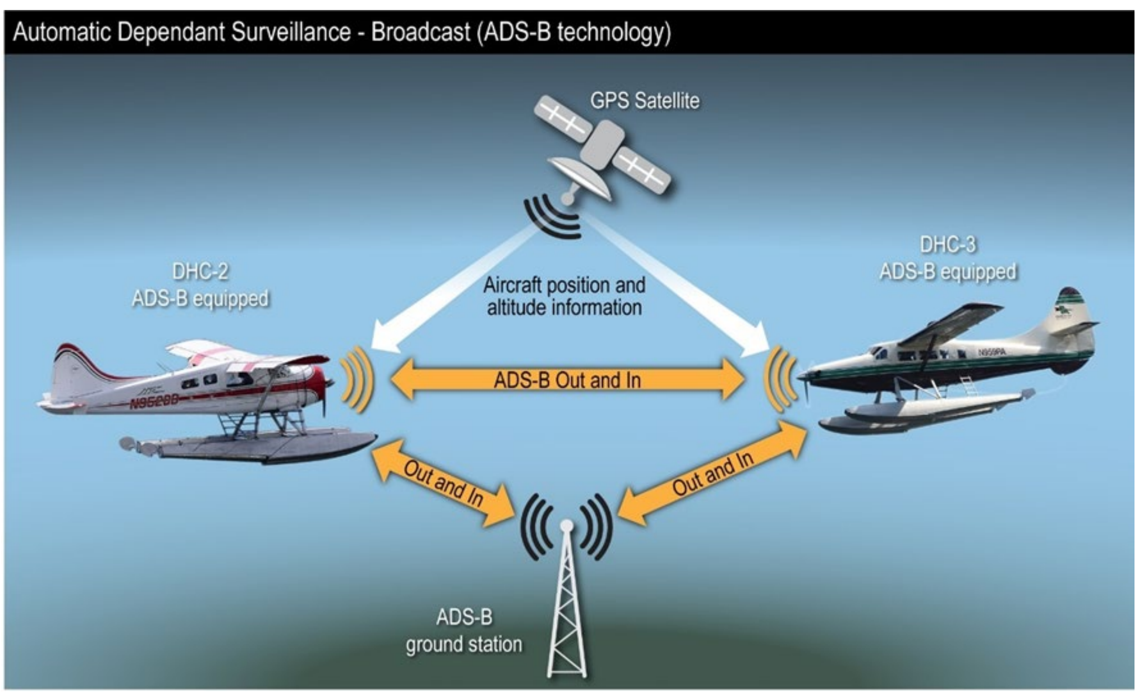

Figure 9. Representation of ADS-B technology.

Depending on the configuration of the transceiver and the CDTI, ADS-B In avionics enable aircraft surveillance applications to display traffic and produce visual and aural alerts of predicted collision threats. One example of these applications is the ADS-B traffic advisory system (ATAS). The ATAS application, previously known as traffic situation awareness with alerts, monitors potential traffic conflicts by combining ADS-B tracking data with proximity-prediction algorithms.[23] When it detects a traffic conflict, ATAS sounds an audio alert or "traffic callout." Conflicting aircraft are also highlighted on cockpit displays when such displays are available in an aircraft. ATAS was designed to operate without excessive nuisance alerts and is the only ADS-B application with an aural-only implementation.[24] Additionally, ATAS was designed to meet FAA Technical Standard Order (TSO) C195b and RTCA Document (DO) No. 317B, Minimum Operational Performance Standards (MOPS) for Aircraft Surveillance Applications System (dated June 17, 2014).[25]

1.5.2 ADS-B Airspace and Additional Requirements

Since January 1, 2020, installation of ADS-B Out equipment is required on all aircraft in the National Airspace System (NAS) operating above 10,000 ft msl and within or above class B and C airspace with certain exceptions.[26] ADS-B Out equipment is not required in the Ketchikan area because the airspace is class E and class G. According to 14 *CFR* 91.225, each person operating an aircraft equipped with ADS-B Out must use transmit mode at all times.[27] ADS-B In is currently not required by the FAA.

1.6 Wreckage and Impact Information

1.6.1 DHC-2

The DHC-2 wreckage was located about 8 miles northeast of Ketchikan. The debris field was about 3,000 ft long and about 800 ft wide and located mostly on land. The debris field included the wings, portions of the fuselage, horizontal stabilizer, vertical stabilizer, and interior components. The main wreckage, which was in the water, included the floats, engine, firewall, instrument panel, lower fuselage structure, and right fuselage structure.

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[23] Neither airplane involved in this accident was equipped with avionics that implemented the ATAS ADS-B In function, as described in Advisory Circular 20-172B.

[24] TSO-C151c defines a nuisance alert as "an inappropriate alert, occurring during normal safe operations, which is the result of the design performance limitation of TAWS [terrain awareness and warning system]." Although this definition relates to TAWS, the same definition applies to other traffic advisory systems.

[25] TSO-C195b will be discussed more in section 2.3 and DO-317B will be discussed more in section 1.9.2. DO-317B was dated June 17, 2014, and superseded DO-317A, which was dated December 13, 2011. Among other changes, DO-317B introduced "Traffic Situation Awareness with Alerts" (TSAA) as a new, optional (non-required) surveillance application for providing traffic alerts; DO-317A did not contain any traffic alerting application. As noted above, the TSAA application has since been renamed to "ADS-B Traffic Advisory System" (ATAS). DO-317A will be discussed in more detail in section 1.11.1.

[26] Title 14 *CFR* 91.225 lists the exceptions to the ADS-B requirement, such as aircraft originally not certificated with an electrical system or not subsequently certified with such a system, including balloons and gliders.

[27] Title 14 *CFR* 91.225 lists two exceptions to the ADS-B operational requirement: (1) if authorized by the FAA when the aircraft is performing a sensitive government mission or (2) if directed by ATC when transmitting would jeopardize the safe execution of ATC functions.

Postaccident examination of the DHC-2 revealed that the right wing was in multiple pieces and separated from the airplane. An initial impact point was noted on the trailing edge of the right aileron and a series of mechanical cuts were noted on the aft portion of the wing from the right aileron inboard to the wing root. Each successive cut penetrated further inboard and forward into the wing structure. Each cut had sawtooth fracture patterns and distinct downward deformation of the upper and lower wing skins and internal structure (see figure 10).

Figure 10. DHC-2 right wing with mechanical cuts that progressively penetrate inboard.

The avionics on the right side of the instrument panel were intact with no significant damage observed. Examination of the TC-978 controller revealed the control head selector knob was in the ALT position.[28] Examination of the cockpit (toggle) switches for the DHC-2 aircraft lighting indicated the switches for the position lights, left and right landing lights, and anti-collision beacon were intact and in the down (OFF) position; the wingtip strobe light switch was intact and in the up (ON) position.

[28] The TC-978 control head selector knob controls the power to the FDL-978 equipment and the operating mode. The following modes can be selected by the placement of the knob: (1) OFF, (2) SBY, (3) ALT, (4) ON, (5) ALT. There is no functional difference between the two ALT (altitude) knob positions.

1.6.2 DHC-3

The main wreckage of the DHC-3 was located about 9.6 miles northeast of Ketchikan adjacent to the eastern shore of George Inlet in about 80 ft of saltwater, about 400 ft from the shoreline. The DHC-3 floats had separated from the airplane and were located about 700 ft north of the main wreckage. The DHC-3's left aft float strut was found at the southern end of the DHC-2 debris field.

Examination of the DHC-3 revealed the fuselage structure forward of the sloping bulkhead that divided the cockpit from the passenger cabin, including the firewall, engine mount, and engine, was mostly separated from the rest of the airplane at the accident site. The engine and propeller remained attached to the engine mount. One propeller blade was missing the outboard 6 inches and was bent forward; the second propeller blade was intact and bent aft; the third propeller blade was missing the outboard 3 inches, had a forward bend, and had a trailing edge dent. All three blades displayed leading edge chunking and gouging, which are deep grooves on a blade formed by a heavy pressure contact with a solid object. Rotational gouging and white paint transfer were found on half of the spinner.

The DHC-3 fuselage was mostly intact aft of the sloping bulkhead. The lower portion of the sloping bulkhead and lower forward fuselage were crushed and deformed up and aft. More significant damage was found on the left side of the lower forward fuselage than the right.

The avionics on the right side of the instrument panel were intact and mostly undamaged. The center switch on the volume control panel was set to ALL. The Garmin GSL 71 control head selector knob was in the OFF position.[29]

Examination of the cockpit (toggle) switches for the DHC-3 aircraft lighting indicated the switches for the position lights and left and right landing lights were intact and in the up (ON) position. The anti-collision beacon switch was broken and in the down (OFF) position.[30]

1.7 Medical Information

The Alaska State Medical Examiner's Office, Anchorage, Alaska, performed an autopsy on the DHC-2 pilot. The DHC-2 pilot's cause of death was multiple blunt force injuries. The examination found no indications of "significant natural disease." Toxicological testing of the DHC-2 pilot's heart blood was negative for tested-for drugs of abuse.

The FAA Forensic Sciences Laboratory performed toxicology testing on postmortem specimens from the DHC-2 pilot. The testing identified 0.061 micrograms per milliliter of cetirizine in cavity blood and in liver tissue. Cetirizine, often marketed as Zyrtec, is used for temporary relief of allergy symptoms; it carries the warning "may cause drowsiness." Cetirizine's

[29] The Garmin GSL 71 control head selector knob can be placed in either the ON or OFF position. The operation mode (IDENT, SBY, ON, ALT, or VFR) can be selected from the pushbuttons to the right of the knob.

[30] The anti-collision beacon switch was labeled STRBE LIGHT.

therapeutic range in blood is 0.19 to 1.45 micrograms per milliliter.[31] The results were negative for all other tested-for substances.

The DHC-3 pilot suffered head trauma during the accident and was admitted to the hospital overnight for observation. A clinical urine drug screen and blood alcohol test performed at the hospital were negative for tested-for drugs and alcohol. Toxicology testing on blood and urine specimens performed by the FAA's Forensic Sciences Laboratory identified no evidence of impairing drugs.

1.8 Survival Aspects

1.8.1 DHC-2 Survival Aspects

The fuselage of the DHC-2 broke up during the midair collision, and all five occupants were ejected from the airplane during impact. Three of the occupants were recovered from George Inlet shortly after the accident, and the other two occupants were recovered the following day from a wooded area near the shoreline. The Alaska State Medical Examiner's Office performed an autopsy on all five DHC-2 occupants and determined that the cause of death for all five was blunt force trauma.

1.8.2 DHC-3 Emergency Egress Sequence

The DHC-3 pilot reported that, before takeoff, he ensured all the occupants of the DHC-3 were wearing seatbelts that were "not loose" (he also believed they were wearing seatbelts at the time of the collision). The pilot additionally briefed the passengers on the location of the life preservers and how to use them. The passenger seated in the first row on the left side of the airplane stated that, after departure, the pilot told the passengers he was going to fly toward a mountain in attempt to see wildlife because it was "such a beautiful day…and they could not normally see the tops of the mountains." According to the passenger, they circled the mountain and returned to "stable cruise flight." Shortly after, he heard a loud impact and the pilot said, "we've been hit!"

The passenger seated in the second row on the right side of the airplane reported that, just before the collision, she heard a passenger yell, "pull up, pull up!"[32] According to the passenger, there was a "big bang" and then the airplane began to spiral to the right. Shortly after, she realized that the left rear door had departed the airplane during the collision. The airplane impacted the water and she felt it "catapult over." Because the windshield was broken, water began rushing through it. Both the first and second row passengers observed that the passenger seated in the right front (co-pilot) seat was slumped motionless over into the pilot's seat with her seatbelt fastened.

The DHC-3 pilot was able to maintain control of the airplane and reported that, upon touch down in the water of George Inlet, the airplane pitched down "very violently" and then pitched over. Water rushed inside the airplane and the pilot was submerged in water; he released his

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[31] For more information see: https://jag.cami.jccbi.gov/toxicology/DrugDetail.asp?did=131 (Updated 1/16/19).

[32] Passengers wore headsets to hear information from the pilot; however, they did not have the ability to speak to the pilot. Additionally, a bulkhead divided the passenger seats from the cockpit.

seatbelt and had to swim through a break in the airplane then through tangled cords, wires, and debris. He surfaced behind the right wing, opened the right aft door, and began to help passengers out of the airplane. As the airplane filled with water, 9 of the 10 passengers released their seatbelts and evacuated the airplane.[33] The occupant in the right front seat did not evacuate, and an autopsy determined her cause of death was "blunt impacts of head, trunk, and extremities." A contributing condition to her death was drowning.

Only one passenger, who was seated in the fourth row on the right side of the airplane, took the life preserver above her seat before exiting the airplane.[34]

1.8.3 Emergency Response

About 1226, a good samaritan on a boat near the accident site notified the US Coast Guard (USCG) of the accident and launched a small skiff toward the DHC-3. Passengers held onto the handles on the side of the skiff and were slowly towed to shore. The good samaritan made multiple trips to shore (about 100 yards away) and eventually transported the 10 survivors; he then relayed information about the remaining missing passenger by radio to the USCG. The USCG launched a boat and a helicopter, and several helicopter operators who heard the USCG radio alert launched to the scene to assist in the search. These helicopters and the USCG boat transported the survivors to local hospitals and located three of the deceased occupants of the DHC-2. Numerous federal, state, and local agencies continued to search for the three remaining missing occupants (one from the DHC-3 and two from the DHC-2). About 1947, the missing passenger from the DHC-3 was located in her seat in the submerged airplane. On May 14, 2019, about 1700, the two missing passengers from the DHC-2 were located in a wooded area near Mahoney Creek.

1.9 Tests and Research

1.9.1 ADS-B Avionics Extraction and Evaluation

The ADS-B transceivers from both airplanes were recovered and transported to the FreeFlight Systems facility for testing. The RANGR 978 transceiver from the DHC-2 was connected to a test stand and powered on. Review of the configuration files indicated that the transceiver received data from local flights (ADS-B In) and also transmitted data (ADS-B Out).[35] The DHC-3 RANGR 978 transceiver's configuration files could not be recovered, and the unit could not be tested for functionality due to damage sustained in the accident.

After the accident, the FAA provided recorded ADS-B data that had been transmitted from both airplanes, which indicated the ADS-B transceivers on both aircraft were operational and transmitting data to the nearest ground station at the time of the accident. However, the data also

[33] Of the 11 occupants on board, 4 occupants initially had difficulty releasing their seatbelts but were assisted by other occupants and eventually evacuated the airplane.

[34] The passenger reported that, once she was in the water, she removed the life preserver from its pouch and inflated it by blowing into the inflation tube. She did not don the life preserver but used it to improve her buoyancy.

[35] These flights were in the Irving, Texas, area, where FreeFlight Systems is located.

showed that the DHC-3 had not transmitted pressure altitude or a valid transponder code.[36] According to the data, the last time the DHC-3 transmitted pressure altitude was during a flight on April 29, 2019.[37]

According to FreeFlight Systems personnel, a RANGR 978 transceiver receives pressure altitude information from an altitude encoder connected to a Garmin GSL 71 control head. If the GSL 71 control head selector knob on the DHC-3 was in the OFF position, no pressure altitude data and no transponder code (mode 3A) would be provided from the transceiver, which was consistent with the recorded data.[38] Additionally, the FreeFlight Systems airplane flight manual supplement stated the following:

> Turning off the dedicated UAT [Universal Access Transceiver] Controller results in turning off the ADS-B Out system. The ramifications of turning off the ADS-B Out system are no ADS-B tracking of the airplane (air to air or ground to air) and unreliable ADS-B In operation.[39]

The DHC-3 pilot stated during a postaccident interview that he was not aware the GSL 71 was off during the accident flight. He stated that he never touched the control head selector knob on the GSL 71, including during the accident flight. He said that he assumed turning the control head off would disable something, but he was unsure of the effect turning it off would have on the airplane's ADS-B system. He stated that if everything was functional on the display, there was no need to manipulate the GSL 71 control head, and he said the display appeared functional during the accident flight. He could see other airplanes depicted on the display, and no other pilots in the area told him they could not see his airplane on their displays.[40] Additional interviews with company personnel revealed the president of Taquan Air was also “not sure about the technical aspect of the GSL 71,” and the director of operations reported the GSL 71 “didn’t require a lot of input from [the pilots].”

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[36] A discrete transponder code (often called a squawk code) is assigned by air traffic controllers to uniquely identify an aircraft on radar. Codes are four digits from zero to seven.

[37] On April 29, 2019, the accident pilot flew the DHC-3 from an inlet 21 nm north of Ketchikan at 1632 and arrived at Ketchikan at 1645.

[38] The power to the RANGR 978 transceiver would not be interrupted with the selector knob in the OFF position.

[39] According to discussions with FreeFlight Systems personnel after the accident, the wording of the sentence in the airplane flight manual supplement was meant to convey to the operator the importance of not turning off the GSL 71 control head. FreeFlight Systems personnel recognized that the RANGR 978 transceiver is wired and configured to not stop transmitting when used with a GSL 71; however, no pressure altitude information will be transmitted.

[40] A review of the DHC-3 pilot’s training records revealed he received 8 hours of ground instruction on the “Capstone EFIS” during his initial training course and another 8 hours during his recurrent and transition training course. During a postaccident interview, he stated that he could not recall receiving any explanation of the purpose of the GSL 71, and company training records were not sufficiently detailed to reveal what specific information was provided to him about it. He stated that his understanding of the Chelton EFIS system was obtained through his independent study of a desktop simulator provided by the company and through use of the system during actual flight operations. He said that he did not consider the system to be very user friendly but believed if there were any weaknesses in his understanding of the system, they would have been corrected during company flight training.

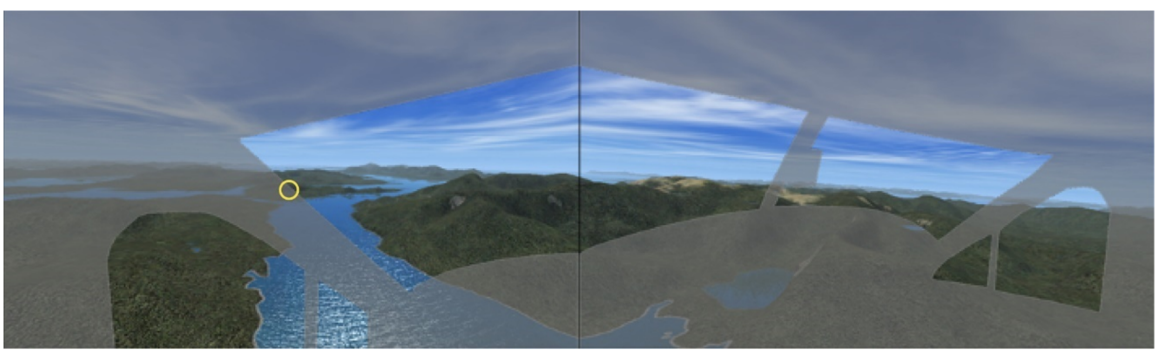
1.9.2 Cockpit Visibility Study

The NTSB completed an aircraft performance and cockpit visibility study to determine the position and orientation of each airplane in the minutes before the collision using ADS-B data for both airplanes, three-dimensional laser scans of the cockpits of exemplars for both airplanes, passenger photos, and recorded avionics data on the DHC-3. This information was then used to estimate the approximate location of each airplane in the other airplane pilot's field of view and to recreate CDTI data that could have been presented to the pilots.

The study determined that, at the time of the collision, for the DHC-3 pilot, the sun would have been in the same direction as the DHC-2 but above the top of the DHC-3's left windshield. Thus, the DHC-3 structure would have shielded the pilot's eyes from direct sun glare, and the DHC-2 would have been silhouetted. For the DHC-2 pilot, the sun would have appeared on his left, while the DHC-3 would have appeared on his right; thus, the sun would not have been in the pilot's eyes if he looked toward the DHC-3.

The cockpit visibility study also revealed that during the 3 minutes before the collision, the DHC-3 would have been obscured from the DHC-2 pilot by the DHC-2's cockpit structure, right wing, and the passenger in the right front seat. Therefore, the DHC-2 pilot would not have had the opportunity to see the DHC-3 (which was above and behind his aircraft), by visually scanning the outside environment.

Regarding whether the DHC-3 pilot could have seen the DHC-2, between 1220:39 and 1221:03, the DHC-2 would have appeared slightly ahead of the DHC-3's left window post as a relatively small, slow moving object below the horizon against a background of terrain and water (see figure 11).



Note: A yellow circle superimposed on the left windshield post represents the location of the DHC-2 in the distance.

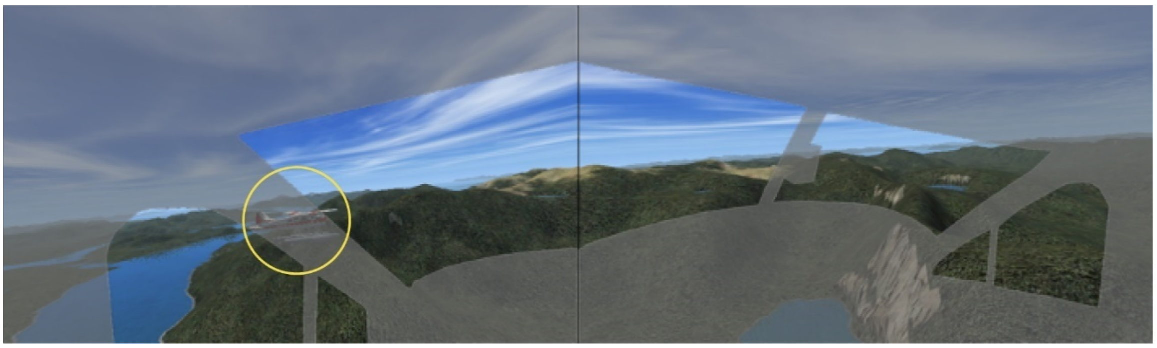
Figure 11. DHC-3 cockpit view at 1220:44 (30.4 seconds before collision).

About 1 minute 20 seconds before the collision, the apparent size of the DHC-2 would have been a subtended visual angle of 0.2° of the DHC-3 pilot's field of view (about one-sixth the height of a thumbnail held at arm's length).[41] At 1220:39, when the DHC-2 would have moved in

[41] The subtended visual angle is the acute angle of a triangle defined by points located at the eye of a viewer and the outside edges of a distant object being viewed. The angle is a function of the size of the viewed object and its distance from the viewer. The angle is directly related to the size of the retinal image, with larger angles corresponding to larger retinal images.

front of the window post in the DHC-3 pilot's field of view, the DHC-2's fuselage would have spanned about 0.35° of the DHC-3 pilot's field of view. At 1221:03, 11.4 seconds before the collision, its apparent size would have increased slowly to 1.2° (slightly less than the height of a thumbnail). At that time, the DHC-2's fuselage would have once again slipped behind the DHC-3's window post, which would have obscured it from the DHC-3 pilot.

At 1221:13.4 (1 second before the collision), the apparent size of the DHC-2 would have grown large enough in the DHC-3 pilot's field of view that portions of the DHC-2 would have been visible through the left window and ahead of the left window post, though most of the airplane would have remained obscured by the window post (see figure 12).



Note: A yellow circle superimposed on the left windshield represents the DHC-2, which is mostly hidden by the left windshield post.

Figure 12. DHC-3 cockpit view at 1221:13.4 (1 second before collision).

The cockpit visibility study also considered whether the geometry of the "blind spots" created by the window supports and other structures could shift based on the position of the pilot in the cockpit. To determine how this geometry changes as the pilot's eye position changes (for example, by the pilot leaning in different directions, or by a seat height adjustment), the study considered 27 potential eye positions and evaluated whether the DHC-3 pilot could have seen the DHC-2 in any of those positions.[42] The study concluded that the DHC-2 may have been visible to the DHC-3 pilot for about 51 seconds before the collision if the DHC-3 pilot's eyes were located 3 inches forward from where they were during the accident flight.[43]

1.9.3 Aircraft Performance Study

As part of the aircraft performance study, the NTSB used recorded ADS-B data to determine what traffic information might have been presented to the pilots on their respective CDTI in the minutes before the collision. The study produced several simulated CDTI "screenshots" corresponding to different time points preceding the collision.

[42] The pilot's actual eye position at the time of the accident was estimated in part from a photo taken by a passenger in the DHC-2. The matrix of alternative eye positions consisted of displacements in different directions from the eye position estimated from the photo.

[43] A similar study was not performed for the DHC-2 pilot's field of view because the passenger in the copilot seat would have obscured the DHC-3 from the DHC-2 pilot in all cases.

A simulation was produced of the DHC-3's CDTI, which the accident pilot would have viewed on a Chelton EFIS. About 4 minutes before the accident, when the pilot reported he last looked at the CDTI, the screen would have displayed two groups of open cyan (blue) triangles (traffic targets) to the left of and ahead of the DHC-3. A filled cyan triangle (a "proximate" traffic target), representing the DHC-2, would have appeared between the DHC-3 and the open cyan triangles to the left, about the DHC-3's 10 o'clock position (see figure 13). [44]

Note: Because of limitations in the simulation, the -500 ft relative altitude depicted in the image is erroneous and should be disregarded (the true relative altitude would have been displayed during the accident).

Figure 13. Reconstructed DHC-3 CDTI at 1217:15 (4 minutes before the collision) over Carroll Inlet. The accident DHC-2 is represented by a cyan filled arrowhead at the 10 o'clock position.

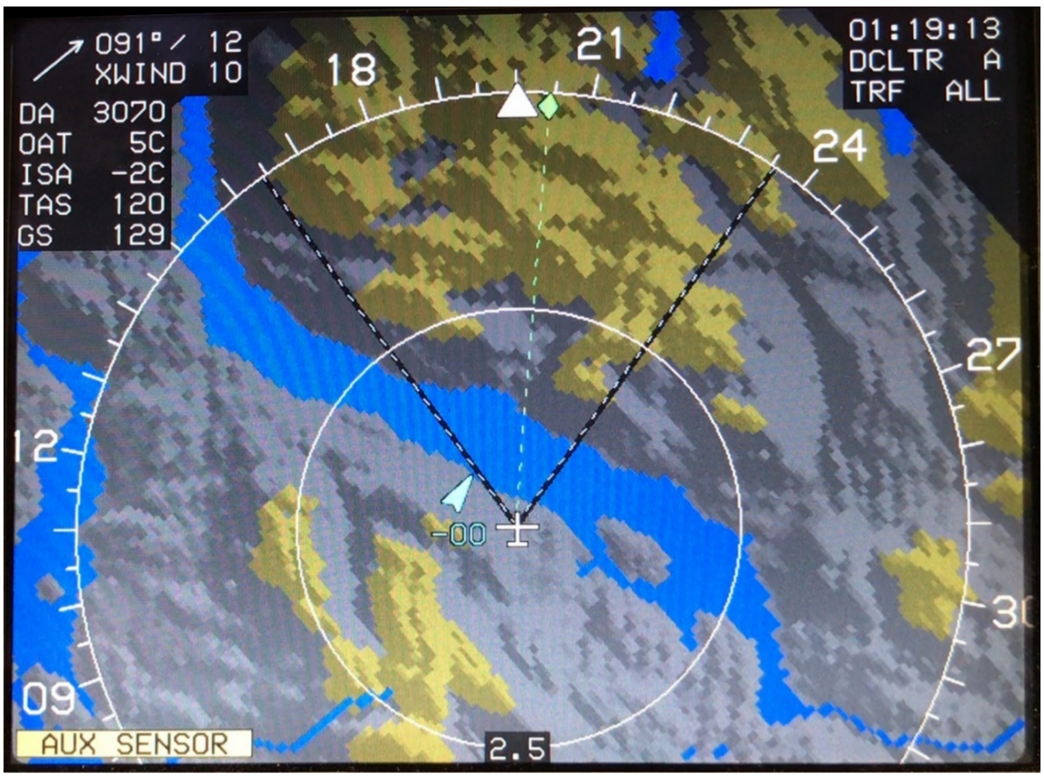
Simulations were also created to compare the display on a DO-317B-compliant device to the likely display on the DHC-3's Chelton EFIS.[45] In the DHC-3 simulation, 37.4 seconds before

[44] To create the Chelton simulation, FreeFlight Systems was provided a file (in comma-separated values format) with all the traffic data for the area around Ketchikan from 0700 to 1300 AKDT. The file was in the standard format for ADS-B ground station reception reports typically generated by the FAA for ADS-B compliance verification.

[45] The DO-317B-compliant simulations were performed at the NTSB using code provided in the digital supplement to DO-317B. The DO-317B standard specifies, among other things, the type of aural annunciation that should accompany an ATAS traffic alert, as well as the color and shape of traffic images on the CDTI display. Specifically, the components of the annunciation that follow an ATAS alert should include the alert "Traffic," followed by the relative traffic bearing expressed as a clock position, the relative altitude, the range to the target in nautical miles, and optionally, the vertical tendency. An example of a complete annunciation is "Traffic, two o'clock, high, two miles, descending." The aural annunciation is provided both when a traffic target first generates an ATAS alert (by the algorithm predicting that the ownship will penetrate a "protected airspace zone" around the target), and again when the algorithm predicts that the ownship will penetrate a smaller, "collision airspace zone" around the target. The NTSB simulations incorporate these elements of the aural annunciation of ATAS alerts.

the collision, a Chelton EFIS and a RANGR transceiver would have displayed the DHC-2 as a filled cyan arrowhead on the DHC-3 Chelton EFIS (see figure 14).[46] However, on a DO-317B-compliant CDTI, the DHC-2 target would have changed from a filled cyan arrowhead to a filled yellow arrowhead with a circle around it (see figure 15).[47] The DO-317B-compliant CDTI also would have generated an aural alert giving bearing, relative altitude, and range from the target; 7 seconds later, a second aural alert would have been given with the same structure: "traffic, 10 o'clock, same altitude, less than one mile."

Before the DHC-3's FreeFlight transceiver upgrade in 2015, the original avionics installed included a Chelton EFIS paired with a Garmin GDL 90 transceiver. A simulation of these original avionics was not performed because a GDL 90 unit was not available and the details of its alerting algorithm are unknown. However, because the GDL 90 can place targets into an "alert" status, this combination of avionics would have likely generated a visual and (single) aural alert similar to the DO-317B alerts described above.

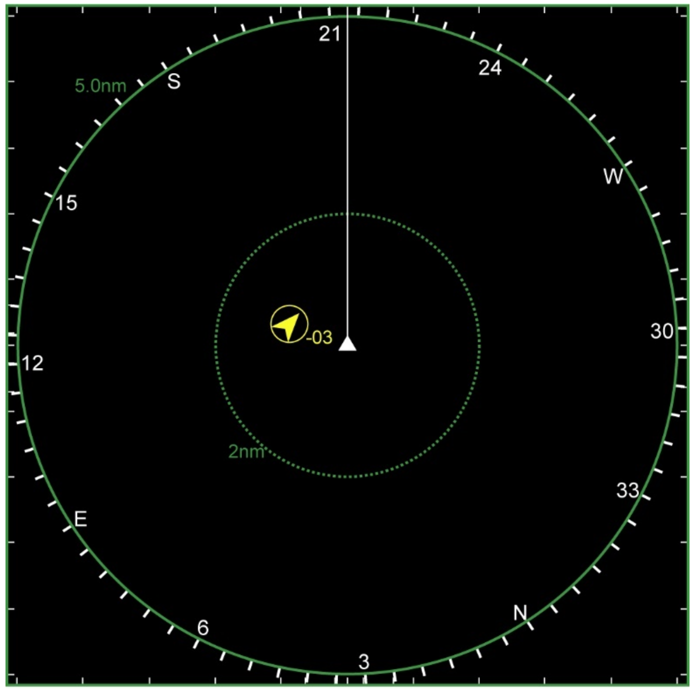


Note: Because of limitations in the simulation, the 0 ft relative altitude depicted in the image is erroneous and should be disregarded (the true relative altitude would have been displayed during the accident).

Figure 14. DHC-3 simulated Chelton EFIS at 1220:37 (37.4 seconds before collision).

[46] The relative altitude of the DHC-2 would also have been displayed. Because of limitations in the simulation, the relative altitude depicted in the simulation image shown in Figure 14 is erroneous. The true relative altitude would have been displayed during the accident.

[47] The vertical altitude difference is also displayed in the simulations as a two-digit number preceded by a plus (+) or a minus (-). For example, at 37.4 seconds before the collision, "-03" was displayed next to the filled yellow triangle, which meant the DHC-2 target was 300 ft below the DHC-3.



ATAS aural alert:
"Traffic, 10 o'clock, low, less than 1 mile"

Figure 15. DHC-3 simulated DO-317B-compliant CDTI at 1220:37 (37.4 seconds before collision).

Simulations of the DHC-2's CDTI, which recreated the ForeFlight application on an iPad, were produced to correspond to three possible scenarios. The scenario that was most representative of the accident circumstances included the DHC-3 not broadcasting pressure altitude. About 1 minute 44 seconds before the collision, the DHC-3 with that setting would have appeared on the DHC-2's ForeFlight application as a filled cyan arrowhead about the DHC-2's 3 o'clock position and on a course that would intersect the DHC-2's flightpath. However, no visual or aural alert would have been generated because no altitude information about the DHC-3 would have been available (see figure 16). This scenario assumed the ForeFlight "Display Traffic" option was enabled and the "Hide Distant Traffic" option was turned off.

Note: This scenario assumes the DHC-3 was not providing pressure altitude. The scale is approximately a 6 nm range.

Figure 16. First DHC-2 simulated ForeFlight display at 12:19:30.1 (1 minute 44.3 seconds before collision). A cyan filled arrowhead represents the DHC-3 at the 3 o'clock position.

If the "Hide Distant Traffic" option was enabled, the DHC-3 would not have appeared on the DHC-2's ForeFlight application at all because no pressure altitude was received from the DHC-3.

If the "Hide Distant Traffic" option was disabled, as time progressed, the symbol representing the DHC-3 would have converged on the DHC-2's symbol without changing relative bearing or heading and without an aural or visual alert until the collision at 1221:14.4.

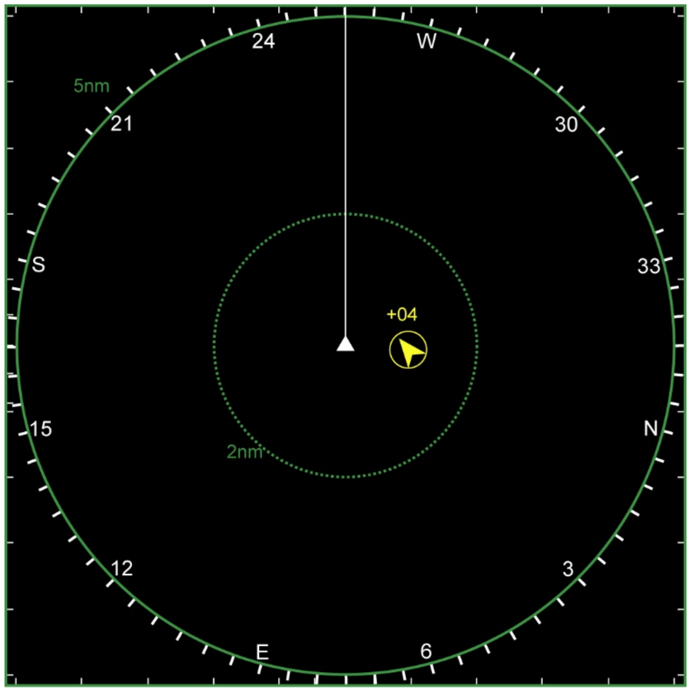
A second simulation was performed to determine the performance of the ForeFlight application if the DHC-3 had been broadcasting pressure altitude. In this scenario, the DHC-2's ForeFlight application would have generated an aural and visual alert about 1 minute 44 seconds before the collision. The DHC-3 target would have been depicted as a filled yellow arrowhead, and visual and aural alerts would have been generated with the position, distance, and relative altitude of the DHC-3 from the DHC-2 (see figure 17). Between the alert and the collision, the

DHC-3 symbol would have remained a filled yellow arrowhead annotated with the relative altitude from the DHC-2 and a downward pointing arrow indicating that the DHC-3 was descending.

Note: The scale is approximately a 20 nm range. The alert in the red text box would also be generated aurally.

Figure 17. Second DHC-2 simulated ForeFlight display at 1219:30.1 (1 minute 44.3 seconds before collision).

A third simulation assumed that the DHC-2 was equipped with a CDTI that was compliant with the traffic symbols and ATAS alert criteria specified in DO-317B and assumed that the DHC-3 was broadcasting pressure altitude. As in the other simulations, the DHC-3 would have appeared on the DHC-2's display about 1 minute 44 seconds before the collision as a filled cyan arrowhead at the 3 o'clock position. An aural alert would have been generated 35.4 seconds before the collision, and the filled cyan arrowhead would have changed to a filled yellow arrowhead enclosed in a circle (see figure 18). Another aural alert would have been generated 29.4 seconds before the collision, which would have indicated the DHC-3 was at the "same altitude, less than one mile, descending."



ATAS aural alert:

"Traffic, 3 o'clock, high, less than 1 mile, decending"

Note: This simulation assumes the DHC-3 was providing pressure altitude.

Figure 18. DHC-2 simulated DO-317B CDTI (not installed in the DHC-2) at 1220:39 (35.4 seconds before collision).

1.10 Organizational and Management Information

1.10.1 DHC-2

Mountain Air Service was a single-pilot operation that held on-demand operations specifications (OpsSpecs), which allowed for operations under Part 135 regulations.[48] The company's headquarters was in Ketchikan, Alaska, and the company only owned one airplane, the accident DHC-2, listed on the OpsSpecs. The accident pilot was the owner and sole pilot for the company. As a single-pilot operator, Mountain Air Service was not required to have a general operations manual (GOM) or FAA-approved training program.

A review of the pre-flight checklist for the DHC-2 revealed no checklist item for the ADS-B equipment or avionics except for a transponder. The checklist stated in part, "check transponder is on"; however, the airplane was not equipped with a transponder.

[48] The FAA issues OpsSpecs to certificated operators as an authorization to conduct operations and outlines how they will operate while complying with federal regulations.

1.10.2 DHC-3

The DHC-3 was operated by Taquan Air, a Part 135 air carrier that held on-demand and commuter OpsSpecs. The company headquarters was in Ketchikan, Alaska, where the president, director of operations, chief pilot, and director of maintenance all resided. At the time of the accident, the company operated 15 airplanes, 3 of which were DHC-3 aircraft. The company employed 25 pilots, most of whom worked for Taquan Air on a seasonal basis.

A review of the checklist for the DHC-3 revealed that it was titled, “PROMECH AIR, NORMAL CHECKLIST (PT6A-34)” and was created for another company.[49] In addition, the checklist did not have an item about the GSL 71 control panel.[50]

1.11 Additional Information

1.11.1 Capstone Program

The NTSB has had a longstanding interest concerning aviation safety in Alaska. In 1995, the NTSB published a safety study titled *Aviation Safety in Alaska* to address the diverse flight operations and unique risks that pilots experience in the state (NTSB 1995). Some of the risks addressed in the study included rough terrain, adverse weather, and extreme isolation. The study recommended practical measures for managing these risks, given the reality of Alaska's aviation environment, and the potential of new technologies.

As part of the safety study, the NTSB issued Safety Recommendation A-95-121 asking the FAA to implement a model program in the arctic and southeast regions of Alaska (by December 31, 1997) to demonstrate a low-altitude instrument flight rules (IFR) system that better fulfills the needs of Alaska’s air transportation system. In response to this recommendation, the FAA developed the Capstone Program to accelerate safety enhancements in Alaska and “concentrate on safety initiatives from the Board’s *Alaska Safety Study*”; one of these safety initiatives was enhanced “see-and-avoid” (NTSB 1995). As a result, Safety Recommendation A-95-121 was classified “Closed—Acceptable Action” on July 1, 2003.

Under the Capstone Program, the FAA provided ADS-B avionics equipment for aircraft and the supporting ground infrastructure to reduce accidents and improve aviation safety. The Capstone Program operated in two phases from 1999 to 2006, and its success in Alaska laid the groundwork for the nationwide deployment of ADS-B.

Phase 1 of the Capstone Program, which was implemented between 1999 and 2004, equipped 208 aircraft in southwest Alaska with ADS-B equipment (189 of these were commercial aircraft operating under 14 *CFR* Parts 135 or 121) (Mitre 2006a). To support traffic awareness, the ADS-B equipment provided both aircraft traffic information and traffic alerting. The traffic

[49] Promech Air was the previous operator of the DHC-3.

[50] The airplane flight manual supplement for FreeFlight FDL-978-series ADS-B systems stated in part, “The Garmin GSL 71 UAT Control Panel (if installed) must be in the ALT Mode during all phases of flight.” However, this information was not included in the airplane’s checklist.

alerting consisted of aural alerts and changes to the visual presentation of the aircraft target on the displays to highlight threats. In addition to traffic awareness, the ADS-B equipment provided other safety improvements, such as weather and terrain awareness.

Phase 2 of the Capstone Program, which was implemented between 2002 and 2006, equipped 109 aircraft in southeast Alaska with a suite of IFR-capable avionics (105 of these aircraft were commercial aircraft operating under 14 *CFR* Parts 133 and 135)[51,52] (Mitre 2006b). Installation of the avionics began in 2003 with the intent to increase pilot situational awareness and navigational performance during IFR and visual flight rules (VFR) operations (Mitre 2006b). In 2005, as part of this program, the accident DHC-3 was equipped with a Chelton EFIS-2000 and a Garmin GDL 90 transceiver; the accident DHC-2 was not part of the Capstone Program.

The original avionics installed in the accident DHC-3, as a part of the Capstone Program, provided visual and aural traffic alerting. The Garmin GDL 90 featured a "conflict situational awareness" (CSA) function designed to place targets that meet certain threat criteria into an "alert status." The alert status triggered the Chelton EFIS to change the target's color to amber on the display and to generate an aural alert concerning the target. According to the FAA, the GDL 90 CSA was a proprietary function owned by Garmin and was never required by the FAA in a TSO.

In December 2012, the FAA solicited proposals to upgrade the existing installed avionics in the Capstone Program phase 1 and 2 aircraft to comply with the requirements of 14 *CFR* 91.227.[53] The upgraded components were required to comply with TSO-C195a standards and MOPS for aircraft surveillance applications systems, as defined in DO-317A.[54] Of note, DO-317A stated in part, "The conflict detection application, which is considered as immature, has been deleted." According to an FAA employee interviewed after the accident, in this context, the term "conflict detection" referred to a rudimentary form of alerting.

The FAA clarified that DO-317A did not require a collision alerting application but did not prohibit a manufacturer from including it as an optional feature. However, an earlier amendment to a request for proposal (RFP) for Capstone Program phase 2 avionics included a requirement for conflict detection and aural alerting indicating that, at that time, the FAA considered this an important safety protection. The RFP stated that "conflict detection requirements should be similar to those specified in RTCA/DO-197, Minimum Operational Performance Standards for an Active Traffic Alert and Collision Avoidance System I (Active TCAS I)." The RFP also stated that the "traffic warning should state 'traffic, traffic' … aural warnings shall be given for each threat aircraft."

In May 2013, the FAA selected FreeFlight Systems to provide the replacement ADS-B transceiver. The FAA funded the upgrade of all 317 ADS-B transceivers equipped in phases 1 and 2 of the Capstone Program. The FreeFlight RANGR 978 ADS-B transceiver did not have any form

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[51] Operations conducted under Part 133 are considered External Load Operations.

[52] The remaining four non-commercial aircraft consisted of one airplane operated by the University of Alaska and three aircraft operated by the Civil Air Patrol.

[53] Title 14 *CFR* 91.227 defines performance requirements for ADS-B Out equipment, such as power requirements, position accuracy, and specific message elements as defined in TSO-C154c.

[54] The ATAS traffic alerting application is an optional component of the DO-317B MOPS.

of collision detection or alerting.[55] FreeFlight Systems personnel indicated the FAA generally discouraged adding non-TSO functionality to a TSO system.[56] The FreeFlight Systems airplane flight manual supplement (dated June 23, 2015) states, "The Chelton FlightLogic EFIS, when integrated with the FreeFlight System, does not provide Conflict Situational Awareness." In addition, according to the FAA, the CSA function that was featured in the Garmin GDL 90 transceiver (which was installed in the DHC-3 before the FreeFlight upgrade) could not have been included in the FreeFlight transceiver because "there was no legal pathway to force Garmin to provide their proprietary software to another manufacturer."

The ADS-B components originally installed in the DHC-3 during phase 2 of the Capstone Program were upgraded to FreeFlight ADS-B components in 2015, and the legacy traffic-alerting capability that was present on the DHC-3 was consequently lost. The FreeFlight ADS-B components installed in the accident DHC-2 were installed in 2015 at the owner's expense and not as a part of the post-Capstone upgrade program (appendix C outlines the features of the ADS-B system on each aircraft).

1.11.2 Safety Management Systems

The investigation revealed that neither company had a safety management system (SMS) in place at the time of the accident.[57] However, according to the president of Taquan Air, he decided after the accident occurred that the company needed an SMS "to earn the trust of our passengers and the traveling public back"; he began the application process to the FAA in the summer of 2019.[58]

According to the FAA, "SMS is the formal, top-down business-like approach to managing safety risk, which includes a systemic approach to managing safety, including the necessary organizational structures, accountabilities, policies, and procedures."[59] The goal of SMS is to identify safety hazards, ensure necessary remedial action is implemented to maintain an acceptable level of safety, provide continuous monitoring and regular assessment of the safety level achieved, and continuously improve a company's overall level of safety. According to Advisory Circular (AC) 120-92B, "Safety Management Systems for Aviation Service Providers," SMS is comprised of four components: safety policy, safety risk management, safety assurance, and safety promotion.

Safety policy establishes senior management's commitment to continually improve safety and defines the methods, processes, and organizational structure needed to meet safety goals. Safety risk management determines the need for, and adequacy of, new or revised risk controls

[55] These FreeFlight ADS-B units were compliant with DO-317A.

[56] This statement was made by the president and chief executive officer of FreeFlight Systems to investigators after the accident.

[57] As will be discussed in section 2.9, SMS was not required by the FAA for Part 135 operators at the time of publication of this report; however, operators could apply for acceptance into the FAA's SMS Voluntary Program.

[58] Correspondence from the FAA revealed Taquan Air was accepted into the FAA's SMS Voluntary Program on January 29, 2021.

[59] More information can be found at Safety Management System (faa.gov).

based on the assessment of acceptable risk. According to AC 120-92B, a certificate holder must apply safety risk management when any of the following changes occur: (1) implementation of new systems, (2) revision of existing systems, (3) development of operational procedures, or (4) identification of hazards or ineffective risk controls through the safety assurance processes identified in AC 120-92B.[60]

Safety assurance evaluates the continued effectiveness of implemented risk control strategies and supports the identification of new hazards. Safety promotion includes training, communication, and other actions to create a positive safety culture within all levels of the workforce. The FAA states in its guidance that scalability is an important concept for SMS that allows its four components to be applied to air service providers both large and small, including single-pilot operations. To demonstrate the scalability of SMS, the FAA released a video that described a process for SMS implementation at small aviation service providers. The video referenced a speech from a former FAA administrator, who stated that "no company is too small for an SMS."[61]

1.11.3 Postaccident Safety Actions

On June 1, 2019, as a result of this accident, an updated letter of agreement (LOA) was published by a group of 14 Ketchikan commercial operators. Originally created on January 15, 2009, the LOA is intended to foster voluntary compliance with the routes, procedures, and safe practices established for operating in the Ketchikan and Misty Fjords National Monument Wilderness area. The changes specifically addressed in the revised LOA were:

- Anti-collision lights, "pulse" lights or aircraft landing lights shall be on at all times when aircraft are being flown.
- All company aircraft are equipped with and use ADS-B Out and In at all times.
- No company aircraft will fly in the Ketchikan Lakes area.
- All company aircraft will stay over water as much as possible on standardized tour routes.
- All company aircraft will follow the route [on page 8 of the LOA] for the George Inlet tours, which is over water and out of the Ketchikan Lakes area.
- All pilots will announce position reports at all reporting points identified in the agreement.

[60] AC 120-92B, "Safety Management Systems for Aviation Service Providers," provides guidance for Part 121 air carriers that are required to implement an SMS program in compliance with 14 *CFR* Part 5. The FAA SMS Voluntary Program also provides non-Part 121 operators a gap analysis tool to identify hazards that need to be addressed to comply with the SMS Voluntary Program standard.

[61] For more information, see the "Safety Management System (SMS) for Small Operators" video.

Taquan Air was one of the operators that signed the LOA. Additionally, Taquan Air had each of its pilots sign a document stating they read and fully understood the LOA and agreed to comply with it.

2. Analysis

2.1 Introduction

This accident occurred when two airplanes collided about 8 miles northeast of Ketchikan, Alaska, following sightseeing flights in day visual meteorological conditions. Six people were killed in the accident, nine people were seriously injured, and one person received minor injuries.

Both airplanes were operating under VFR; therefore, the pilots of both airplanes were responsible for maintaining visual separation from other aircraft (primarily using the "see-and-avoid" concept for collision avoidance, which will be discussed in section 2.2). According to recorded ADS-B data, at 1217:15 (about 4 minutes before the collision), the DHC-3 was about level at 4,000 ft on a track of 225°. About this time, the pilot of the DHC-3 checked his cockpit traffic display and noted "there were two groups of blue triangles, but not on my line. They were to the left of where I was going"; he did not check his display again before the collision. At the same time, the DHC-2 was 4.2 nm south of the DHC-3, climbing through 2,800 ft, on a track of 255°.

About 1219, the DHC-3 started a descent from 4,000 ft, and the DHC-2 was at 3,175 ft and climbing. Over the next 1 minute 21 seconds, the DHC-3 continued to descend on a track between 224° and 237°, and the DHC-2 continued to climb on a track of about 255°. The airplanes collided at 1221:14 at an altitude of 3,350 ft, 7.4 nm northeast of 5KE, with the DHC-3 approaching the DHC-2 from above and to the right, and the DHC-2 approaching the DHC-3 from below and to the left.

The analysis discusses and evaluates the following:

- The inherent limitations of the see-and-avoid collision avoidance concept (section 2.2).
- The benefit of aural alerts on CDTIs, which can draw a pilot's attention to conflicting traffic and play an important role in the prevention of midair collisions (section 2.3).
- The need for ADS-B Out and In for all Part 135 operators, particularly those operating in high-traffic areas (sections 2.4 and 2.5).
- The need for ForeFlight Systems to update its software algorithms to treat missing altitude information as a potential collision risk (section 2.6.1).
- The termination of pressure altitude reporting if the Garmin GSL 71 control head selector knob is in the OFF position and the lack of traffic alerting that can result (section 2.6.2).
- The loss of alerting capabilities with ADS-B systems installed as part of the post-Capstone upgrade program (section 2.6.3).
- The hazard of an inadequate checklist (section 2.7).
- The lack of a requirement for SMS in Part 135 operations (section 2.9).

Having completed a comprehensive review of the circumstances that led to the accident, the investigation established that the following factors did not contribute to its cause:

- *Pilot qualifications*: Both pilots were properly certificated and qualified in accordance with their respective company procedures and Part 135.
- *Pilot medical conditions*: Both pilots held valid and current medical certificates. A review of the information available to the NTSB regarding both pilots' work and sleep schedules revealed no evidence of factors that would have adversely affected their performance on the day of the accident. Although the sedating drug cetirizine was identified in the DHC-2 pilot's cavity blood and liver, it was below the therapeutic range and, therefore, was believed not to be a factor in his performance.
- *Airplane mechanical conditions*: Both airplanes were properly certificated, equipped, and maintained in accordance with Part 135. The investigation found no evidence of any structural, engine, or system failures with either airplane. The damage observed on both airplanes was consistent with an in-flight impact followed by an impact with the water and terrain.

Thus, the NTSB concludes that none of the following safety issues were identified for the accident flight: (1) pilot qualification deficiencies; (2) pilot impairment; or (3) a malfunction or failure on either airplane.

2.2 See-And-Avoid Limitations

Both airplanes were operated in a high-traffic area under VFR. To mitigate the risk of a collision in VFR conditions, it is a pilot's responsibility to visually acquire aircraft flying in the vicinity of their own aircraft and maintain separation from them. This concept is referred to as "see-and-avoid." To emphasize the catastrophic consequences of a midair collision, 14 *CFR* 91.111(a) states, "no person may operate an aircraft so close to another aircraft as to create a collision hazard." Also, 14 *CFR* 91.113(b), "Right-of-Way Rules," states, "when weather conditions permit, regardless of whether an operation is conducted under instrument flight rules or visual flight rules, vigilance shall be maintained by each person operating an aircraft so as to see and avoid other aircraft." In addition, AC 90-48D, "Pilots' Role in Collision Avoidance," states that the see-and-avoid concept requires vigilance by each person operating an aircraft when weather conditions permit regardless of whether the flight is conducted under IFR or VFR (FAA 2016).

Research involving actual flight tests indicates that most unalerted visual acquisition of conflicting aircraft occurs after the two aircraft have closed to within 1 to 2 nautical miles of each other. Mathematical modeling of the probability of visual acquisition indicates that for a closure rate of 120 knots, an 85% probability of detecting an intruder aircraft does not occur until 12 seconds before a collision. By contrast, pilots using aural and visual traffic alerting can be expected to visually acquire conflicting traffic about 8 seconds earlier (Andrews 1991).

The see-and-avoid concept relies on a pilot to look through the cockpit windows, identify other aircraft, decide if any aircraft are collision threats, and take the appropriate action to avert a collision, if necessary. There are inherent limitations of this concept, including the limited field of view from the cockpit (including the obscuring effects of aircraft structures) and the limitations of human attention and visual performance that prevent pilots from visually detecting other aircraft. According to the *Aeronautical Information Manual* (*AIM*), pilots are reminded of the requirement to move one's head in order to search around the physical obstructions, such as door and window posts. The doorpost can cover a considerable amount of sky, but a small head movement may uncover an area that might be concealing a threat.

In this accident, the DHC-2 pilot would not have had the opportunity to see and avoid the DHC-3 (which was above and behind his aircraft) by visually scanning the outside environment, no matter how diligent and efficient his scanning might have been. The DHC-3 was obscured by the DHC-2 cockpit structure, right wing, and a passenger in the copilot's seat.

Regarding the DHC-3 pilot's ability to see and avoid the DHC-2, the DHC-2 would have produced little apparent motion as the two airplanes converged at a relatively constant angle for about 3 minutes before the collision. About 1 minute 20 seconds before the collision, the apparent size of the DHC-2 would have been a subtended visual angle of 0.2° of the DHC-3 pilot's field of view (about one-sixth the height of a thumbnail held at arm's length).

At 1220:39, 35 seconds before the collision, the DHC-2 would have moved forward of the window post and its apparent size would have grown to 0.35° of the DHC-3 pilot's field of view. About 24 seconds later, as the DHC-2 moved back to a position behind a window post in the DHC-3 cockpit, its apparent size would have increased slowly to 1.2° (slightly less than the height of a thumbnail). The lack of apparent motion or rapid expansion up to that point reduced the likelihood that the DHC-3 pilot would see the DHC-2 in his periphery. This limitation is because human ambient vision (a component of the human visual system that processes information in peripheral field of view) is more sensitive to motion than to fine detail (Gibb et al 2010a). Furthermore, the DHC-2's proximity to a window post in the DHC-3 pilot's field of view further reduced the likelihood of detection due to the tendency of the eye to focus at an intermediate distance when scanning for distant objects in the vicinity of close objects (Chong and Triggs 1989).

The DHC-2 would have likely remained hidden behind the DHC-3 window post until 0.5 second before the collision. At that time, even if the DHC-3 pilot had seen the DHC-2, he would not have had enough time to avoid the collision. Thus, the DHC-3 pilot had a limited opportunity to visually acquire the DHC-2. AC 90-48D indicates that the minimum time for a pilot to detect another aircraft, judge a collision course, and take evasive action is about 12.5 seconds. Thus, by the time the DHC-2 slipped undetected back behind the window post (11.4 seconds before the collision), a collision was likely already inevitable.

Attentional limitations were also a factor in the DHC-3 pilot's ability to see the DHC-2. Research on pilot monitoring indicates that pilots spend, on average, about 30% to 35% of their time scanning the outside environment and less than that when they are engaged in some tasks (Wickens et al 2001). This limited monitoring time reduces the likelihood that pilots will visually detect outside traffic. Furthermore, it is unlikely that all a pilot's time spent monitoring the outside environment is devoted to systematically scanning the entire field of view. Pilots have a bias for scanning the area directly in front of them and toward features of the environment pertinent to current tasks (Colvin et al 2005). For example, the accident DHC-3 pilot reported that, before the collision, he was looking to the right so that he could maneuver his airplane toward a waterfall that he planned to show his passengers. The direction of the pilot's scan reduced his opportunity for detecting an unexpected airplane to the left about that time.

In addition, before the collision, the DHC-2 was at a lower altitude than the DHC-3, and it was superimposed on a complex background of terrain and water. Perception of form is determined by a form's interaction with background features, and the presence of a complex background can cause melding of a form with that background, making it harder to see. This visual effect would have made the DHC-2 even more difficult to notice even if the DHC-3 pilot had looked directly at it (Morris 2005).

Therefore, the NTSB concludes that the circumstances of this accident underscore the inherent limitations of the see-and-avoid collision avoidance concept, including how collision geometry, obscuration by aircraft structures, and limitations of human performance can make it difficult to see nearby aircraft.

2.3 Lack of Alerting

This accident underscores the serious inherent limitations of the see-and-avoid concept, which remains the primary means of collision avoidance in VFR conditions. Scientific literature on human performance in aviation (Gibb et al 2010b) and previous NTSB accident reports (discussed below) have described these limitations and argued that they cannot be overcome simply by pilot diligence in scanning for traffic. In previous midair accident investigations, the NTSB has noted that CDTI can supplement pilots' visual scans and provide awareness of conflicting traffic targets minutes before these targets become a collision threat.

In 2015, a Cessna 150M and a Lockheed Martin F-16CM collided in flight near Moncks Corner, South Carolina. Because of the high closure rate involved, each pilot had a limited opportunity to see and avoid the other airplane. A postaccident simulation showed that devices in the cockpit that display or alert to traffic conflicts might have provided both pilots with clear traffic depictions and aural alerts as the conflict developed and could have enabled them to avoid the collision.[62]

In addition, in 2015, a Cessna 172M and an NA265-60SC Sabreliner collided while maneuvering for landing at Brown Field Municipal Airport, San Diego, California. A postaccident simulation showed that a CDTI in one or both of the airplanes could have provided a traffic picture that likely would have allowed the pilots to become aware of and look for the other airplane and may have prevented the accident.[63] As a result, in 2016, the NTSB issued Safety Alert 58, "Prevent

[62] More information about this accident, NTSB case number ERA15MA259A/B, is available by using the NTSB's CAROL Query Tool.

[63] More information about this accident, NTSB case number WPR15MA243A/B, is available by using the NTSB's CAROL Query Tool.

Midair Collisions: Don't Depend on Vision Alone," to inform pilots of the benefits of technologies that provide traffic displays and alerts in the cockpit to enhance safe separation from traffic.[64]

Although both aircraft involved in the Ketchikan midair collision were equipped with CDTIs capable of displaying ADS-B In data and producing visual and aural alerts of collision threats, no alerts were produced on either airplane during the accident flights. The Chelton EFIS display on the DHC-3 could produce aural and visual traffic alerts, but to do so required that the relevant traffic messages it received from the RANGR 978 transceiver be in "alert status." The RANGR 978 did not have an algorithm to place traffic messages in an "alert status" (nor was it required to), so the alerting feature available on the Chelton EFIS could not be activated. Therefore, although traffic would have been displayed on the Chelton EFIS, the DHC-3 pilot would not have received any visual alerts or aural annunciations of conflicting traffic. Thus, the DHC-3 pilot's awareness of the DHC-2's presence and location before the collision depended on frequent visual scanning of the CDTI, a process subject to the limitations of human monitoring and selective attention, particularly as a pilot is navigating in the visual environment.

The ForeFlight application on the DHC-2 pilot's tablet also had the ability to produce visual and aural alerts but required the altitude of relevant traffic targets to do so. The DHC-3 was not broadcasting pressure altitude because its GSL 71 control head was powered off; as a result, the ForeFlight application did not identify the DHC-3 as a collision threat and did not initiate a corresponding alert.[65] Moreover, if the DHC-2's ForeFlight "Hide Distant Traffic" option had been enabled, the DHC-3 would not have been displayed at all due to a lack of pressure altitude information from the DHC-3. (The system limitations for both aircraft will be discussed further in section 2.6.)

The NTSB has highlighted other CDTI alerting issues in past investigations. For example, in the NTSB's investigation of the 2007 midair collision of two electronic news gathering helicopters in Phoenix, Arizona, the NTSB noted one helicopter involved in that accident had a CDTI with aural alerting capability installed (NTSB 2009). However, the alert volume might have been turned down to avoid nuisance alerts while loitering near another helicopter. As a result, the NTSB issued Safety Recommendation A-09-4 to the FAA, which recommended that the FAA develop standards for helicopter cockpit electronic traffic advisory systems so that pilots can be alerted to the presence of other aircraft operating in the same area regardless of their position.[66]

The NTSB also noted the ineffective use of available electronic traffic information in its report on a midair collision over the Hudson River involving a general aviation airplane and a sightseeing helicopter (NTSB 2010). In its report on that accident, the NTSB noted that it would have been difficult for the airplane pilot to see the helicopter until the final seconds before the collision, and it found both pilots' use of available electronic traffic information to be ineffective. Both aircraft were equipped with avionics that could receive and display data from the FAA's

[64] For more information, see: https://www.ntsb.gov/safety/safety-alerts/Documents/SA_058.pdf

[65] The ForeFlight application can use geometric, GPS-based altitude in lieu of pressure altitude to create traffic alerts, but geometric altitude was not included in the traffic messages transmitted by Wi-Fi to ForeFlight by the DHC-2's FreeFlight RANGR transceiver.

[66] Safety Recommendation A-09-4 was classified "Closed—Unacceptable Action" on October 18, 2010, and superseded by Safety Recommendation A-10-127 (discussed further in the following paragraphs).

radar-based traffic information service and provide visual and aural traffic alerts. However, the investigation could not determine whether these systems were functioning at the time of the accident.

In that report, the NTSB issued Safety Recommendation A-10-127, which recommended that the FAA develop standards for helicopter cockpit electronic traffic advisory systems that (in part) reduce nuisance alerts when nearby aircraft enter the systems' alerting envelope. In response to this recommendation, the FAA published TSO-C195b, "Automatic Dependent Surveillance-Broadcast (ADS-B) Aircraft Surveillance Applications." TSO-C195b contained standards for an ADS-B-based traffic advisory application, ADS-B ATAS, which the FAA described as a low-cost traffic advisory system for general aviation that can be installed on both fixed-wing aircraft and rotorcraft. As a result, on April 16, 2015, the NTSB classified Safety Recommendation A-10-127 as "Closed—Acceptable Action."

In a postaccident interview, the DHC-3 pilot stated that he last recalled looking for traffic on the CDTI about 4 minutes before the collision. He recalled seeing "two groups of blue triangles, but not on my line. They were to the left of where I was going." He did not report looking at the display again. If the DHC-3 CDTI had given the pilot an aural alert to notify him of the impending traffic conflict, the pilot may have reacted differently and avoided the collision.

A CDTI's real-time, "complete picture" presentation of the traffic environment can help pilots visually identify conflicting traffic and avoid that traffic without aggressive maneuvering. However, like the DHC-3 pilot in this accident, pilots might not always include the CDTI in their visual scan. The addition of an aural alert can draw a pilot's attention to a potential conflict depicted on a CDTI and assist them in directing their outside visual search, thereby promoting awareness of potential traffic conflicts. The visual alert can also assist the pilot by continuously depicting the information contained in the more transitory aural alert. Therefore, the NTSB concludes that aural and visual alerts that draw the pilots' attention to conflicting traffic presented on the CDTI can greatly increase the pilots' awareness of potentially conflicting traffic and avoid a collision.

2.4 Traffic Alerting in High-Traffic Tour Areas

A review of NTSB accident data indicates that midair collisions accounted for approximately 7% of fatal accidents involving Part 135 sightseeing operators between January 1982 and August 2020.[67] Conversely, during the same period, midair collisions for all operations involving US-registered airplanes and helicopters accounted for about 2.1% of all fatal accidents in the United States. A unique risk factor for some Part 91 or Part 135 air tour operators is the increased number of aircraft flying near scenic landmarks.[68] The use of CDTI with aural and visual alerting (combined with an effective visual scan) can mitigate the risk of collisions in these congested environments by making the pilot aware of nearby traffic.

[67] During this period there were 86 fatal sightseeing accidents, 6 of which (7%) were associated with a midair collision.

[68] The NTSB has previously cited the common routes and limited number of scenic points overflown by scenic air tour operators as unique risk factors for midair collisions involving air tour operators (NTSB 1987).

CDTI provides visual displays of nearby traffic, which can include alerts with an aircraft's position or distance, direction of travel, relative altitude, and whether an aircraft is climbing or descending. Incorporating these systems in a pilot's visual traffic scan is of particular importance for air tour flights because a single pilot is often tasked with multiple concurrent duties, including radio communications, tour narration, visual traffic scans, maintaining a safe distance from obstacles and weather, and flying the aircraft.

The NTSB recognizes that CDTI can only supplement, not replace, pilot visual scanning of the outside view. However, electronic presentation of traffic information is an essential resource for pilots to overcome the previously discussed limitations of human performance. It is particularly important that traffic alerting systems include both visual and aural alerting features. The aural alert should draw the pilot's attention to the display when another aircraft becomes a potential collision threat, especially in single-pilot operations. The visual alert should highlight the conflicting traffic on a visual display, allowing the pilot to quickly locate the conflicting aircraft on the display and determine its relative position. This visual display of information eases the burden on the pilot to remember information provided by an aural alert and can help the pilot visually acquire the conflicting traffic or otherwise avoid it if the traffic cannot be seen outside the aircraft (due to obscuration by aircraft structure).

Title 14 *CFR* 25.1322(c)(2) requires redundant presentation of alert information for transport-category airplanes, stating that warning and caution alerts must provide "timely attention-getting cues through at least two different senses by a combination of aural, visual, or tactile indications." Although this requirement does not apply to the alerting systems of smaller, normal-category airplanes, the NTSB believes it is justified to apply the more stringent standard to alerting systems that are used in commercial air tour aircraft operated by a single pilot in areas with a high concentration of air tours.

The NTSB has noted previously in other accident investigations that the exclusive reliance on the see-and-avoid method of collision avoidance has serious inherent limitations and that CDTI alerts can assist pilots in scanning for airborne traffic. The assistance that CDTI alerts provide is particularly important in single-pilot operations conducted in high-traffic air tour areas, like many sightseeing flights. Therefore, the NTSB concludes that because of the high concentration of traffic in popular air tour areas, the risk of collision is higher than in the general NAS and technology that supplements pilots' traffic scans by providing aural and visual alerts can mitigate this risk.

ADS-B supported airborne traffic advisory systems can mitigate the risk of midair collision accidents; however, ADS-B Out is only required in certain airspace. In addition, there is currently no requirement for ADS-B In, which can provide pilots awareness of nearby traffic by displaying targets on the CDTI.

The NTSB has previously advocated for ADS-B In technology. In a letter dated February 14, 2008, in response to the FAA's notice of proposed rulemaking (NPRM) to require ADS-B Out, the NTSB expressed concern that the FAA did not plan to require ADS-B In capability because, according to the NPRM, it "has not been identified as a requirement for maintaining the safety and efficiency of NAS operations." The letter continued that the Board believed that this assessment was incorrect and that the equipage of aircraft with ADS-B In capability would provide an immediate and substantial contribution to safety, especially during operations in and around airports.

The FAA Modernization and Reform Act of 2012 required the FAA to identify the type of avionics required for all classes of airspace. It also specifically required the FAA to initiate rulemaking to require aircraft operating in capacity-constrained airspace, at capacity-constrained airports, or in "any other airspace deemed appropriate by the administrator" be equipped with ADS-B In technology by 2020. An aviation rulemaking committee chartered in April 2012 recommended that the FAA focus on the development of key ADS-B In applications, including airborne traffic awareness systems, that would provide benefits to operators. In 2014, the FAA developed a rulemaking action plan to issue a NPRM by 2018 and a final rule in 2022.

In 2014, an RTCA committee chartered by the FAA completed the development of standards for ADS-B-supported aircraft surveillance applications, DO-317B. As discussed in section 1.9.3, the DO-317B standard specifies, among other things, the type of aural annunciation that should accompany an ATAS traffic alert, as well as the color and shape of traffic symbols on the CDTI.

However, the FAA Reauthorization Act of 2018 repealed the requirement that the FAA initiate rulemaking to require ADS-B In technology and instead directed the FAA to ensure that any regulations resulting from that rulemaking had no effect.[69] Because the FAA had not yet issued any regulations, no action was required to change any regulations. As of the date of this report, conformity with the standards prescribed in DO-317B remains optional. Thus, the NTSB concludes that although existing ADS-B traffic alerting applications can help draw pilots' attention to conflicting traffic, these applications are currently not required.

One option available to the FAA is its authority to establish special federal aviation regulations (SFARs) for a finite period. The FAA has previously used this authority to establish SFAR 50 for air tour operations over the Grand Canyon and SFAR 71 for air tour operators in the state of Hawaii.[70] Both SFAR 50 and SFAR 71 imposed several important safety requirements, some of which had been recommended by the NTSB. According to a study conducted by researchers from the Johns Hopkins Bloomberg School of Public Health's Center for Injury Research and Policy, the implementation of SFAR 71 resulted in a 47% reduction in sightseeing

[69] Section 522 of the 2018 FAA Reauthorization Act titled, "Automatic Dependent Surveillance-Broadcast," states: "(a) REPEAL.—Subsection (b) of section 211 of the FAA Modernization and Reform Act of 2012 (49 U.S.C. 40101 note) is repealed; (b) REQUIREMENT.—The Administrator shall ensure that any regulation issued pursuant to such subsection has no force or effect."

[70] FAA established SFAR 50 in 1987 following a midair collision in 1986 between two air tour aircraft. SFAR 50 was amended to include additional specifications in 1988 and renamed SFAR 50-2. SFAR 50-2 created flight-free zones and specific flight corridors to accommodate air tour routes and general aviation flights. It also established minimum altitude restrictions on all types of flights, including air tours, general aviation, and high altitude commercial and military aircraft. The FAA established SFAR 71 in 1994 in response to multiple crashes of helicopter sightseeing tours in Hawaii that year. SFAR 71 established minimum flight altitudes and clearances from terrain, emphasized passenger safety precautions, mandated performance plans before each flight, and required flotation equipment or the wearing of life preservers on flights beyond the shoreline.

crashes in a 13-year period after SFAR 71 was implemented (Haaland et al 2009).[71] SFAR 71 was later permanently incorporated into 14 *CFR* Part 136, which contains national regulations specific to air tour operations.

In addition to establishing SFARs, the FAA has the authority to establish special flight rules areas (SFRAs). An SFRA comprises airspace with defined vertical and lateral dimensions for which the FAA has established special operational rules and restrictions under 14 *CFR* Part 93.

On August 8, 2009, a Eurocopter AS350 BA helicopter and a Piper PA-32R-300 airplane collided in flight over the Hudson River near Hoboken, New Jersey. As a result, on August 27, 2009, the NTSB issued Safety Recommendation A-09-84 to the FAA:

> Amend 14 *Code of Federal Regulations* Part 93 to establish a special flight rules area (SFRA) including the Hudson River class B exclusion area, the East River class B exclusion area, and the area surrounding Ellis Island and the Statue of Liberty; define operational procedures for use within the SFRA; and require that pilots complete specific training on the SFRA requirements before flight within the area.

In response, on November 19, 2009, the FAA published a final rule, "Modification of the New York, NY, Class B Airspace Area; and Establishment of the New York Class B Airspace Hudson River and East River Exclusion Special Flight Rules Area." Among other actions, it established an SFRA over the Hudson River and East River that mandated pilot operating practices within the Hudson River and East River class B airspace exclusion areas. The FAA also developed a training course for pilots who planned to fly in the SFRA to ensure that they were prepared to meet the required flight procedures. Because the FAA developed this training and made it readily available, the NTSB classified Safety Recommendation A-09-84 as "Closed—Acceptable Alternate Action."

The NTSB remains concerned that, without a requirement to install and use ADS-B-supported airborne traffic advisory systems, midair collisions will continue to occur, particularly in passenger-carrying flight operations conducted in high-traffic areas. The NTSB recognizes the effective use of this technology will require the installation of ADS-B Out and In, compatible CDTIs, and aural traffic alerting capabilities. The NTSB also notes that the aural alerting function must be capable of directing pilots' attention to converging aircraft in time to prevent a collision while also minimizing nuisance alerts. Therefore, the NTSB concludes that requiring ADS-B-supported airborne traffic advisory systems with aural alerting in high-traffic air tour areas, through an SFAR or other means, would mitigate the risk of midair collisions.

The NTSB believes that if the implementation of ADS-B-enabled aural alerts does not minimize nuisance alerts, pilots will be tempted to turn down the alert volume or otherwise ignore the alerts, negating the safety benefit of the system. As discussed in section 2.3, a pilot might have turned down the CDTI alert volume to avoid nuisance alerts in the 2007 midair collision of two

[71] The study compared accidents during the period from 1995 to 2008 as compared to the period from 1981 to 1994. For more information see Sightseeing Helicopter Crashes in Hawaii Decrease Following FAA Regulations - 2009 - News Releases - News - Johns Hopkins Bloomberg School of Public Health (jhsph.edu).

electronic news gathering helicopters in Phoenix, Arizona; the NTSB issued Safety Recommendation A-09-4 to address this concern. As a result, ADS-B ATAS was designed to minimize nuisance alerts.

Some examples of dense air tour traffic areas include Ketchikan, Alaska; Juneau, Alaska; Denali National Park; the Hawaiian Islands; the Grand Canyon; Las Vegas, Nevada; and New York City, New York. Therefore, the NTSB recommends that the FAA identify high-traffic air tour areas and require, through an SFAR or other means, that Parts 91 and 135 air tour operators that operate within those areas be equipped with an ADS-B Out- and In-supported traffic advisory system that 1) includes both visual and aural alerts, 2) is driven by an algorithm designed to minimize nuisance alerts, and 3) is operational during all flight operations.

Because some of these areas may involve operations conducted below radar coverage or outside the range of an ADS-B ground station, air tour aircraft equipped with ADS-B traffic advisory systems may not receive alerts for aircraft not equipped with ADS-B Out operating within the air tour area. As a result, it would be important that all aircraft operating within the air tour area be equipped with ADS-B Out. Therefore, the NTSB recommends that, in the high-traffic air tour areas identified in Safety Recommendation A-21-15, the FAA require that all non–air tour aircraft operating within the airspace be equipped with ADS-B Out.

2.5 Part 135 Operations

Although this accident occurred in a high-traffic air tour area, midair collisions can happen anywhere. On July 31, 2020, a De Havilland DHC-2 and a Piper PA-12 were involved in a midair collision in Soldotna, Alaska.[72] The accident resulted in seven fatalities (six on the DHC-2 and one on the PA-12) and destroyed both aircraft. The DHC-2 was being operated as a Part 135 on-demand charter flight, and the PA-12 was operating as a Part 91 personal flight. The DHC-2 had no traffic awareness equipment installed, but ADS-B Out and In were installed on the PA-12.

Although this accident is still under investigation at the time this report was published, a NTSB performance study concluded that if both aircraft had been equipped with ATAS-capable devices conforming to DO-371B standards, the PA-12 pilot would have received an alert 26 seconds before the collision and another alert 9 seconds before the collision. The DHC-2 pilot would have received an alert 26 seconds before the collision and another alert 19 seconds before the collision.

As described in section 2.2, FAA guidance indicates that 12.5 seconds is the minimum time for a pilot to visually acquire another aircraft, judge a collision course, and take evasive action. Therefore, it is likely the pilots of both aircraft could have maneuvered to avoid the collision if their aircraft were equipped with ATAS-capable devices conforming to DO-371B standards, and these devices were operational.

The FAA recognized the differences between Part 91, Part 121, and Part 135 operations from the perspective of a passenger in the agency's NPRM for fractional aircraft ownership. In the

[72] More information about this accident, NTSB case number ANC20LA074, is available by using the NTSB's CAROL Query Tool.

NPRM, the FAA stated that aircraft owners flying aboard aircraft that they own or lease "exercise full control over and bear full responsibility for the airworthiness and operation of their aircraft." In contrast, the FAA stated that passengers who are transported under Parts 121 and 135 "exercise no control over and bear no responsibility for the airworthiness or operation of the aircraft aboard which they are flown" (NARA 2001). As a result, the FAA concluded that the "appropriate level of public safety is provided by…very stringent regulations and oversight under Part 121 and Part 135."

However, the NTSB believes the lack of a requirement for ADS-B In-based traffic awareness displays for all aircraft conducting Part 135 operations fails to take advantage of the demonstrated benefit of this technology in mitigating the midair collision hazard. In addition, aircraft without ADS-B do not demonstrate the "appropriate level of safety" for passenger-carrying operations conducted under Part 135 regulations. Therefore, the NTSB recommends that the FAA require the installation of ADS-B Out- and In-supported airborne traffic advisory systems that include aural and visual alerting functions in all aircraft conducting operations under Part 135.

2.6 System Limitations

Although both accident aircraft had CDTIs installed, limitations in these systems disabled their aural and visual alerting functions, and neither pilot was alerted to conflicting traffic. As will be presented in sections 2.6.1 and 2.6.3, if the ADS-B-supported airborne traffic advisory systems had been working as intended in both accident aircraft, the resulting aural traffic alerts in each airplane would have occurred early enough for the pilots to have taken action to prevent the collision.

2.6.1 DHC-2 Lack of Alerting

The DHC-2 pilot's CDTI likely would have shown the DHC-3 as a filled cyan arrowhead on a course that would intersect the DHC-2's flightpath. However, because the DHC-3 was not broadcasting pressure altitude data over its ADS-B data link (because the Garmin GSL 71 control head had been turned off), the DHC-2 pilot would not have received any visual or aural alerts (or relative altitude information) regarding the DHC-3.

The ForeFlight application requires altitude data to determine whether a particular traffic target's relative altitude is within 1,200 ft of the ownship (and a potential collision threat, depending on its horizontal proximity), or more than 3,500 ft above or below the ownship (and consequently "distant"). If the target's altitude data are not available, the application cannot determine the target's relative altitude from the ownship and treats the target as distant. Consequently, with the "Hide Distant Traffic" feature enabled, targets without altitude information do not appear on the ForeFlight application at all. With the feature turned off, the targets are displayed on the moving map without relative altitude information, but they are never determined to be within 1,200 ft vertically and consequently will never trigger an alert. The pilot's tablet was destroyed during the accident; therefore, no information was available regarding whether the pilot was using it or how the ForeFlight application was configured. Information recorded on the pilot's online ForeFlight account also did not contain any relevant information about the application's settings.

Therefore, the NTSB concludes that the manner in which the ForeFlight application currently handles missing altitude data from traffic targets precludes the application from providing visual and aural alerts concerning these targets and, in certain configurations of the application, removes the targets from the moving map entirely, which degrades the ability of the application to call attention to potential collision threats. Therefore, the NTSB recommends that ForeFlight update its traffic alerting algorithms so that traffic targets for which there is no altitude information are assumed to be at the same altitude as the ownship (that is, the aircraft receiving the target data).

2.6.2 DHC-3 Failure to Broadcast Pressure Altitude

As mentioned in section 1.9.1, the DHC-3 was not broadcasting pressure altitude because the Garmin GSL 71 control head selector knob was in the OFF position. In a postaccident interview, the DHC-3 pilot stated that he was not aware the GSL 71 was off and he did not touch it during the accident flight. He stated that if everything was functional on the display, there was no need to manipulate the GSL 71 control head, and the display appeared functional to him during the accident flight. He could see other airplanes depicted on the display, and no other pilots told him that they could not see his aircraft on their displays. Interviews with company personnel also revealed a lack of understanding regarding the role of the GSL 71 in broadcasting pressure altitude. The last time the DHC-3 transmitted pressure altitude data was during a flight on April 29, 2019; following the flight, the airplane underwent a monthly maintenance inspection, and no pressure altitude was obtained from subsequent flights. The investigation was unable to determine who turned off the GSL 71.[73]

According to FreeFlight Systems, the altitude source for the Garmin GSL 71 could be either the pitot static system or an altitude encoder. According to its supplemental type certificate (STC), which outlines the installation of the Garmin GSL 71, hard-wiring the pressure altitude source from the altitude encoder to the RANGR 978 transceiver is not prohibited even if a Garmin GSL 71 control panel is installed.[74] Thus, the NTSB concludes that because the Garmin GSL 71 can be manually turned off without any obvious indication on the Chelton display that pressure altitude is not being reported with the ADS-B data, there is a potential for the GSL 71 to be inadvertently left in the OFF position, which can lead to other pilots not receiving appropriate visual and aural alerts of traffic. As a result, the NTSB recommends that the FAA review current and future STC installation instructions and flight manual supplements to ensure they provide provisions to prevent the inadvertent disabling of the broadcast of pressure altitude data, by design, where practicable.

2.6.3 DHC-3 Lack of Alerting

The algorithm the RANGR 978 transceiver used to process ADS-B traffic data did not include (and was not required to include) criteria to determine if a given traffic target posed a collision threat. Therefore, none of the traffic messages sent by the RANGR 978 transceiver to the

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[73] As described in section 1.5.2, 14 *CFR* Part 91.225 states that each person operating an aircraft equipped with ADS-B Out must use transmit mode at all times.

[74] "Hard-wiring" means creating a switchless, direct electrical connection that cannot be interrupted.

Chelton EFIS would have been in an "alert status" or would have been able to generate aural and visual alerts. For this reason, the DHC-2 would have appeared on the DHC-3's Chelton EFIS screen as a filled cyan arrowhead (a proximate target) but never would have changed to a filled yellow arrowhead (alert status) or generated a "traffic, traffic" aural alert if a collision threat were imminent.

Because the Chelton EFIS pre-dates DO-317B, the aural alerts provided by the Chelton EFIS (when available) consist of a "traffic, traffic" alert, but no additional information is provided as specified in DO 317B (for example, bearing, range, and relative altitude). Conversely, if a DO-317B-compliant CDTI had been installed in the DHC-3, the DHC-2 target display would have changed from a filled cyan arrowhead (proximate target) to filled yellow arrowhead with a circle around it (alert status). In addition, an aural alert would have been generated 37.4 seconds before the collision indicating bearing, relative altitude, and range from the target. Seven seconds later, a second aural alert ("traffic, 10 o'clock, same altitude, less than one mile") would have sounded.

The ADS-B components originally installed in the DHC-3 in 2005 were installed as part of phase 2 of the Capstone Program, funded by the FAA. In 2012, the FAA decided to upgrade the ADS-B components in participating Capstone Program aircraft to comply with ADS-B Out performance requirements (as defined in 14 *CFR* 91.227 and TSO-C154c), which included specific elements for traffic messages that must be broadcast. No alerting function was required. As a result, the Garmin GDL-90 transceiver originally installed in the DHC-3 was replaced with the RANGR 978 transceiver, which did not maintain the traffic alerting function provided by the originally installed transceiver.

According to the FAA, the upgraded ADS-B components were required to comply with the specifications contained in DO-317A and TSO-C195a, which were in effect at the time, but neither required a conflict detection application. However, without such an application, targets cannot be placed in an alert status or generate aural and visual alerts on the Chelton EFIS. Therefore, the NTSB concludes that the combination of ADS-B components in the de Havilland DHC-3 did not have the same conflict detection capability that was present in systems installed as part of the Capstone Program, which provided visual and aural alerting; this reduction in capability was a result of the FAA's upgrade of ADS-B equipment for aircraft participating in the Capstone Program with components that did not maintain the existing alerting functions.

The NTSB is concerned additional aircraft that transitioned from the equipment used during the Capstone Program to ADS-B components like those in the DHC-3 could still be in operation. However, we believe that if the FAA acts on our recommendation to require the installation of ADS-B Out and In-supported airborne traffic advisory systems that include aural and visual alerting functions in all aircraft operating under Part 135 regulations (Safety Recommendation A-21-17), any remaining aircraft from the Capstone Program operating without aural alerting will be identified and updated.

2.7 Organizational Issues

The checklist found in the DHC-3 did not contain a checklist item to ensure that the GSL 71 control head selector knob was in the ON position before takeoff, which is required to transmit pressure altitude. When the DHC-3 pilot was asked whether the GSL 71 control head selector knob was included in his personal flow of checks before takeoff, he said that it was not part of his typical flow. He also stated that if the ADS-B system appeared to be operating, he did not need to manipulate the control head selector knob.

As stated by Taquan Air's director of operations, pilots do not normally need to manipulate the control head selector knob, and the accident pilot noted the absence of any obvious effect on the airplane's ADS-B components when the knob was in the OFF position. Therefore, it was highly likely that, if the knob was placed in the OFF position during maintenance (or for some other reason), it would remain in that position indefinitely, resulting in no pressure altitude data being transmitted. The resulting absence of pressure altitude data would thus impair the ability of other airplanes' traffic alerting systems to provide traffic alerts. The NTSB concludes that a procedural safeguard, such as a checklist item that addresses the position of the Garmin GSL 71 control head selector knob, can mitigate the hazard of the selector knob being inadvertently and indefinitely placed in the OFF position. As a result, the NTSB recommends that Taquan Air revise the checklists for its fleet of aircraft to ensure they include verification that the Garmin GSL 71 control head selector knob is in the ON position and that the unit is in ALT mode before takeoff.

As discussed in section 2.6.3, the NTSB is concerned that there may be additional legacy Capstone Program aircraft operating with the same combination of avionics as the DHC-3 and that these aircraft could operate without broadcasting pressure altitude if the GSL 71 is inadvertently turned off. Therefore, the NTSB recommends that the FAA ensure that checklists for all Capstone Program (phase 2) aircraft include verification that the Garmin GSL 71 control head selector knob is in the ON position and that the unit is in ALT mode before takeoff.

2.8 Resources Available to Pilots

As detailed throughout this report, the circumstances of this accident highlight the limitations of the see-and-avoid concept and the importance of combining an effective visual scan with CDTIs in the cockpit. The FAA has published guidance in the *AIM* and in the *Pilot's Handbook of Aeronautical Knowledge* on the topic. Guidance contained in *AIM* section 4-4-14, "Visual Separation," states, in part:

> Scanning the sky for other aircraft is a key factor in collision avoidance. Pilots and copilots (or the right seat passenger) should continuously scan to cover all areas of the sky visible from the cockpit. Pilots must develop an effective scanning technique which maximizes one's visual capabilities. Spotting a potential collision threat increases directly as more time is spent looking outside the aircraft. One must use timesharing techniques to effectively scan the surrounding airspace while monitoring instruments as well.

The *Pilot's Handbook of Aeronautical Knowledge* states, in part, that pilots should be constantly alert to all traffic movement within their field of vision and should periodically scan the entire visual field outside their aircraft.

However, neither the *AIM* nor the *Pilot's Handbook of Aeronautical Knowledge* specifically address the limitations of human visual monitoring, the benefits of incorporating CDTIs in a pilot's traffic scan, or how to strategically use this information to minimize the risk of a collision. Although the DHC-3 pilot recalled looking at his CDTI during the flight, the last time he looked at it was about 4 minutes before the collision. As discussed in section 2.6.3, if the CDTI had produced an alert, the pilot might have become aware of the impending collision and had an opportunity to maneuver the airplane and avoid the collision.

As demonstrated in this accident, the presence of a CDTI in the cockpit does not by itself guarantee the effectiveness of the technology. Pilots must also be familiar with the functions and limitations of the system. Pilots should know whether their equipment includes a conflict alerting feature and, if so, what types of alerts will be given under different scenarios. Because of the variety of CDTIs available and the different capabilities of these systems, pilots might not be aware of the aural or visual information their system can provide. Understanding the potential differences between CDTIs is particularly important for pilots who fly multiple aircraft with different systems.

The NTSB concludes that increasing pilots' awareness of the inherent limitations of the see-and-avoid collision avoidance concept and the benefits of CDTIs with traffic alerting can mitigate the risk of midair collisions. Therefore, the NTSB recommends that the FAA update the *AIM* and the *Pilot's Handbook of Aeronautical Knowledge* to include the limitations inherent in visual scans for traffic and the benefits and best practices of using CDTIs to supplement visual scans to help overcome these limitations.

The NTSB recognizes that updating FAA publications can take time. In the meantime, there are numerous aviation industry groups that can quickly and effectively disseminate information to their members and encourage operators to make safety changes that will prevent future midair collisions from occurring. Therefore, the NTSB recommends that aviation industry groups (Aircraft Owners and Pilots Association, Experimental Aircraft Association, National Business Aviation Association, Tour Operators Program of Safety, Tongass Aircraft Pilots Association, and Helicopter Association International) inform their members about the circumstances of this accident and encourage them to take the following actions: (1) become familiar with the traffic display equipment installed in their aircraft; (2) if their equipment does not provide an aural alert concerning proximate targets that might pose a collision threat, encourage pilots/operators to supplement the equipment with devices that provide both an aural and visual alert; and (3) remind pilots to include the traffic display when scanning for traffic through the aircraft's windows.

Additionally, the NTSB recommends that the National Association of Flight Instructors and the Society of Aviation and Flight Educators inform their members of the circumstances of this accident and incorporate instruction on including the traffic display when scanning for traffic through an aircraft's windows in both initial and recurrent pilot training.

2.9 Safety Management Systems

The NTSB has long advocated for the implementation of SMS in Part 135 operations, having issued our first safety recommendation (which applied to helicopter air ambulance operations) in 2009.[75] On February 21, 2014, the FAA published a final rule titled "Helicopter Air

[75] Safety Recommendation A-09-89, issued September 24, 2009, recommended that the FAA require SMS for helicopter air ambulance operations.

Ambulance, Commercial Helicopter, and Part 91 Helicopter Operations." Although the final rule required helicopter air ambulance operators to implement additional tools and procedures that the FAA believed contained elements of an effective SMS program, the rule did not require the complete SMS program that the NTSB recommended. Consequently, Safety Recommendation A-09-89 was classified "Closed—Unacceptable Action."

In 2016, the NTSB issued Safety Recommendation A-16-36 to the FAA to require all Part 135 operators to implement an SMS (NTSB 2016). This recommendation is on the NTSB's current Most Wanted List of Transportation Safety Improvements under the issue area, "Require and Verify the Effectiveness of Safety Management Systems in all Revenue Passenger-Carrying Aviation Operations." In a response dated January 9, 2017, the FAA noted that Part 135 operators could participate in its voluntary SMS program. The FAA also stated its intention to conduct a review and hold meetings to determine if further action was needed on SMS for Part 135 operators. The FAA's SMS Voluntary Program included provisions by which a Part 135 operator could apply for FAA recognition of its SMS and receive FAA assistance with implementing and validating it. An SMS developed within the FAA's SMS Voluntary Program would also be subject to ongoing FAA oversight and compliance monitoring to ensure conformance with safety policy, safety risk management, safety assurance, and safety promotion functions, which operators were expected to fully implement.

The FAA did not respond again for 3 years until April 13, 2020, when it said it was still evaluating the feasibility of rulemaking to require SMS for Part 135 operators. Given the delays experienced by this and several other rulemaking projects addressing NTSB recommendations, as well as the impact of Executive Orders 13771 and 13777 (requiring the removal of two regulations for every new regulation implemented), the FAA stated that it was considering potential alternate courses of action to address this recommendation (both executive orders were revoked on January 20, 2021, by Executive Order 13992).[76] Because the FAA had not taken any further action to satisfy it, the NTSB classified Safety Recommendation A-16-36 as "Open—Unacceptable Response" on June 8, 2020.

In the 4 years since the FAA's initial response, we have reiterated Safety Recommendation A-16-36 five times based on our findings from investigations of other fatal Part 135 operator accidents (NTSB 2017, 2018, 2019, 2020, and 2021). On October 27, 2020, during a speech at the FAA's Rotorcraft Safety Conference, the FAA administrator said the FAA was hoping to publish a proposed SMS rule in 2022 that will apply to "air taxis," "air tour operators," and other types of operators (FAA 2020). We are also aware that the Office of Management and Budget's Fall 2020 Unified Agenda of Regulatory and Deregulatory Actions (published December 9, 2020) listed the

[76] Executive Order 13771, published on February 3, 2017, requires any executive department or agency that plans to publicly announce a new regulation to propose at least two regulations that will in turn be repealed. Executive Order 13777, published March 1, 2017, requires: (1) each agency head to designate a regulatory reform officer responsible for overseeing the implementation of regulatory reform initiatives and policies; (2) each agency to establish a Regulatory Reform Task Force to evaluate existing regulations and make recommendations to the agency head regarding regulations to repeal, replace, or modify; and (3) each agency listed in 31 US Code paragraph 901(b)(1) to incorporate into its Annual Performance Plan performance indicators to measure progress toward achieving regulatory reform initiatives and policies and identifying regulations to repeal, replace, or modify.

FAA's "Safety Management System (SMS) for Parts 21, 91, 135, and 145," as a "long-term action" item (OMB 2020).[77]

We note that, although the FAA has promoted Part 135 operators' participation in its SMS Voluntary Program in advance of any potential rulemaking, the participation level has been low. A review of FAA data showed that, of the 1,940 certificate holders currently authorized to conduct Part 135 operations, only 20 have an FAA-accepted SMS; 149 others, whose SMS programs are in various stages of development, have applied for FAA acceptance.[78] The NTSB is encouraged by the FAA's reported intent for rulemaking, but until the FAA requires SMS for Part 135 operators, Safety Recommendation A-16-36 remains classified "Open—Unacceptable Response."

One of the components of SMS is safety risk management. According to AC 120-92B, part of safety risk management includes performing a system analysis when a new system, system change, or new operational procedure is introduced. The system analysis is designed to identify hazards and implement control measures to mitigate those hazards. According to the director of operations at Taquan Air, he was not aware that the Chelton EFIS traffic alerting capability was lost when the equipment was upgraded to a RANGR 978 transceiver as part of the post-Capstone upgrade program. However, a review of the flight manual supplement for the RANGR 978 transceiver indicated that it did not support traffic alerting.

Although Taquan Air implemented an SMS after the accident, it did not have one at the time. If it did, it is possible that a system analysis of the new equipment would have identified the loss of the traffic alerting capability in the flight manual supplement. If this change had been identified, the company could have evaluated the potential increase in risk associated with the removal of this safety protection and considered strategies for mitigating the increased risk of a midair collision introduced by this change.

Additionally, a system analysis could have identified the potential for broadcasting incomplete ADS-B information with the GSL 71 turned off. This realization could have prompted the implementation of design, training, or procedural safeguards (such as a checklist item) to protect against broadcasting incomplete location information before an accident occurred. Thus, the NTSB concludes that if Taquan Air had been required to have an SMS at the time of the accident, the activities required by the safety risk management element would have provided better opportunities for Taquan Air to discover and mitigate the increased risk of airborne collision posed by changes to the Capstone-affiliated avionics installed in its aircraft, which provides another example of the value of SMS for all Part 135 operators. Therefore, the NTSB reiterates Safety Recommendation A-16-36.

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[77] A long-term action is an item that an agency has under development but does not expect to have a regulatory action for it within 12 months. The Unified Agenda of Regulatory and Deregulatory Actions lists long-term actions separately from active rulemakings, which are in either the prerule, proposed rule, or final rule stage (RISC 2020).

[78] These FAA data were current as of April 1, 2021.

3. Conclusions

3.1 Findings

1. None of the following safety issues were identified for the accident flight: (1) pilot qualification deficiencies; (2) pilot impairment; or (3) a malfunction or failure on either airplane.

2. The circumstances of this accident underscore the inherent limitations of the see-and-avoid collision avoidance concept, including how collision geometry, obscuration by aircraft structures, and limitations of human performance can make it difficult to see nearby aircraft.

3. Aural and visual alerts that draw the pilots' attention to conflicting traffic presented on the cockpit display of traffic information can greatly increase the pilots' awareness of potentially conflicting traffic and avoid a collision.

4. Because of the high concentration of traffic in popular air tour areas, the risk of collision is higher than in the general National Airspace System and technology that supplements pilots' traffic scans by providing aural and visual alerts can mitigate this risk.

5. Although existing automatic dependent surveillance-broadcast traffic alerting applications can help draw pilots' attention to conflicting traffic, these applications are currently not required.

6. Requiring automatic dependent surveillance-broadcast–supported airborne traffic advisory systems with aural alerting in high-traffic air tour areas, through a special federal aviation regulation or other means, would mitigate the risk of midair collisions.

7. The manner in which the ForeFlight application currently handles missing altitude data from traffic targets precludes the application from providing visual and aural alerts concerning these targets and, in certain configurations of the application, removes the targets from the moving map entirely, which degrades the ability of the application to call attention to potential collision threats.

8. Because the Garmin GSL 71 can be manually turned off without any obvious indication on the Chelton display that pressure altitude is not being reported with the automatic dependent surveillance-broadcast data, there is a potential for the GSL 71 to be inadvertently left in the OFF position, which can lead to other pilots not receiving appropriate visual and aural alerts of traffic.

9. The combination of automatic dependent surveillance-broadcast (ADS-B) components in the de Havilland DHC-3 did not have the same conflict detection capability that was present in systems installed as part of the Capstone Program, which provided visual and aural alerting; this reduction in capability was a result of the Federal Aviation

Administration's upgrade of ADS-B equipment for aircraft participating in the Capstone Program with components that did not maintain the existing alerting functions.

10. A procedural safeguard, such as a checklist item that addresses the position of the Garmin GSL 71 control head selector knob, can mitigate the hazard of the selector knob being inadvertently and indefinitely placed in the OFF position.

11. Increasing pilots' awareness of the inherent limitations of the see-and-avoid collision avoidance concept and the benefits of cockpit displays of traffic information with traffic alerting can mitigate the risk of midair collisions.

12. If Taquan Air had been required to have a safety management system (SMS) at the time of the accident, the activities required by the safety risk management element would have provided better opportunities for Taquan Air to discover and mitigate the increased risk of airborne collision posed by changes to the Capstone-affiliated avionics installed in its aircraft, which provides another example of the value of SMS for all Title 14 *Code of Federal Regulations* Part 135 operators.

3.2 Probable Cause

The NTSB determines that the probable cause of this accident was the inherent limitations of the see-and-avoid concept, which prevented the two pilots from seeing the other airplane before the collision, and the absence of visual and aural alerts from both airplanes' traffic display systems, while operating in a geographic area with a high concentration of air tour activity. Contributing to the accident were (1) the Federal Aviation Administration's provision of new transceivers that lacked alerting capability to Capstone Program operators without adequately mitigating the increased risk associated with the consequent loss of the previously available alerting capability and (2) the absence of a requirement for airborne traffic advisory systems with aural alerting among operators who carry passengers for hire.

4. Recommendations

4.1 New Recommendations

To the Federal Aviation Administration:

Identify high-traffic air tour areas and require, through a special federal aviation regulation or other means, that Title 14 *Code of Federal Regulations* Parts 91 and 135 air tour operators that operate within those areas be equipped with an Automatic Dependent Surveillance-Broadcast Out- and In-supported traffic advisory system that 1) includes both visual and aural alerts, 2) is driven by an algorithm designed to minimize nuisance alerts, and 3) is operational during all flight operations. (A-21-15)

In the high-traffic air tour areas identified in Safety Recommendation A-21-15, require that all non–air tour aircraft operating within the airspace be equipped with Automatic Dependent Surveillance-Broadcast Out. (A-21-16)

Require the installation of Automatic Dependent Surveillance-Broadcast Out- and In-supported airborne traffic advisory systems that include aural and visual alerting functions in all aircraft conducting operations under Title 14 *Code of Federal Regulations* Part 135. (A-21-17)

Review current and future supplemental type certificate installation instructions and flight manual supplements to ensure they provide provisions to prevent the inadvertent disabling of the broadcast of pressure altitude data, by design, where practicable. (A-21-18)

Ensure that checklists for all Capstone Program (phase 2) aircraft include verification that the Garmin GSL 71 control head selector knob is in the ON position and that the unit is in ALT mode before takeoff. (A-21-19)

Update the *Aeronautical Information Manual* and the *Pilot's Handbook of Aeronautical Knowledge* to include the limitations inherent in visual scans for traffic and the benefits and best practices of using cockpit displays of traffic information to supplement visual scans to help overcome these limitations. (A-21-20)

To ForeFlight:

Update your traffic alerting algorithms so that traffic targets for which there is no altitude information are assumed to be at the same altitude as the ownship (that is, the aircraft receiving the target data). (A-21-21)

To Taquan Air:

Revise the checklists for your fleet of aircraft to ensure they include verification that the Garmin GSL 71 control head selector knob is in the ON position and that the unit is in ALT mode before takeoff. (A-21-22)

To aviation industry groups (Aircraft Owners and Pilots Association, Experimental Aircraft Association, National Business Aviation Association, Tour Operators Program of Safety, Tongass Aircraft Pilots Association, and Helicopter Association International):

Inform your members about the circumstances of this accident and encourage them to take the following actions: (1) become familiar with the traffic display equipment installed in their aircraft; (2) if their equipment does not provide an aural alert concerning proximate targets that might pose a collision threat, encourage pilots/operators to supplement the equipment with devices that provide both an aural and visual alert; and (3) remind pilots to include the traffic display when scanning for traffic through the aircraft's windows. (A-21-23)

To the National Association of Flight Instructors and the Society of Aviation and Flight Educators:

Inform your members of the circumstances of this accident and incorporate instruction on including the traffic display when scanning for traffic through an aircraft's windows in both initial and recurrent pilot training. (A-21-24)

4.2 Previously Issued Recommendation Reiterated in This Report

The National Transportation Safety Board reiterates the following safety recommendation.

To the Federal Aviation Administration:

Require all 14 *Code of Federal Regulations* Part 135 operators to establish safety management system programs. (A-16-36)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

ROBERT L. SUMWALT
Chairman

JENNIFER HOMENDY
Member

BRUCE LANDSBERG
Vice Chairman

MICHAEL GRAHAM
Member

THOMAS B. CHAPMAN
Member

Report Date: April 20, 2021

Board Member Statement

Member Chapman filed the following concurring statement on April 27, 2021.

I concur and join in the Board's unanimous adoption of the accident report.

I write separately to offer my perspective on a relevant legislative provision discussed within the body of the accident report and mentioned during the Board meeting. The report notes that language in the FAA Reauthorization Act of 2018 repealed earlier legislation passed in 2012. The 2012 legislation had directed FAA to initiate rulemaking (which FAA never did) to issue guidelines and regulations relating to ADS-B "In" technology. The repeal language appears as Section 522 of the FAA Reauthorization Act of 2018.[1]

The issue is the possibility Section 522 might be interpreted as limiting FAA's authority to engage in rulemaking related to ADS-B "In." That concern arises because Section 522 directs FAA to ensure that any regulation issued pursuant to the repealed 2012 legislative mandate has no force or effect.

I do not believe Section 522 should be interpreted as limiting FAA's rulemaking authority. I read Section 522 as simply repealing the previous mandate for FAA to adopt ADS-B "In" regulations. This was an area where there were already significant challenges at the time the 2018 legislation was negotiated and passed. FAA was appropriately focused on implementing its pending regulatory ADS-B "Out" requirement. As for the language of Section 522 regarding "no force and effect" of regulations issued pursuant to the earlier 2012 ADS-B "In" directive, that legislative language seems to be superfluous. There were no such regulations in existence because FAA had failed to initiate an ADS-B "In" rulemaking.

I was among the core group of congressional staff tasked with helping to negotiate the FAA Reauthorization Act of 2018. I can recall no significant discussion of Section 522 during the House & Senate staff negotiations on the final bill. I believe it was considered a relatively non-controversial provision. It was not seen as tying FAA's hands or limiting the agency's discretion to regulate. I suspect negotiation on this point would have been lively had congressional staff believed Section 522 would establish a limitation on rulemaking. Congressional staff are typically

[1] ***SEC. 522. AUTOMATIC DEPENDENT SURVEILLANCE-BROADCAST.***

(a) REPEAL.—Subsection (b) of section 211 of the FAA Modernization and Reform Act of 2012 (49 U.S.C. 40101 note) is repealed.

(b) REQUIREMENT.—The Administrator shall ensure that any regulation issued pursuant to such subsection has no force or effect.

wary of putting their bosses in a position of limiting the ability of a safety agency such as FAA to exercise its regulatory authority.[2]

Our report recommends that FAA should require ADS-B supported traffic advisory systems and aural alerting in high traffic air tour areas. The report and the associated recommendations include references to FAA's authority to establish "special federal aviation regulations" and "special flight rules areas." These alternatives are suggested as possible mechanisms allowing FAA to require ADS-B "In" capability for air tour operators in high-traffic air tour areas. While I agree they are among the tools available to FAA, these are, in fact, rulemaking mechanisms. They probably do not represent a path for circumventing a possible interpretation of Section 522 as limiting FAA's rulemaking authority. Further, these are typically site specific mechanisms which often involve a time consuming and cumbersome process. In part, that is because there is inevitably some degree of local controversy.

Rather than requiring ADS-B on a site specific basis in certain designated *airspace*, I suggest a better approach is to require ADS-B for all those conducting certain specified types of *operations*—in this case, commercial air tours. For example, ADS-B capability could be required by including a regulatory mandate in Part 136 of the FAA regulations, which applies to all air tour operators. Likewise, a broad requirement applicable to *all* Part 135 operators (as is also recommended in our report) would necessarily apply to all those conducting commercial air tours under Part 135—comprising the substantial majority of air tour operators.

I hope FAA will take expedited action to implement the recommendations in this report. My former colleagues on the congressional staff should monitor the possibility that Section 522 might be interpreted as limiting FAA's authority to engage in rulemaking related to ADS-B "In." Congress should consider passing legislation to clarify the meaning of Section 522 if such an interpretation prevails.

[2] I spoke with several of my former Capitol Hill colleagues who were involved in the staff negotiations to complete work on the final version of the 2018 FAA Reauthorization. Those with whom I spoke agree that Section 522 was considered a relatively non-controversial provision. None saw it as a limit on the agency's discretion to regulate.

5. Appendixes

Appendix A: Investigation

The National Transportation Safety Board (NTSB) was notified of this accident on May 13, 2019, and members of the investigative team arrived on scene the following day. Member Jennifer Homendy accompanied the team.

Investigative groups were formed to evaluate operations, human performance, airworthiness, and systems.

The Federal Aviation Administration, Venture Travel LLC (dba as Taquan Air), FreeFlight Systems, and Genesys Aerosystems were parties to the investigation. In accordance with the provisions of Annex 13 to the Convention on International Civil Aviation, the Transportation Safety Board (TSB) of Canada served as an accredited representative to the investigation representing the state of manufacture of both airplanes. Viking Air Ltd. participated as a technical advisor to the TSB.

Appendix B: Consolidated Recommendation Information

Title 49 *United States Code* 1117(b) requires the following information on the recommendations in this report.

For each recommendation—

(1) a brief summary of the Board's collection and analysis of the specific accident investigation information most relevant to the recommendation;

(2) a description of the Board's use of external information, including studies, reports, and experts, other than the findings of a specific accident investigation, if any were used to inform or support the recommendation, including a brief summary of the specific safety benefits and other effects identified by each study, report, or expert; and

(3) a brief summary of any examples of actions taken by regulated entities before the publication of the safety recommendation, to the extent such actions are known to the Board, that were consistent with the recommendation.

To the Federal Aviation Administration:

A-21-15

Identify high-traffic air tour areas and require, through a special federal aviation regulation or other means, that Title 14 *Code of Federal Regulations* Parts 91 and 135 air tour operators that operate within those areas be equipped with an Automatic Dependent Surveillance-Broadcast Out- and In-supported traffic advisory system that 1) includes both visual and aural alerts, 2) is driven by an algorithm designed to minimize nuisance alerts, and 3) is operational during all flight operations.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.4, Traffic Alerting in High-Traffic Tour Areas. Information supporting (b)(1) can be found on pages 40–43; (b)(2) is not applicable; and (b)(3) can be found on pages 40–43.

A-21-16

In the high-traffic air tour areas identified in Safety Recommendation A-21-15, require that all non–air tour aircraft operating within the airspace be equipped with Automatic Dependent Surveillance-Broadcast Out.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.4, Traffic Alerting in High-Traffic Tour Areas. Information supporting (b)(1) can be found on page 43; (b)(2) is not applicable; and (b)(3) can be found on page 43.

A-21-17

> Require the installation of Automatic Dependent Surveillance-Broadcast Out- and In-supported airborne traffic advisory systems that include aural and visual alerting functions in all aircraft conducting operations under Title 14 *Code of Federal Regulations* Part 135.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.5, Part 135 Operations. Information supporting (b)(1) can be found on page 44; (b)(2) is not applicable; and (b)(3) can be found on page 44.

A-21-18

> Review current and future supplemental type certificate installation instructions and flight manual supplements to ensure they provide provisions to prevent the inadvertent disabling of the broadcast of pressure altitude data, by design, where practicable.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.6.2, DHC-3 Failure to Broadcast Pressure Altitude. Information supporting (b)(1) can be found on pages 45–46; (b)(2) is not applicable; and (b)(3) can be found on pages 45–46.

A-21-19

> Ensure that checklists for all Capstone Program (phase 2) aircraft include verification that the Garmin GSL 71 control head selector knob is in the ON position and that the unit is in ALT mode before takeoff.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.7, Organizational Issues. Information supporting (b)(1) can be found on pages 46–47; (b)(2) is not applicable; and (b)(3) can be found on pages 46–47.

A-21-20

> Update the *Aeronautical Information Manual* and the *Pilot's Handbook of Aeronautical Knowledge* to include the limitations inherent in visual scans for traffic and the benefits and best practices of using cockpit displays of traffic information to supplement visual scans to help overcome these limitations.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.8, Resources Available to Pilots. Information supporting (b)(1) can be found on pages 47–48; (b)(2) is not applicable; and (b)(3) can be found on pages 47–48.

To ForeFlight:

A-21-21

> Update your traffic alerting algorithms so that traffic targets for which there is no altitude information are assumed to be at the same altitude as the ownship (that is, the aircraft receiving the target data).

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.6.1, DHC-2 Lack of Alerting. Information supporting (b)(1) can be found on page 44; (b)(2) is not applicable; and (b)(3) can be found on page 44.

To Taquan Air:

A-21-22

> Revise the checklists for your fleet of aircraft to ensure they include verification that the Garmin GSL 71 control head selector knob is in the ON position and that the unit is in ALT mode before takeoff.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.7, Organizational Issues. Information supporting (b)(1) can be found on pages 46–47; (b)(2) is not applicable; and (b)(3) can be found on pages 46–47.

To aviation industry groups (Aircraft Owners and Pilots Association, Experimental Aircraft Association, National Business Aviation Association, Tour Operators Program of Safety, Tongass Aircraft Pilots Association, and Helicopter Association International):

A-21-23

> Inform your members about the circumstances of this accident and encourage them to take the following actions: (1) become familiar with the traffic display equipment installed in their aircraft; (2) if their equipment does not provide an aural alert concerning proximate targets that might pose a collision threat, encourage pilots/operators to supplement the equipment with devices that provide both an aural and visual alert; and (3) remind pilots to include the traffic display when scanning for traffic through the aircraft's windows.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.8, Resources Available to Pilots. Information supporting (b)(1) can be found on pages 47–48; (b)(2) is not applicable; and (b)(3) is not applicable.

To the National Association of Flight Instructors and the Society of Aviation and Flight Educators:

A-21-24

> Inform your members of the circumstances of this accident and incorporate instruction on including the traffic display when scanning for traffic through an aircraft's windows in both initial and recurrent pilot training.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.8, Resources Available to Pilots. Information supporting (b)(1) can be found on pages 47–48; (b)(2) is not applicable; and (b)(3) is not applicable.

Appendix C: Comparison of ADS-B Equipment Installed in the DHC-2 and DHC-3

	DHC-2	DHC-3 Before UAT Update	DHC-3 After UAT Update
ADS-B Equipment	FreeFlight RANGR 978 UAT ADS-B TC-978 Controller (interface between pilot and ADS-B UAT) WiFI Controller (Allowed Wi-Fi connection to iPad)	Garmin GDL-90 UAT ADS-B Garmin GSL 71 UAT control panel (interface between pilot and ADS-B UAT)	FreeFlight RANGR 978 UAT ADS-B Garmin GSL 71 UAT control panel (Must be on and in ALT mode to provide pressure altitude to the RANGR 978 UAT)
Cockpit Display of Traffic Information (CDTI)	iPad using ForeFlight app to display traffic	Chelton FlightLogic EFIS 2000 MFD with moving map	Chelton FlightLogic EFIS 2000 MFD with moving map
Alerting Capabilities	The ForeFlight app could generate visual and aural alerts. However, because the DHC-3 was not transmitting pressure altitude, the alert feature could not operate.	The Garmin GDL-90 UAT ADS-B could generate visual and aural alerts, which are sent to the Chelton for display and annunciation	None. Designed to the DO-317A MOPS, the FreeFlight RANGR 978 UAT ADS-B did not have algorithms to generate alert messages to send to the Chelton display.

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