December 4, 2024 Aviation Investigation Report AIR-24-07

In-Flight Collision During Air Show Commemorative Air Force Boeing B-17G, N7227C, and Bell P-63F, N6763

Dallas, Texas
November 12, 2022

Abstract: This report discusses the November 12, 2022, accident involving two historic, former military airplanes operated by the Commemorative Air Force (CAF) that collided in flight during a performance in the CAF's Wings Over Dallas air show. The pilot, copilot, flight engineer, and two scanners on board the Boeing B-17G and the pilot of the Bell P-63F were fatally injured, and both airplanes were destroyed. No injuries to persons on the ground were reported. Safety issues identified in this report included the limited ability of the Boeing B-17G pilot and the Bell P-63F pilot to see and avoid each other's airplane due, in part, to the inherent limitations of the see-and-avoid concept for collision avoidance; the air boss's ineffective aircraft deconfliction strategy for the accident performance; the lack of adequate air show safety oversight, risk assessments, and air boss oversight; air show safety culture issues; and the need for standardized terms for air show communications to ensure clarity and brevity. As a result of this investigation, the National Transportation Safety Board makes four safety recommendations to the Federal Aviation Administration, two safety recommendations to the International Council of Air Shows Inc., and one safety recommendation to the CAF.

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Acronyms and Abbreviations

AAIP	Approved Airplane Inspection Program
ABRP	Air Boss Recognition Program
CAF	Commemorative Air Force
CFR	*Code of Federal Regulations*
FAA	Federal Aviation Administration
ICARUS	ICAS Confidential Reporting System
ICAS	International Council of Air Shows Inc.
IIC	inspector-in-charge
KRBD	Dallas Executive Airport
LHFE	living history flight experience
LOA	letter of authorization
msl	mean sea level
NTSB	National Transportation Safety Board
PIC	pilot-in-command
SAFO	safety alert for operators
SMS	safety management system
SWIFS	Southwestern Institute of Forensic Sciences

Executive Summary

What Happened

On November 12, 2022, about 1322 central standard time, a Boeing B-17G, N7227C, and a Bell P-63F, N6763, collided in flight during a performance at the Commemorative Air Force's (CAF) Wings Over Dallas air show at Dallas Executive Airport (KRBD) in Dallas, Texas. The pilot, copilot, flight engineer, and two scanners on board the Boeing B-17G and the pilot of the Bell P-63F were fatally injured, and both airplanes were destroyed. No injuries to persons on the ground were reported. Both accident airplanes (and six other historic, former military airplanes that were airborne as part of the same performance) were operated by the CAF under the provisions of Title 14 *Code of Federal Regulations* (*CFR*) Part 91 and a certificate of waiver for the air show.

The Boeing B-17G was in the first position of five historic bomber airplanes flying as solo aircraft in trail, and the Bell P-63F was in the last position of three historic fighter airplanes flying in formation. The takeoffs, repositioning turns, and passes of the eight airplanes in the accident performance were directed in real time via radio by the air boss, who had primary responsibility for the control of air show operations.

Just before the accident, the bomber group and the fighter formation completed a pass in front of the crowd of spectators from show right to left (that is, right to left from the crowd's perspective). The airplanes were setting up for the next pass when the accident occurred. This pass was intended to be from show left to right in front of the crowd, and the air boss issued directives for the fighter formation to pass off the left side of the bomber group airplanes and then cross in front of them. The position data showed that the flight path for the fighter lead and position 2 fighter airplanes passed the bomber airplanes off the bombers' left side before crossing in front of the Boeing B-17G but that the Bell P-63F's flight path converged with that of the Boeing B-17G. Video and photographic evidence captured by witnesses on the ground showed that the Bell P-63F was in a descending, left-banked turn when it struck the left side of the Boeing B-17G near the trailing edge of the left wing, then both airplanes broke apart in flight.

What We Found

The National Transportation Safety Board (NTSB) found that the accident pilots had limited ability to see and avoid each other's airplane due to flight path geometry, out-the-window view obscuration by aircraft structures, the attention demands associated with the air show performance, and the limitations of human performance that can make it difficult to see another aircraft.

We also found that the air boss's deconfliction strategy for the accident performance, which relied on the air boss's real-time, predictive assessment of airplane locations and the ability of the CAF pilots to see and avoid other airplanes, was ineffective because the flight paths of the Boeing B-17G and the Bell P-63F converged as each pilot maneuvered to set up for the pass.

We found evidence that the air show guidance provided by the Federal Aviation Administration (FAA) and the International Council of Air Shows Inc. (ICAS) did not adequately address the need to better mitigate the collision risks associated with air boss–directed performances involving multiple, dissimilar aircraft. We determined that a lack of administrative controls and a documented risk assessment process for ensuring air show aircraft separation directly contributed to the in-flight collision.

We found that, unlike the FAA regulatory requirements for pilots and air traffic controllers, air bosses are not subject to any recurrent evaluations, and there are no standardized communications terms for air boss–provided directives to ensure the clarity and brevity of radio communications. Further, the lack of guidance and required surveillance tasks for FAA inspectors assigned to air shows related to the direct observation of an air boss's performance represents a missed opportunity for inspectors to detect and provide debriefing feedback to address performance-related safety issues.

We also found that the CAF's lack of a strong, clearly defined safety risk assessment plan resulted in air show production decisions that were not systematically developed to determine acceptable levels of risk and were susceptible to influences unrelated to safety.

We determined that the probable cause of this accident was the air boss's and air show event organizer's lack of an adequate, prebriefed aircraft separation plan for the air show performance, relying instead on the air boss's real-time deconfliction directives and the see-and-avoid strategy for collision avoidance, which allowed for the loss of separation between the Boeing B-17G and the Bell P-63F airplanes. Also causal was the diminished ability of the accident pilots to see and avoid the other aircraft due to flight path geometry, out-the-window view obscuration by aircraft structures, attention demands associated with the air show performance, and the inherent limitations of human performance that can make it difficult to see another aircraft. Contributing to the accident were the lack of FAA guidance for air bosses and air show event organizers on developing plans and performing risk assessments that ensure the separation of aircraft that are not part of an approved maneuvers package and the lack of FAA requirements and guidance for recurrent evaluations of air bosses and direct surveillance of their performance.

What We Recommended

As a result of this investigation, we made two new recommendations each to the FAA and to the ICAS. We recommended that they work together with other air show industry stakeholders to develop standardized terms to help ensure the clarity and brevity of air boss–provided directives to performers. We also recommended that they both work with the warbird community to establish standard operating procedures for air show event organizers and air bosses that include applying effective administrative controls to ensure air show aircraft separation, performing a safety risk assessment for each performance, and completing a daily debriefing with continuous feedback to the FAA and the ICAS to address any identified deficiencies.

We also made two new recommendations to the FAA to require recurrent air boss evaluations as part of the letter of authorization renewal process and to revise FAA Order 8900.1 to provide guidance and a job aid for FAA inspectors who evaluate an air boss's performance, including requirements for the FAA inspector-in-charge of an air show to observe an air boss's performance visually and on the air boss radio frequency and provide appropriate feedback during the air show debriefing. We made one new recommendation to the CAF to establish a safety risk assessment process for identifying and mitigating risks, tracking safety hazards, and routinely assessing trend data to include policies and procedures that specifically address the unique aspects of air show operations.

1. Factual Information

1.1 History of Flight

On November 12, 2022, about 1322 central standard time, a Boeing B-17G airplane, N7227C, and a Bell P-63F airplane, N6763, collided in flight during a performance at the Commemorative Air Force's (CAF) Wings Over Dallas air show at Dallas Executive Airport (KRBD) in Dallas, Texas.[1] The pilot, copilot, flight engineer, and two scanners on board the Boeing B-17G and the pilot of the Bell P-63F were fatally injured, and both airplanes were destroyed. No injuries to persons on the ground were reported. Both accident airplanes (and six other historic, former military airplanes that were airborne as part of the same performance) were operated by the CAF under the provisions of Title 14 *Code of Federal Regulations* (*CFR*) Part 91 and a certificate of waiver for the air show. The Boeing B-17G and the Bell P-63F departed from KRBD about 1310 and 1315, respectively, for the local flights.

The air show started at 1050, and the accident performance (listed on the schedule as "warbirds," a common name for historic, former military airplanes) was the seventh performance on the schedule. As part of the performance, the Boeing B-17G was in the lead position of five historic bomber airplanes flying as solo aircraft in trail, and the Bell P-63F was in the last position of three historic fighter airplanes flying in formation.[2] The takeoffs, repositioning turns, and passes of the eight airplanes in the accident performance were directed by the air boss, who had primary responsibility for the control of air show operations, via radio on the air show radio frequency.[3]

[1] (a.) Visit ntsb.gov to find additional information in the public docket for this NTSB accident investigation (case CEN23MA034). Use the CAROL Query to search safety recommendations and investigations. (b.) Different organizations may use different spellings for certain aviation event–specific terms (for example, "air show" versus "airshow"). The spellings used in this report are consistent with those used in Federal Aviation Administration (FAA) inspector guidance related to oversight of air shows and other aviation events (FAA 2020a).

[2] "Formation flight" (like the three-ship fighter formation) refers to two or more aircraft under the command of a flight lead that are flown solely with reference to another aircraft in the formation. Performers who fly in formation are subject to certain credentialing requirements (see section 1.2.2) and may fly within 500 ft of other aircraft in the formation (FAA 2020a, 11 and 12). "In trail" refers to aircraft that are flown behind and solely with reference to another aircraft. Performers who fly multiple solo aircraft in trail (like the bomber group) fly each airplane independently (that is, not part of a formation) and must maintain more than 500 ft lateral separation from the aircraft they are following.

[3] The air boss briefed general aspects of the performance with the participants before the show during the required Air Show Participants Safety Briefing. (See section 1.9.2.1 for more information.)

Before the accident, the bomber group completed multiple passes in front of the crowd of spectators and was joined by the fighter formation, which completed a pass and other maneuvers, as directed by the air boss. Generally, the previously completed passes were flown along the 1,000-ft show line (that is, the further of two designated lines parallel to runway 13/31 spaced 1,000 ft and 500 ft laterally from the crowd), as directed by the air boss. (See section 1.8.2.1 and figure 12 for the bomber group's and fighter formation's previous passes.) The air boss stood atop a set of air stairs on the field that provided him with an unobstructed view of the flying display area and beyond (see figure 1).

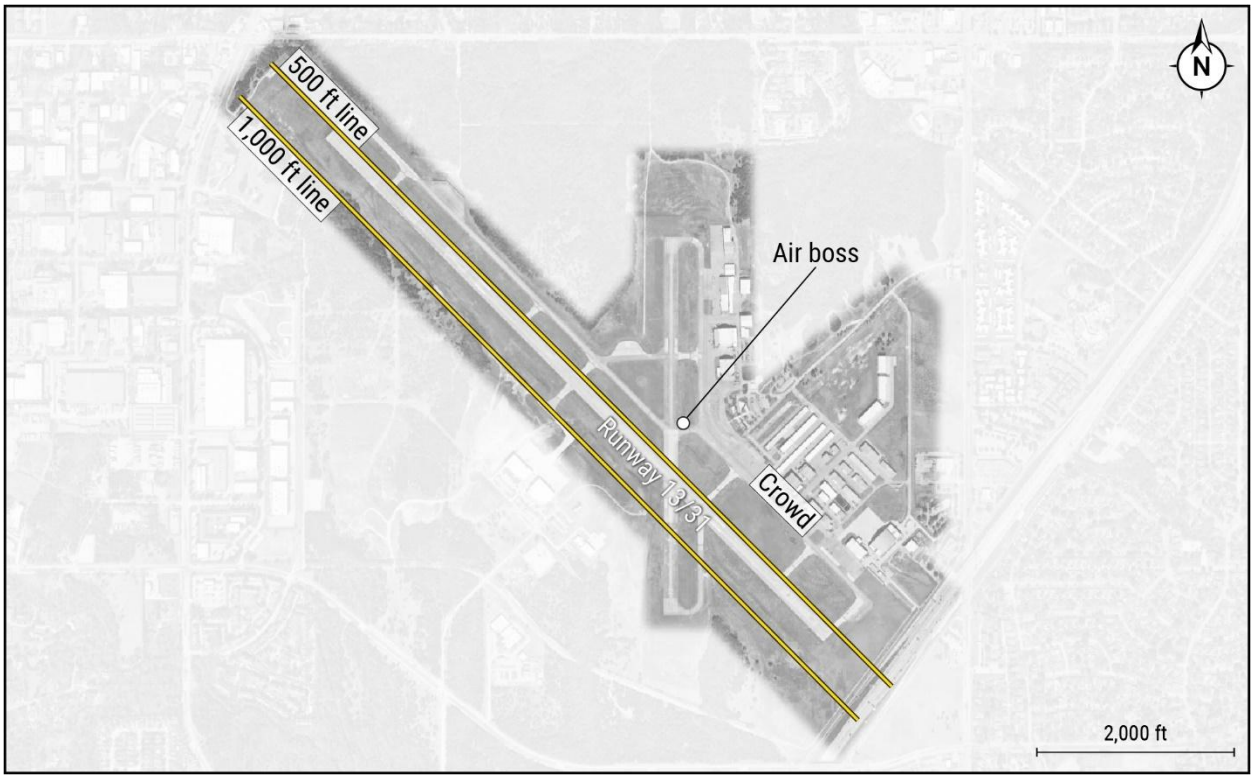

Figure 1. Relative locations of the runway, show lines, crowd, and air boss.

The airplanes' altitudes and airspeeds varied throughout the performance, which included descending passes from the bomber group (to demonstrate historic bombing mission profiles), fighter formation maneuvers (to demonstrate the historic role of fighter airplanes during such missions), the coordinated detonation of ground pyrotechnics (to simulate historic bomb detonations and strafing fire), and a real-time narration (from an air show announcer on the ground).

The air boss directed all these activities and ground movements (taxi, takeoff, and landing clearances) using radio call signs to address individual airplanes, the bomber group, or the fighter formation, as applicable. According to a CAF pilot, typically, the flight leads (in this case, one for the bomber group and one for the

fighter formation) communicate with the air boss and set the flight patterns (in this case, in response to air boss directives) that the other airplanes in the group will follow, and the trailing airplanes in the group "just need to listen to know what's coming next, but they do not respond" on the radio (see table 1).

Table 1. Performing airplanes, positions preceding the accident, and radio call signs.

Bomber airplanes (Common name)	Group position	Radio call signs
Boeing B-17G (Flying Fortress)	Bomber lead	"B-17," "Fortress," "Texas Raiders," or "Raiders" ("bombers" when referring to bomber group)
Consolidated B-24 (Liberator)	2	"B-24" or "Diamond Lil"
Curtiss Wright SB2C (Helldiver)	3	"SB2C" or "Helldiver"
North American B-25J (Mitchell)	4	"Devil Dog" ("B-25s" when referring to both B-25Js)
North American B-25J (Mitchell)	5	"Yellow Rose"
Fighter airplanes (Common name)	**Formation position**	**Radio call signs**
North American P-51D (Mustang)	Fighter lead	"Gunfighter" ("American fighters" or "fighters" when referring to fighter formation)
North American P-51C (Mustang)	2	No noted preaccident radio communications
Bell P-63F (Kingcobra)	3	No noted preaccident radio communications

In addition to the eight airborne airplanes in the performance, the air boss directed the ground and airborne movements of two other CAF-operated airplanes within 3 minutes before the accident. At 1319:32, the air boss cleared the crew of a CAF-operated Boeing B-29 (historic, former military bomber airplane, commonly called a Superfortress) to taxi to runway 31. The Boeing B-29 was scheduled to take off about 1320 and join the performance, but it had not yet departed when the accident occurred. At 1320:43, the air boss cleared the pilot of a CAF-operated Boeing PT-17 (historic, former military, two-seat, trainer airplane, commonly called a Stearman) to land on runway 31. The Boeing PT-17 flight was the second of two CAF-operated revenue passenger rides operated during, but not part of, the accident performance.[4]

[4] The first revenue ride airplane, a Beechcraft T-34B (historic, former military, two-seat, trainer airplane, commonly called a Mentor) departed about 1259:35 and returned for landing on runway 31, as cleared by the air boss, about 7 minutes before the accident (see section 1.9.1.4 for more information).

Automatic dependent surveillance-broadcast (ADS-B) ground track data were available for seven of the eight airplanes in the performance (all but the bomber in position 5), as well as for the CAF-operated Boeing PT-17.[5] A National Transportation Safety Board (NTSB) aircraft performance study used the available position data to plot the airplanes' flight paths and determine their groundspeeds and altitudes in feet above ground level (agl) (see section 1.8.2.1 for more information).

The performance study showed that, at 1320, the accident Boeing B-17G had begun a pass from show right to left (that is, right to left from the crowd's perspective), heading southeast, parallel to runway 13, with the other bombers spaced variously in trail. The fighter formation with the accident Bell P-63F was inbound from the northwest (see figure 2).

[5] No data were available for the bomber in position 5, which was flown in trail of the bomber in position 4.

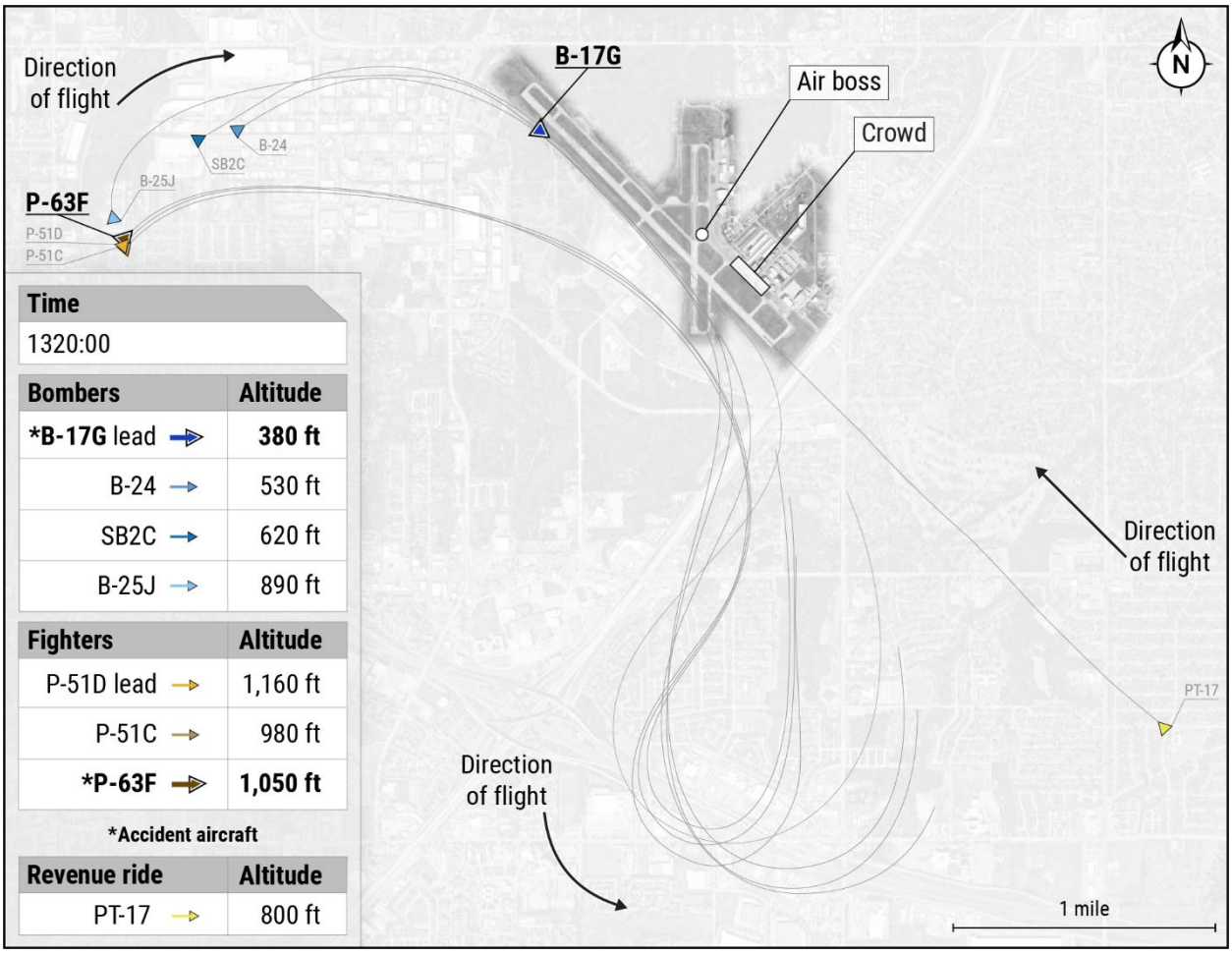

Figure 2. Positions and altitudes (in agl) of seven of the eight airplanes in the performance and one revenue ride flight airplane at 1320:00.

Note: Their future flight paths for the next 2 minutes before the collision are shown in gray.

According to the recorded audio for the air show radio frequency, between about 1319:47 and 1320:10, the air boss provided instructions to the bomber group and the fighter formation about the pass, repositioning turns, and intended next

pass.[6] The air boss addressed the accident Boeing B-17G, stating, "B-17, after this pass, right 90 left 270," and a crewmember replied, "Raiders, right dog bone."[7]

Beginning about 1319:57, the air boss issued three back-to-back directives to the fighter formation, stating, "Fighters, you can walk your way up to the B-17, I'm going to break y'all out after this, um—," followed by, "you're going to end up breaking left," then, "so, you're going to follow the bombers to the right 90 out, and then you're going to roll back in left and be on the 500-ft line if y'all want to set up for an echelon for a break so y'all can get in trail."[8] At 1320:10, the fighter lead pilot (in the North American P-51D) replied, "Okay, uh, say again for the fighters, that was not clear." The air boss stated, "Uh, fighters go echelon, uh, right, go to echelon right," and, at 1320:18, the fighter lead pilot responded, "Okay, fighters, echelon right."

At 1320:22, the air boss addressed two of the bombers, stating, "Okay, B-24 [the Consolidated B-24 in bomber position 2], if you could give me a couple of mi—, uh, inches and close the gap, I'd appreciate it. B-17, let's keep the turn a little flat for me." The audio recorded an unintelligible transmission, then the air boss stated, "Just a little bit. When you come back through, you're coming through on the 1,000-ft line." A crewmember from the Boeing B-17G replied, "Roger." The performance study showed that, about this time, the Boeing B-17G was entering the right 90° portion of the repositioning turns, and the Bell P-63F continued inbound with the fighter formation (see figure 3).

[6] Communications quoted in this report are based on the NTSB's transcript of the audio recording. Times are rounded to the nearest second. The time of some communications could not be determined from the recording but could be estimated based on their sequence between communications for which the time could be determined (see section 1.8.3 for more information).

[7] The air boss's turn directives and the term "right dog bone" refer to a repositioning maneuver involving a right 90° turn followed by a left 270° turn. Other repositioning turns directed during the performance included racetrack turns, which involve making two 180° turns (separated by a period of straight flight) in the same direction (see section 1.8.2.1 for more information).

[8] Echelon right refers to a formation in which each airplane is positioned behind and to the right of the airplane in front of it (FAST 2016, 10).

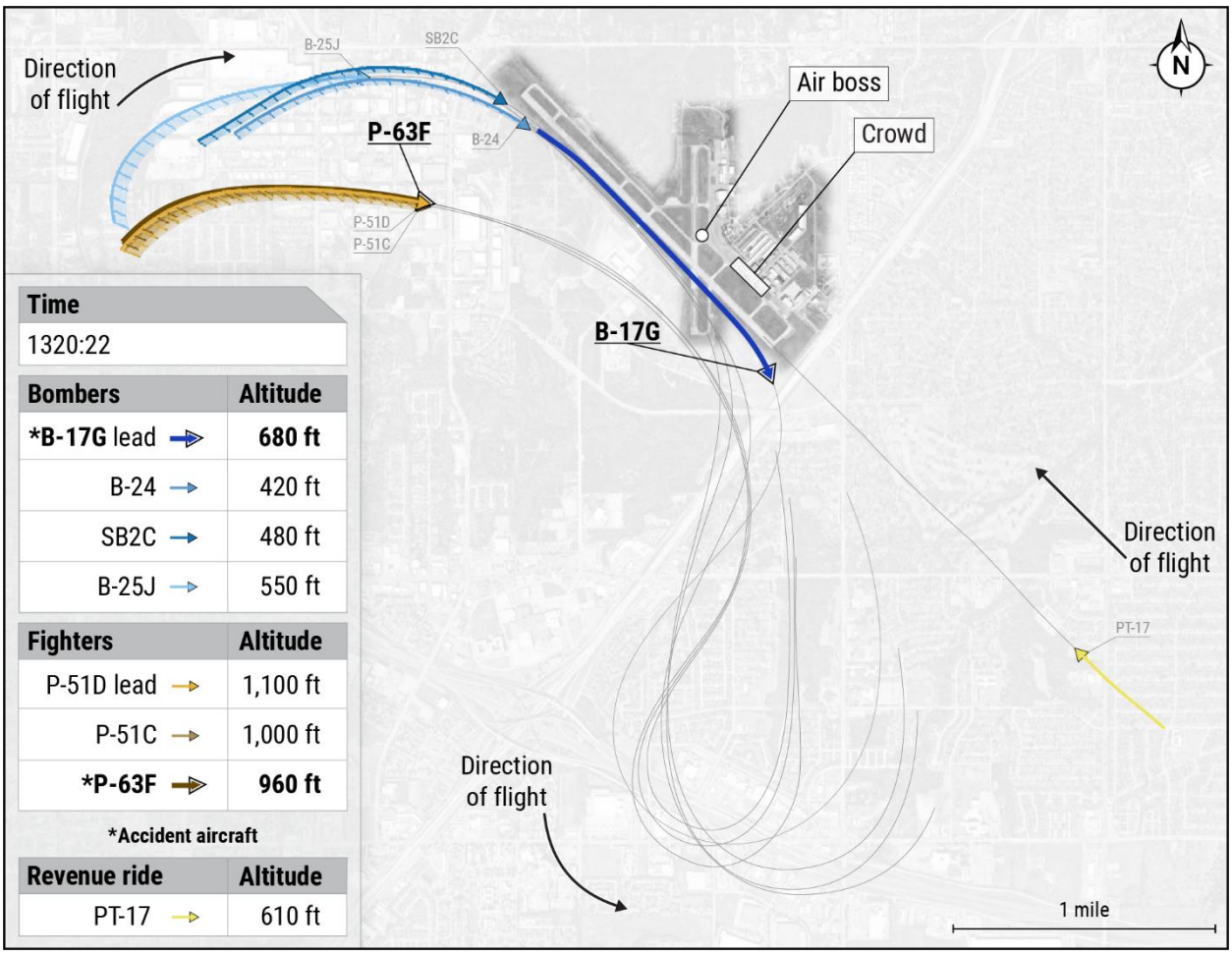

Figure 3. Position and altitude of each airplane at 1320:22.

The performance study determined that, throughout much of the subsequent maneuvering turns, the Boeing B-17G climbed to and maintained an altitude between about 800 to 1,000 ft agl and an airspeed below about 130 kts.

At 1320:37, the air boss stated, "American fighters should be in a right turn. You're going to follow the bombers out on a right 90 turn, and then I'm going to roll you back in front of them." The air boss then cleared the Boeing PT-17 revenue ride flight to land on runway 31, and the pilot of that airplane acknowledged. The performance study showed that, about this time, the accident Boeing B-17G had completed the right 90° turn, the fighter formation was passing the trailing bombers, and the Boeing PT-17 was approaching the airport from the southeast (see figure 4).

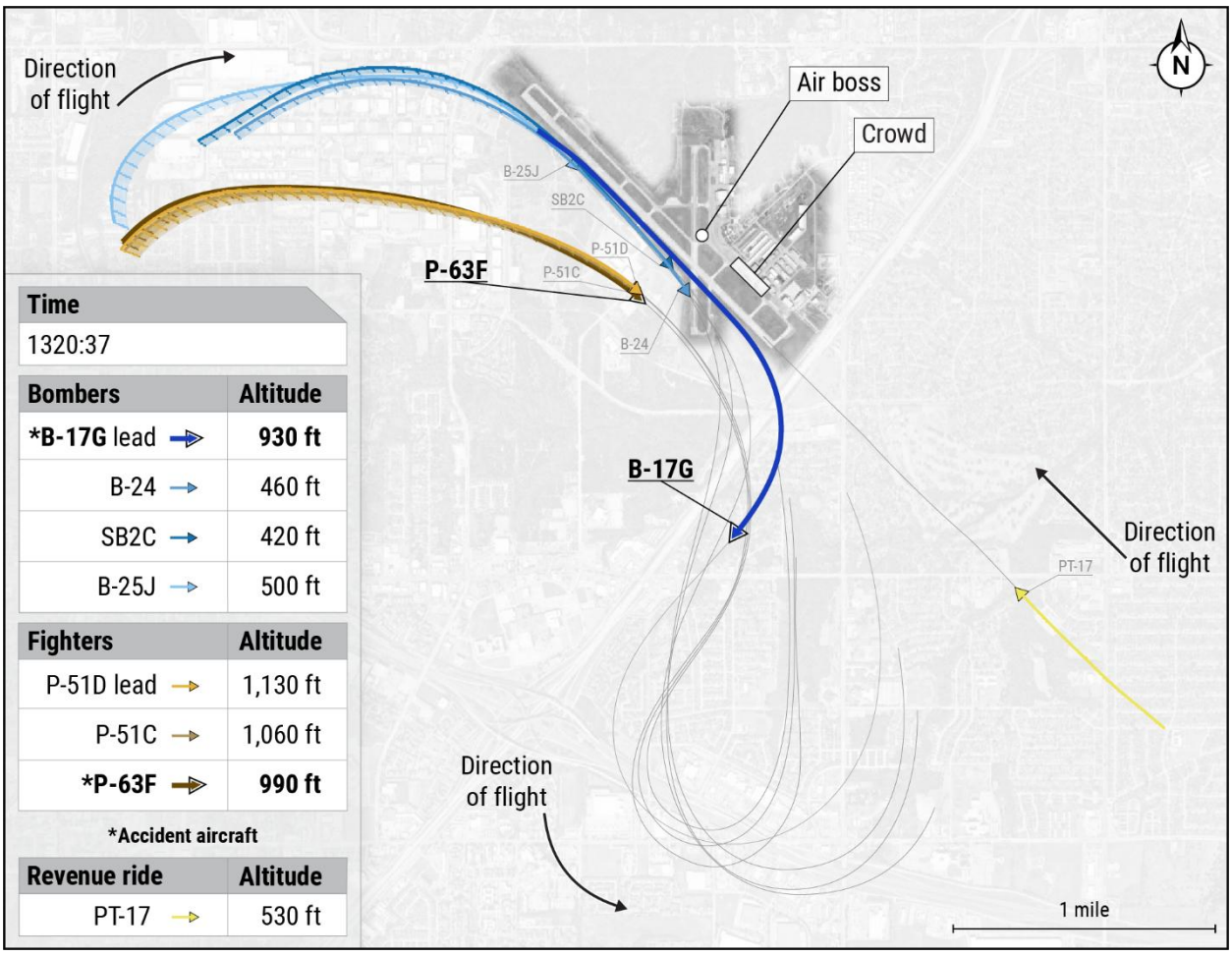

Figure 4. Position and altitude of each airplane at 1320:37.

The performance study determined that the fighter formation entered the right 90° turn at 1320:45 at altitudes between 1,000 and 1,200 ft agl and climbing and airspeeds of about 160 kts and slowing as they climbed.

At 1320:51, the air boss stated, "There ya go, B-17. Yup. Gentle flat roll it around 1,000-ft line," and a Boeing B-17G crewmember acknowledged, "1,000-ft line for Raiders." At 1320:58, the air boss stated, "Fighters, roll it back to the left. Lead fighter, roll it back to the left, and y'all get in trail," and the fighter lead pilot replied, "Okay, fighters in trail." The air boss continued, "Yeah, and Gunfighter, look out your left side and find the B-17," and the fighter lead pilot replied, "We see the B-17." The performance study showed that, at 1321:08, the fighter formation was entering the left 270° turn, having flown past and above the position 3 bomber, with the position 2

bomber and the Boeing B-17G to the fighter pilots' left, also at lower altitudes than the fighters (see figure 5).[9]

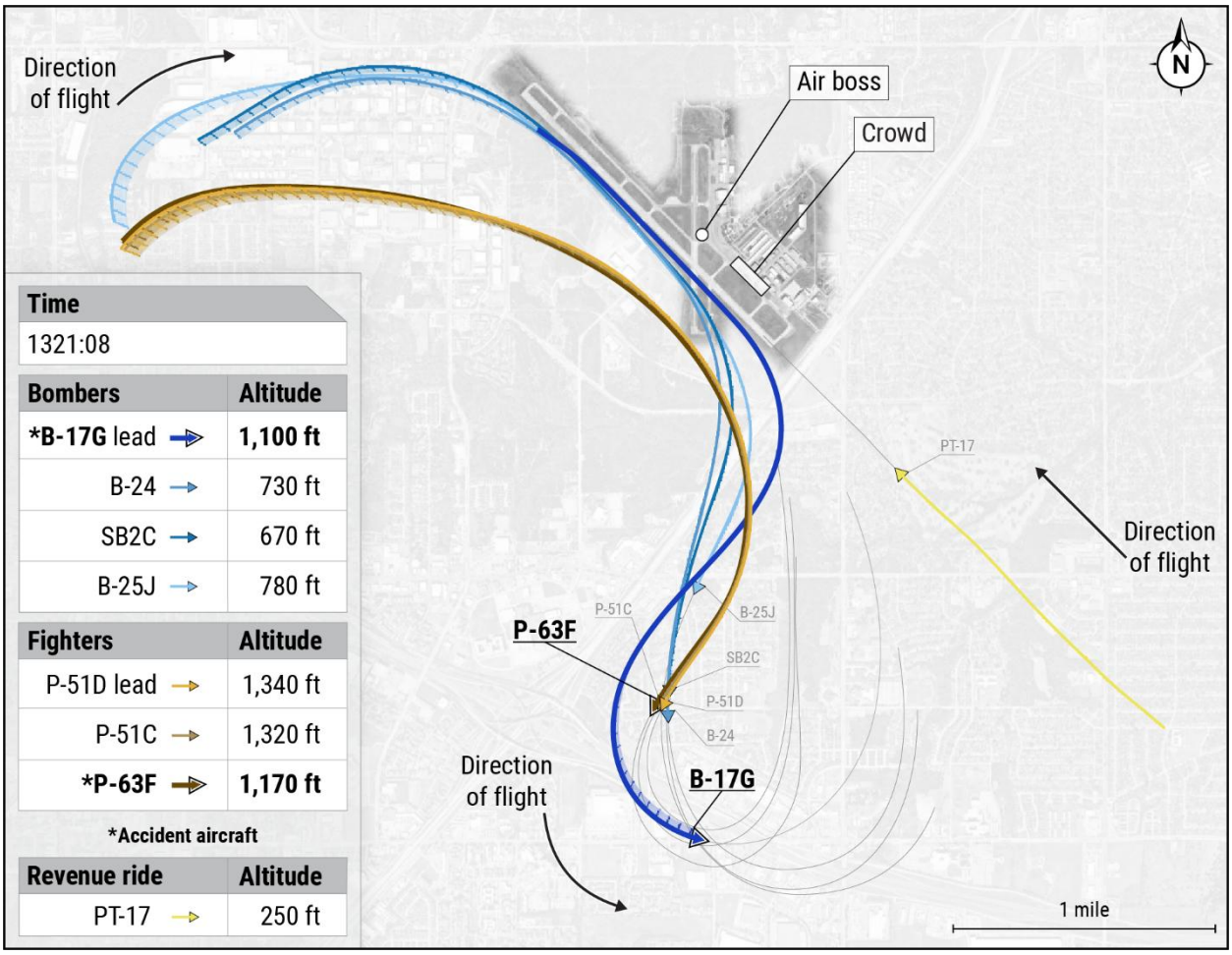

Figure 5. Position and altitude of each airplane at 1321:08.

At 1321:10, the air boss stated, "Yeah, there you go. Roll it back to the left. I want you to get in front of the bombers. I want you to come through on the outside edge of the runway," and the fighter lead pilot replied, "Okay." The air boss then provided wind information, stating that the wind was from 330° at 12 kts with gusts to 18 kts.

The performance study determined that the airplanes in the fighter formation climbed to about 1,600 ft agl while making a tighter left turn than the bomber group airplanes, which stayed below 1,000 ft agl. The fighter formation reached the apex of

[9] See section 1.8.2.1 for more information about each airplane's respective altitude.

their turn about 1321:20, and their airspeeds increased from about 150 kts to 230 kts as they subsequently descended in trail off the fighter lead.

At 1321:31 (during the fighters' descent), the air boss stated, "Nice job, fighters, you're coming through first. That will work out. B-17 and all the bombers on the 1,000-ft line," then asked, "B-17, you got the fighters in front of you off your left?" There was an unintelligible transmission before the air boss stated at 1321:45, "Nice job, fighters, come on through." The performance study determined that, at the time, the fighter lead had passed off the Boeing B-17G's left side and was ahead of it, the fighter in position 2 was passing off its left side, and the Bell P-63F was in trail (see figure 6).

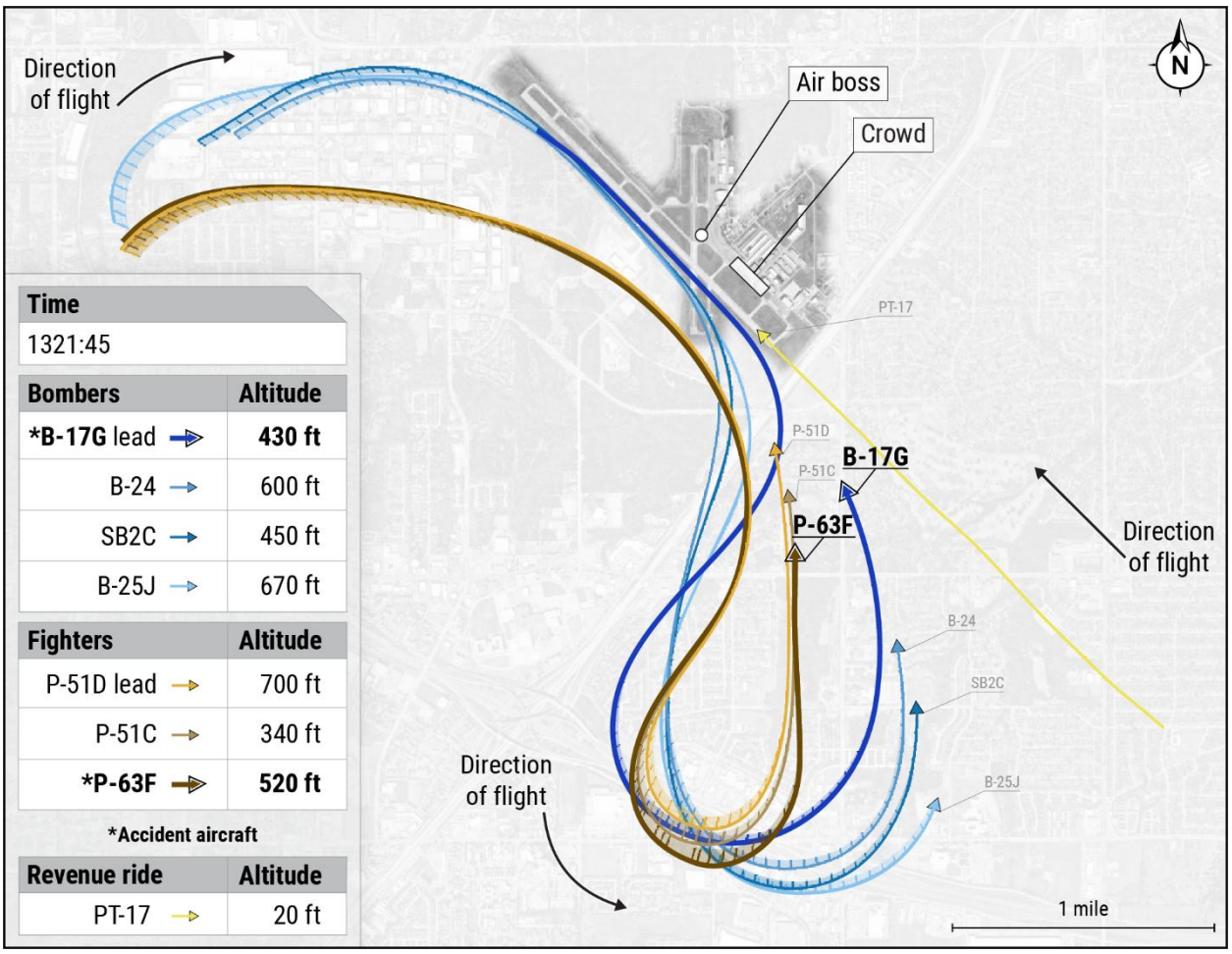

Figure 6. Position and altitude of each airplane at 1321:45.

The performance study determined that the fighter lead and the fighter in position 2 were coming onto the 1,000-ft show line.[10] The Bell P-63F's flight path closely followed the fighter in position 2 until about 1321:47, when its flight path no longer curved toward the 1,000-ft show line but became somewhat straighter. The Bell P-63F was descending at a rate of 1,500 ft per minute, and its airspeed was about 230 kts. The Boeing B-17G's flight path was curving toward the 1,000-ft show line.

Position data for the Boeing B-17G and the Bell P-63F ended at 1321:53, when the airplanes had a lateral separation of about 150 ft at nearly the same altitude. An oblique view plot from the performance study shows the airplanes' relative positions throughout the final turn and descent that preceded the collision (see figure 7).

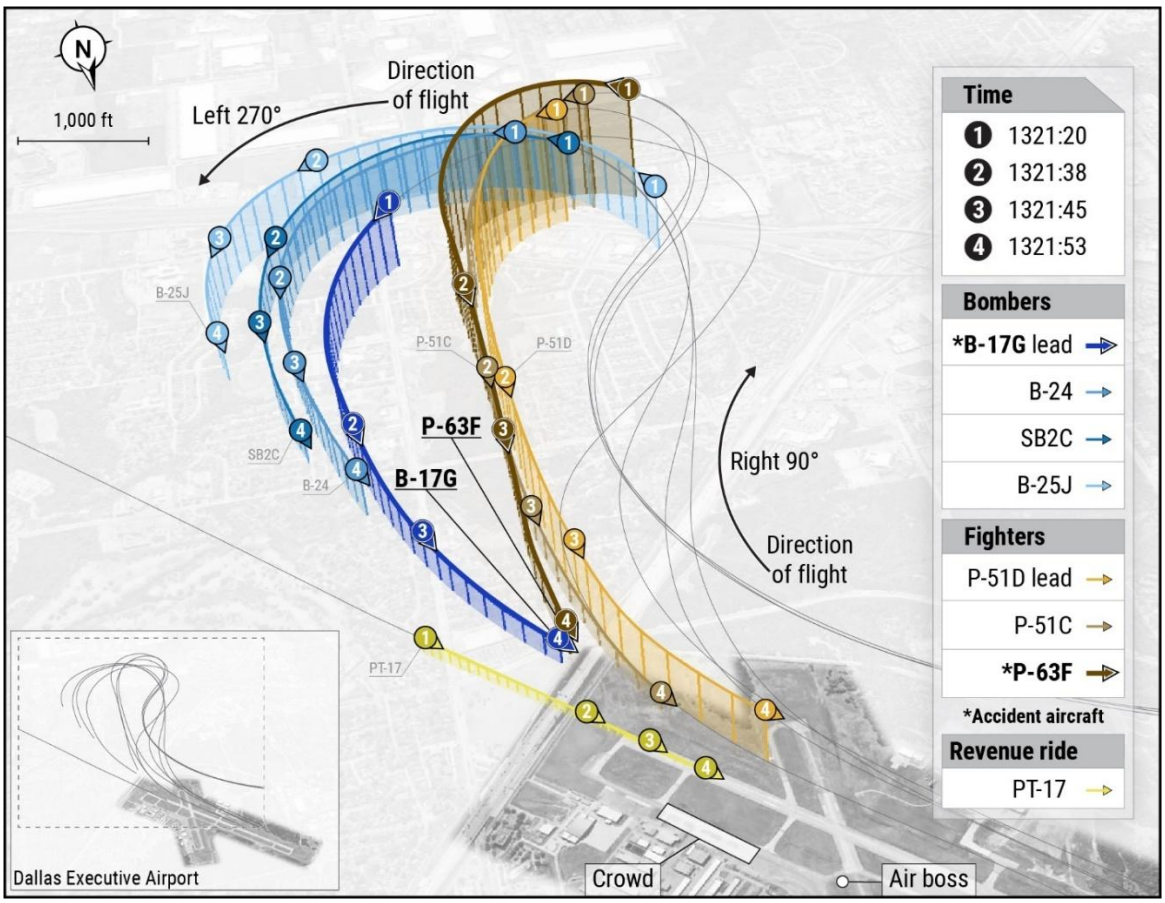

Figure 7. Oblique view (looking southwest) showing the airplanes' descending flight paths during the final turn up to 1321:53.

[10] According to postaccident interview summaries, the fighter lead pilot stated that he believed that the air boss told the fighters to fly down the 1,000-ft show line (see section 1.9.2.3 for more information).

A witness in the crowd with a hand-held camera captured video that showed the collision. The video showed that each of the three fighters approached the show lines from a left turn, that is, in a left roll with flight deck canopies angled away from the Boeing B-17G (see section 1.8.2.2 for more information). A photograph taken by another witness in the crowd showed the relative positions of the Boeing B-17G, Bell P-63F, and the position 2 bomber before the collision (see figure 8).

Figure 8. Photograph showing, from left to right, the accident Boeing B-17G, accident Bell P-63F, and position 2 bomber before the collision. (Source: Gary Daniels)

Note: The Bell P-63F is in a left turn behind and off the left side of the Boeing B-17G and is ahead of the position 2 bomber.

The video showed that the Bell P-63F airplane struck the Boeing B-17G near the trailing edge of the left wing, then both airplanes broke apart in flight. A fire erupted in the wing center section of the Boeing B-17G as it descended, and the airplane exploded upon ground impact. The Bell P-63F descended and collided with terrain. Both wreckages came to rest in a grassy area on the airport property, south of the approach end of runway 31. Within a few seconds after the collision, the air boss stated, "Knock it off, knock it off. Roll the trucks," indicating that the other performers were to proceed to their prebriefed holding patterns and that emergency response was needed (see section 1.9.2.1). The video showed that the Boeing PT-17 landed at

nearly the same time as the midair collision and that wreckage debris fell near its location.

1.2 Personnel Information

1.2.1 Boeing B-17G Crew

1.2.1.1 Pilot

The pilot (who occupied the left seat in the accident airplane), age 66, held an airline transport pilot certificate with a rating for multiengine land airplanes and commercial pilot privileges for gliders and single-engine land and sea airplanes. He also held a flight instructor certificate for single-engine, multiengine, and instrument airplanes and a flight engineer certificate for turbojet-powered airplanes. He held type ratings for 12 different airplanes, including the Boeing B-17, DC-3, and modern transport-category jets. He held an FAA first-class medical certificate dated September 2, 2022, with the limitation that he must have available glasses for near vision.

Based on CAF and FAA records, the pilot accumulated about 28,000 hours of flight experience with about 24,000 hours of pilot-in-command (PIC) time. He had about 500 hours of flight experience in the Boeing B-17G with about 450 hours as PIC. In the 30 days before the accident, he had flown 7.1 hours in CAF airplanes, 1.7 hours of which were in the Boeing B-17G.

According to CAF records, the pilot's most recent ground and flight training were completed in September 2022, his most recent crew resource management training was completed in January 2022, and his most recent flight review was completed in May 2021. According to the CAF director of operations, the pilot was an active member of the CAF's standardization and safety committee.

1.2.1.2 Copilot

The copilot (who occupied the right seat in the accident airplane), age 67, held an airline transport pilot certificate with a rating for multiengine land airplanes and commercial pilot privileges for single-engine land airplanes, helicopters, and glider towing. He also held a flight instructor certificate for single-engine, multiengine, and instrument airplanes, a flight engineer certificate for turbojet-powered airplanes, and an airframe and powerplant mechanic certificate. He held type ratings for six different airplanes, including modern transport-category jets. He held an FAA first-class medical certificate dated October 21, 2022, with the limitations that he must wear corrective lenses and possess glasses for near and intermediate vision.

Based on CAF and FAA records, the copilot accumulated about 25,300 hours of flight experience with about 20,000 hours of PIC time. He had about 90 hours of flight experience in Boeing B-17 airplanes. In the 30 days before the accident, he had flown 0.3 hours in the CAF Boeing B-17G (with no time logged in any other CAF airplanes during that period).

According to CAF records, the copilot's most recent flight training and flight review were completed in March 2022, and his most recent ground and crew resource management training were completed in January 2022.

1.2.1.3 Flight Engineer

The flight engineer's most recent aviation medical examination was August 25, 2022. He was issued a second-class medical certificate limited by a requirement to wear corrective lenses.

1.2.1.4 Scanners

The two scanners on board the Boeing B-17G were CAF members. Neither were pilots nor had medical certification files, and no such certifications were required. According to the CAF's loadmaster operations manual, the in-flight responsibilities of a scanner on the Boeing B-17G primarily involved aircraft safety-related tasks, including visually monitoring the engines and tailwheel for operational anomalies and alerting the flight crew of "anything unusual."[11] According to the CAF's chief aviation officer, typically, only one scanner would have been on board the accident airplane, but the PIC could choose to have more. He said that, with two scanners, one would be on each side of the airplane, looking out the side door (behind each wing).[12] He said that "in a dynamic air show environment where planes are going left and right, it's important to have people in the back looking out." The CAF's loadmaster manual and ground training agenda did not contain any specific procedures or training for scanners regarding looking for or alerting the flight crew about potential traffic conflicts.

The CAF director of operations stated that he served in the role of scanner on board the accident airplane when it was flown in an earlier performance that day. He said that he did so to familiarize himself with how that performance was operated and

[11] Per the manual, each scanner on the Boeing B-17G would use a microphone-equipped headset to communicate with the flight crew via the airplane's main intercom.

[12] The investigation did not determine where each scanner was seated during the accident flight.

to "[look] for traffic in the aircraft." He said that, for that flight, he was seated in the nose of the airplane.

1.2.2 Bell P-63F Pilot

The P-63F pilot, age 63, held an airline transport pilot certificate with a rating for multiengine land airplanes and commercial pilot privileges for single-engine land and sea airplanes and gliders. He held type ratings for five different airplanes, including modern midsize and transport-category jets, and was authorized for three experimental airplanes: the Bell P-63, Bell P-39, and Curtiss P-40 (visual flight rules operations only). He held an FAA first-class medical certificate dated November 1, 2022, with no limitations.

Based on CAF and FAA records, the pilot accumulated about 34,000 total hours, with about 20,000 hours as PIC and 108 hours in the Bell P-63F. In the 30 days before the accident, he had flown about 7.8 hours in CAF airplanes, 2.8 of which were in the Bell P-63F.

According to CAF records, the pilot's most recent flight review and annual check ride were completed in March 2022, and his most recent ground training was completed in February 2022.

His most recent Statement of Aerobatic Competency card was issued September 19, 2022, with a proficiency expiration of December 31, 2023. Authorized aircraft included the Bell P-63F and the North American P-51 and T-6 (category C "piston warbirds") to an altitude no lower than 250 ft agl (level 2) with an endorsement for solo aerobatics.[13] He also held a CAF formation leader card with an expiration of December 31, 2022. According to the CAF director of operations, the pilot was also a CAF instructor and evaluator in the Bell P-63F and two other airplanes and was a CAF fighter evaluator pilot.

1.2.3 Air Boss

The air boss held a valid FAA-issued air boss letter of authorization (LOA) with a "recognized air boss, multiple venues" designation (the highest of four air boss

[13] The FAA requires a Statement of Aerobatic Competency card for all civil aircraft pilots who perform aerobatics or dynamic maneuvers at an air show, which are defined by certain pitch angle, bank angle, and other criteria (FAA 2020a, 22 and 53-54).

levels), which authorized him to serve as an air boss of any complex, standard, or basic air show.[14]

The air boss stated that he had 20 years of experience as an air boss, having done 16 air shows in the year before the accident and more than 300 during his career. He also held an air traffic control tower operator certificate and a private pilot certificate (neither of which were required for his LOA) with endorsements that included high performance, high altitude, tailwheel, and complex aircraft. He said that his control tower experience was in 2008 and 2009.

According to the air boss, air boss qualification was a multi-year process that generally began with time observing other air bosses, discussing theory about different scenarios and building performance schedules, gaining experience on the radio while supervised by another air boss, and continuously building skills. He noted that, for some people, it can take 6 to 8 years, and others may do it in 4 years. He said that the LOA renewal process, which occurs every 3 years, did not require any evaluator observation but rather letters of recommendation and a minimum experience requirement (see section 1.9.3).

1.3 Aircraft Information

1.3.1 Boeing B-17G

General Design

The Boeing B-17G was a four-engine, high-altitude, heavy bomber originally developed in the 1930s for the US Army Air Corps. It was 74 ft long, 19 ft tall at the tail (when parked), and had a 104-ft wingspan and 43-ft horizontal stabilizer span.[15] The airplane's primary and secondary wing, fuselage, and tail structures were of all-metal construction, and the ailerons, elevators, and rudder were fabric-covered aluminum structures. It was equipped with four Wright Cyclone R-1820 nine-cylinder,

[14] The FAA defines a complex air show as having any one of a variety of defined military demonstration elements (such as the participation of US, Canadian, or non-North American military demonstration teams or single-ship demonstrations); certain simulated military exercise demonstrations involving multiple aircraft with either contemporary military personnel or civilian reenactors; or aircraft operations on an additional active runway not dedicated to air show operations while the air show is being held (FAA 2019b, 3). The other three levels of air boss designation are "basic air boss," "standard air boss," and "recognized air boss, single venue," and the respective limitations for each are defined in the FAA inspector guidance (FAA 2019b, 6).

[15] Dimensions rounded to the nearest foot.

reciprocating, radial engines and Hamilton Standard full-feathering, three-blade propellers. It had a gross weight of 54,000 lbs and a cruise airspeed of 158 kts.

Accident Airplane

The accident airplane was manufactured in 1944 under license from Boeing by the Douglas Aircraft Corporation in Long Beach, California, and delivered to the US Army Air Force on July 12, 1945. The airplane was transferred to the US Navy on July 20, 1945, and the CAF acquired it in 1967 (see figure 9).

Figure 9. Accident Boeing B-17G. (Source: CAF)

On the day of the accident, the airplane completed two revenue passenger flights and an earlier air show performance before the accident flight.

The airplane was maintained under an Approved Airplane Inspection Program (AAIP) that was approved by the FAA on October 27, 2020, with a revision approved on February 25, 2021.[16] The airplane had accrued 9,239 hours total time before the accident.

A review of maintenance records revealed that the airplane's most recent AAIP inspection (inspection No. 1 in a sequence of four) was completed on November 1, 2022, at an airplane total time of 9,228 hours. Previous AAIP inspections were completed in September 2022 at a total time of 9,206.2 hours (inspection No. 4), August 2022 at a total time of 9,189.7 hours (inspection No. 3), and June 2022 at a

[16] The AAIP consisted of four sequenced inspections to be performed at 25-hour intervals. All four inspections were to be completed every 12 months and at least two were to be completed every 6 months. The AAIP also listed six special inspections with varying compliance times.

total time of 9,165.3 hours (inspection No. 2). Six specified special inspections were most recently completed in March 2022 at a total time of 9,116.7 hours.

The maintenance records showed compliance with three FAA airworthiness directives that applied to wing structure inspections and two that applied to the propellers.

1.3.2 Bell P-63F

General Design

The Bell P-63F was a single-engine, low-wing fighter airplane originally developed in the early 1940s for the US Army Air Forces. It was 33 ft long, 13 ft tall at the tail (when parked), and had a 38-ft wingspan. The airplane's primary and secondary wing, fuselage, and tail structures were of all-metal construction, and the elevators and rudder were fabric-covered, aluminum-skeleton structures. It was equipped with an Allison V-1710-135 12-cylinder, reciprocating engine and an Aeroproducts constant-speed, four-blade propeller. It had a gross weight of 8,800 lbs and a maximum airspeed of 360 kts.

Accident Airplane

The accident airplane, designated a Bell P-63F-1-BE, was manufactured in 1943 and was one of only two built. The CAF acquired it in 1981 (see figure 10).

Figure 10. Accident Bell P-63F. (Source: CAF)

The airplane arrived at KRBD on October 31 in preparation for the air show and was not flown again until the accident flight.

The airplane was maintained as an experimental aircraft, and the operating limitations required a condition inspection every 12 months. The airplane had accrued 1,232 hours total time before the accident.[17]

A review of maintenance records revealed the airplane's most recent condition inspection was completed on March 23, 2022, at an airplane total time of 1,211.6 hours, engine time of 217.3 hours, and propeller time of 171.7 hours. The records indicated that all applicable FAA airworthiness directives were checked for compliance through the date of the inspection.

1.4 Meteorological Information

Reported weather information for KRBD at 1253 included a temperature of 48°F (9°C), dew point of 25°F (–4°C), wind from 350° at 14 kts gusting to 18 kts, sky condition clear below 12,000 ft, and visibility of 10 statute miles or more.

1.5 Airport Information

KRBD, elevation 661 ft, was located 6 miles southwest of Dallas. The airport was owned by the City of Dallas and was serviced by an FAA air traffic control tower. At the time of the accident, the air boss had control of the waivered air space for the air show, which included runway 13/31.

At the time of the accident, KRBD had two paved landing surfaces for airplanes designated as runway 13/31 and 17/35. Runway 13/31 was 7,136 ft long and 100 ft wide, and runway 17/35 was 3,800 ft long and 150 ft wide. The air show used runway 13/31 for takeoffs and landings.

1.6 Wreckage and Impact Information

Most of the wreckage from both airplanes was concentrated in three main locations (with smaller pieces scattered between them) in a grassy area south of the approach end of runway 31. Some smaller, lightweight debris was located on and adjacent to US Hwy 67, which ran along the southeast end of the airport property. The full debris field was about 1,880 ft long by about 410 ft wide, generally aligned on a magnetic heading of 320°. All major flight control components for both

[17] Maintenance records indicated that the airplane had accrued 1,211.6 hours total time, at 212.3 hours Hobbs time, as of March 23, 2022. (A Hobbs meter is an instrument installed in an aircraft that tracks the elapsed time that the aircraft is being operated.) Flight logs showed that, for all flights since March 24, the duration of each flight was logged but the Hobbs time entered for each flight did not change. Adding the times for these flights to the March 23 totals resulted in 1,232 total hours.

airplanes were located in the debris field. Photographic and video evidence showed that both airplanes were intact and operating as designed before the collision.

The Boeing B-17G was found highly fragmented and with extensive fire damage to the forward half. Flight control continuity could not be established during examination due to the extent of the damage. The Bell P-63F was found in pieces with both wings, the propeller, gearbox, nose landing gear, and several parts of the fuselage separated from the airplane. Several pieces of the left wing's leading edge had significant crushing and mechanical damage. All four propeller blades were bent, had leading edge damage, and showed chordwise scratches, gouges, and paint transfer marks. Examination of the recovered flight control components from the cockpit to their respective surfaces found no evidence of precollision anomaly or failure.

An Avidyne IFD540 unit recovered from the Boeing B-17G and a Garmin GPSMAP 496 unit recovered from the Bell P-63F were sent to the NTSB's Vehicle Recorders Laboratory for examination (see section 1.8.2).

1.7 Medical and Pathological Information

The NTSB reviewed the FAA medical case review pertaining to the flight crewmembers of both involved airplanes. The Southwestern Institute of Forensic Sciences (SWIFS) in Dallas performed autopsies for all six personnel on board both airplanes. Both the FAA Forensic Sciences laboratory and the SWIFS performed toxicological testing of postmortem specimens from all personnel.[18]

According to the respective autopsy reports, the cause of death for each person was blunt force injuries. Evaluation for natural disease (such as of the brain, heart, and lungs) was limited in some cases due to injury severity.

1.7.1 Boeing B-17G Crew

1.7.1.1 Pilot

The pilot's most recent aviation medical examination (September 2, 2022) identified no significant issues, and he reported no medication use at that time. According to his autopsy report, his coronary arteries exhibited mild-to-moderate

[18] The FAA Forensic Sciences laboratory has the capability to test for around a thousand substances, including toxins, prescription and over-the-counter medications, and illicit drugs (FAA 2019a).

narrowing by plaque. The remainder of his limited autopsy, which included visual examination of the heart, did not identify any other significant natural disease.

The FAA's postmortem toxicological testing for the pilot detected meclizine in liver tissue and cavity blood; the SWIFS's testing detected no tested-for substances in chest cavity blood. Meclizine is a sedating antihistamine medication available over the counter for prevention and treatment of dizziness, nausea, and vomiting associated with motion sickness or to treat vertigo symptoms caused by inner ear problems. It typically carries a label warning that it can cause drowsiness and may adversely affect a user's ability to safely drive a motor vehicle or operate machinery. FAA guidance states that, for any drug with that warning (including any sedating antihistamine), a pilot who uses it should observe a waiting period for the drug to be cleared from circulation before flying (FAA 2023). According to the FAA medical case review for this accident, a pilot should not use meclizine within 36 hours before flying, and the FAA considers regular use by a pilot (as opposed to occasional use) to be unacceptable.

1.7.1.2 Copilot

At the copilot's most recent aviation medical examination on October 21, 2022, he reported using the prescription medication tamsulosin.[19] He also reported a history of seasonal, environmental allergies and asthma, conditions for which he had received an FAA letter of eligibility for first-class medical certification in 1999. His autopsy, as limited, did not identify significant natural disease.

The FAA's postmortem toxicological testing for the copilot detected no ethanol in brain or liver tissue and detected tamsulosin and dextromethorphan in muscle and liver tissue. The SWIFS's testing identified ethanol in a muscle tissue specimen at 0.027 g/hg.[20] Ethanol, if consumed, can impair judgment, psychomotor performance, cognition, and vigilance (Cook 1997, 539-55).[21] Consumption is not the only possible source of ethanol in postmortem specimens; ethanol can be produced by microbes in a person's body after death.[22] Tamsulosin is not generally considered impairing. Dextromethorphan, a cough suppressant medication that is available over

[19] Tamsulosin is a prescription medication used to treat the symptoms of an enlarged prostate or kidney stones.

[20] In tissue, concentrations in g/hg are approximately equivalent to concentrations in g/dL. Title 14 *CFR* 91.17 prohibits pilots from flying with a blood ethanol level of 0.04 g/dL or greater.

[21] Ethanol is a type of alcohol and includes the intoxicating alcohol in beer, wine, and liquor.

[22] Such production is made more likely by extensive traumatic injury and can cause an affected toxicological specimen to test positive for ethanol while another specimen from the same person tests negative.

the counter in a variety of cold and allergy products, is not typically impairing at levels associated with medicinal use. FAA guidance states that pilots who use it should observe a waiting period for the drug to be cleared from circulation before flying (FAA 2024b).

1.7.1.3 Flight Engineer

At the flight engineer's most recent aviation medical examination on August 25, 2022, he reported a history of seasonal/environmental allergies and no medication use. His autopsy did not identify significant natural disease.

The FAA's postmortem toxicological testing detected ethanol at 0.023 g/hg in liver tissue, no ethanol in brain tissue or vitreous, and meclizine and naproxen in muscle and liver tissue. The SWIFS's testing (which included testing for ethanol) detected no tested-for substances in blood and vitreous. Ethanol and meclizine are described in the previous section. Naproxen is not generally considered impairing.[23]

1.7.1.4 Scanners

As stated in section 1.2.1.4, no FAA medical certification was required for the individuals acting as scanners. Their respective autopsies, as limited, did not identify significant natural disease.

The FAA and SWIFS performed postmortem toxicological testing of specimens from both scanners. For one scanner, rousouvastatin was detected.[24] For the other scanner, diazepam (and its metabolite nordiazepam), diphenhydramine, chlorpheniramine, amlodipine, valsartan, metoprolol, and timolol were detected.[25]

1.7.2 Bell P-63F Pilot

The pilot's most recent aviation medical examination (November 1, 2022) identified no significant issues, and he reported no medication use and no active

[23] Naproxen is an anti-inflammatory medication available over the counter and commonly used for control of pain and fever.

[24] Rosuvastatin is a prescription statin medication commonly used to control cholesterol and reduce cardiovascular risk. It is not generally considered impairing.

[25] Diazepam is a potentially impairing prescription benzodiazepine medication. Diphenhydramine and chlorpheniramine are potentially impairing sedating antihistamine medications available over the counter. Amlodipine, valsartan, and metoprolol are prescription medications that can be used to treat conditions including high blood pressure, and timolol is a prescription medication with uses including topical treatment of glaucoma. Amlodipine, valsartan, metoprolol, and timolol are not generally considered impairing.

medical conditions at that time. According to his autopsy report, his coronary arteries exhibited mild-to-severe narrowing by plaque.[26] The remainder of his limited autopsy, which included visual examination of heart muscle, did not identify any other significant natural disease.

The FAA's and the SWIFS's postmortem toxicological testing for the pilot did not detect any tested-for substances in the urine (FAA) and muscle tissue (SWIFS).

1.8 Tests and Research

1.8.1 Video Study

As stated in section 1.1, a witness in the crowd with a hand-held camera captured video that showed the collision. The NTSB performed a video study to estimate the aircraft orientation angles (roll, heading, and pitch) and altitudes (in agl) of the Boeing B-17G and Bell P-63F up to the time of the collision.

The video began 4.5 seconds before the collision and captured imagery at a rate of 30 frames per second. The video analysis was performed from video time 1.4 seconds to video time 4.5 seconds because the visibility of the Bell P-63F during the first 1.4 seconds of the video was poor. A still frame from the video at 0.63 seconds before the collision showed the Bell P-63F in a left turn behind and off the left side of the Boeing B-17G (see figure 11).

[26] Specifically, 85–95% narrowing of the first diagonal branch artery, 50–75% narrowing of the right coronary artery, 25–60% narrowing of the left circumflex coronary artery, and 25–50% narrowing of the left anterior descending coronary artery.

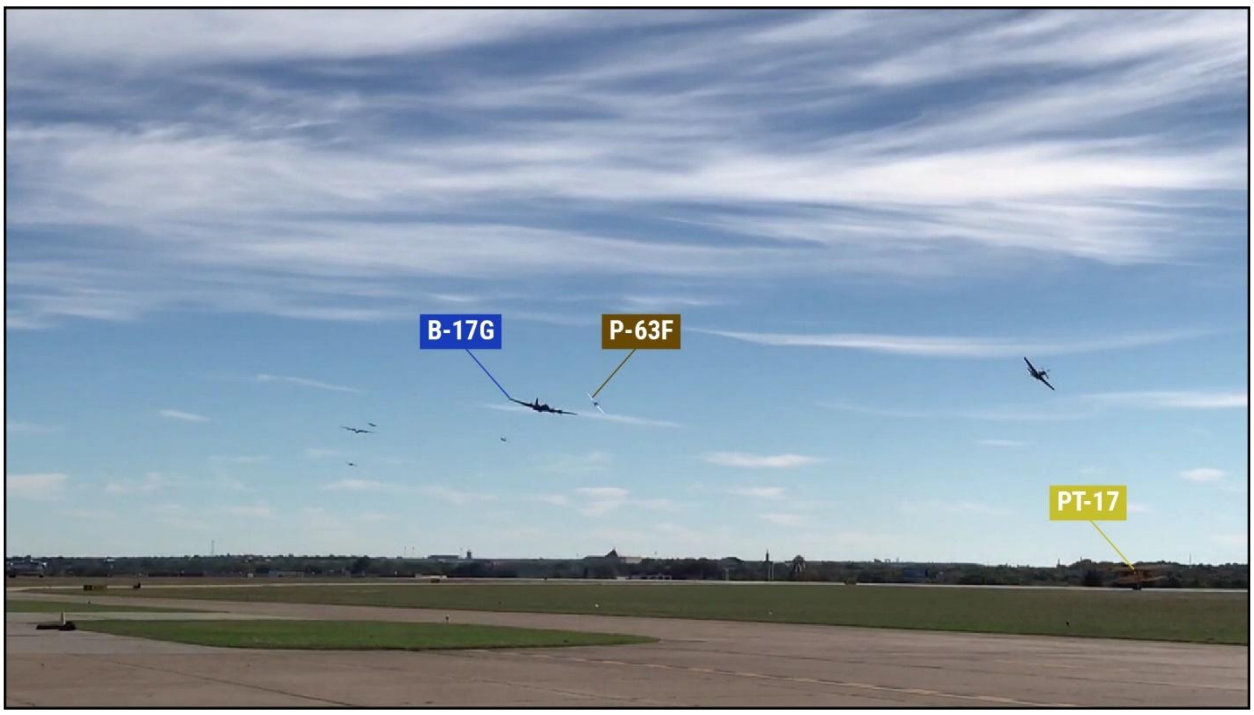

Figure 11. Video frame recorded 0.63 seconds before the collision showing the Bell P-63F in a left turn behind and off the left side of the Boeing B-17G. The revenue ride flight Boeing PT-17 is on the runway.

The video analysis used a mathematical model of the optics of the camera that recorded the video. Accurate ADS-B ground track data for the two airplanes were used to verify the accuracy of the video-based ground-track locations and estimates of the airplanes' altitudes (in agl) and roll angles. Airplane heading and pitch estimates were relatively less accurate because both airplanes were flying approximately toward the camera. The aircraft performance study used the aircraft orientation estimates to support the aircraft visibility simulation. (See section 1.8.2.2.)

1.8.2 Aircraft Performance Study

1.8.2.1 Flight Paths and Airspeeds

As stated in section 1.1, ADS-B data were available for seven of the eight airplanes in the performance (all but the bomber in position 5), as well as the CAF-operated Boeing PT-17. Additional data were obtained from an Avidyne IFD540 unit recovered from the Boeing B-17G. An NTSB aircraft performance study used the available data as the basis to plot the airplanes' flight paths and determine their groundspeeds (which were used as a basis to calculate calibrated airspeeds using wind and meteorological conditions) and altitudes in feet agl. The airplane flight path information discussed in section 1.1 and shown in figures 2 through 7 came from the

study. Figure 12 shows the flight paths of the Boeing B-17G and the fighter formation from takeoff to the time of the collision.

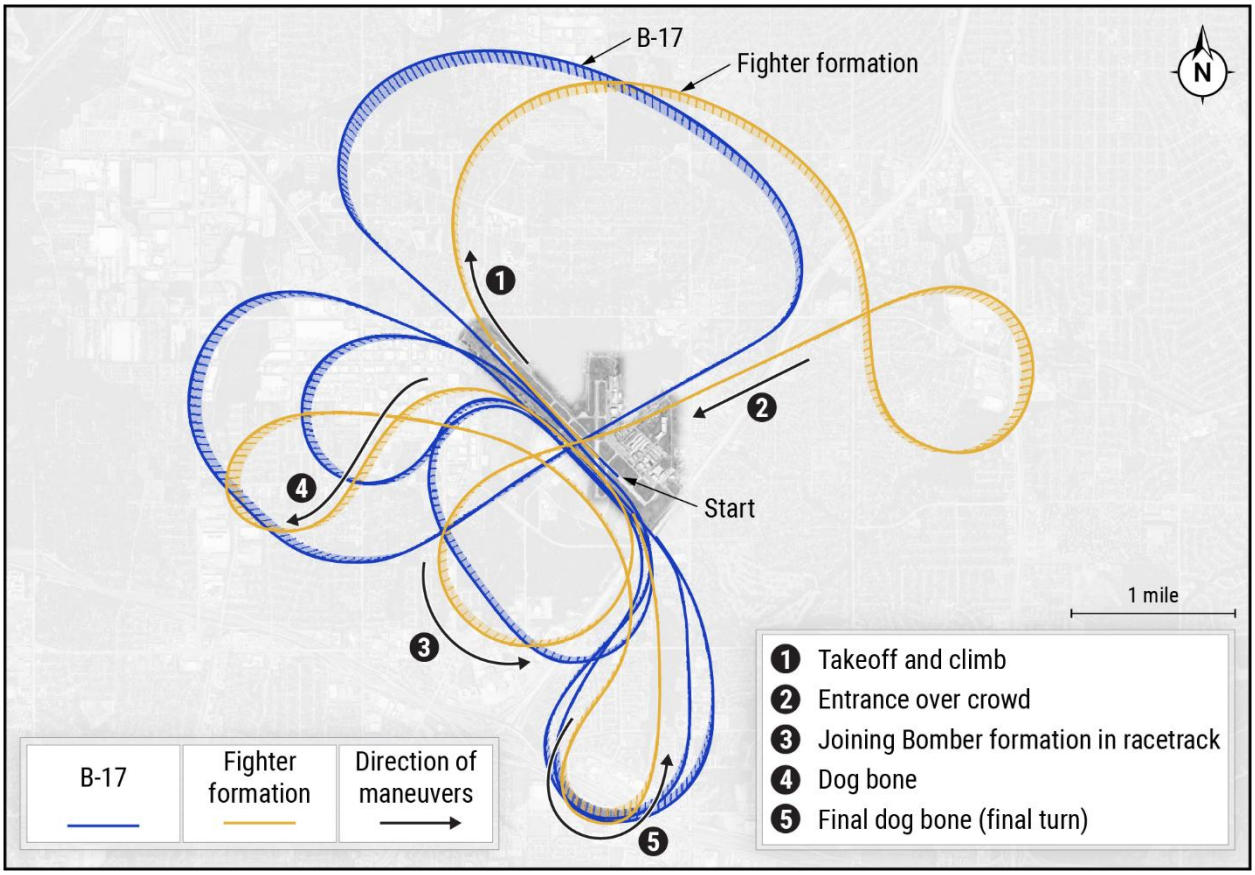

Figure 12. Boeing B-17G flight path (blue) and fighter formation flight path (yellow) during the performance.

Note: Repositioning maneuvers are labeled in sequence and with directional arrows.

The study determined that, generally, during each pass, the pilots of the bombers (the four for which data were available) flew along the 1,000-ft show line, descending their airplanes to between 200 ft and 500 ft agl, then climbing during the repositioning turns, remaining below 1,000 ft agl. The Boeing B-17G was the slowest of the bombers, with airspeeds varying between 110 kts and 170 kts. The other bombers' airspeeds varied between 130 kts and 190 kts. The crew of the Boeing B-17G made smaller, tighter repositioning turns than the other bombers to maintain its position as the group lead. Figure 13 shows the altitudes and airspeeds of the bombers from 1314 to 1322.

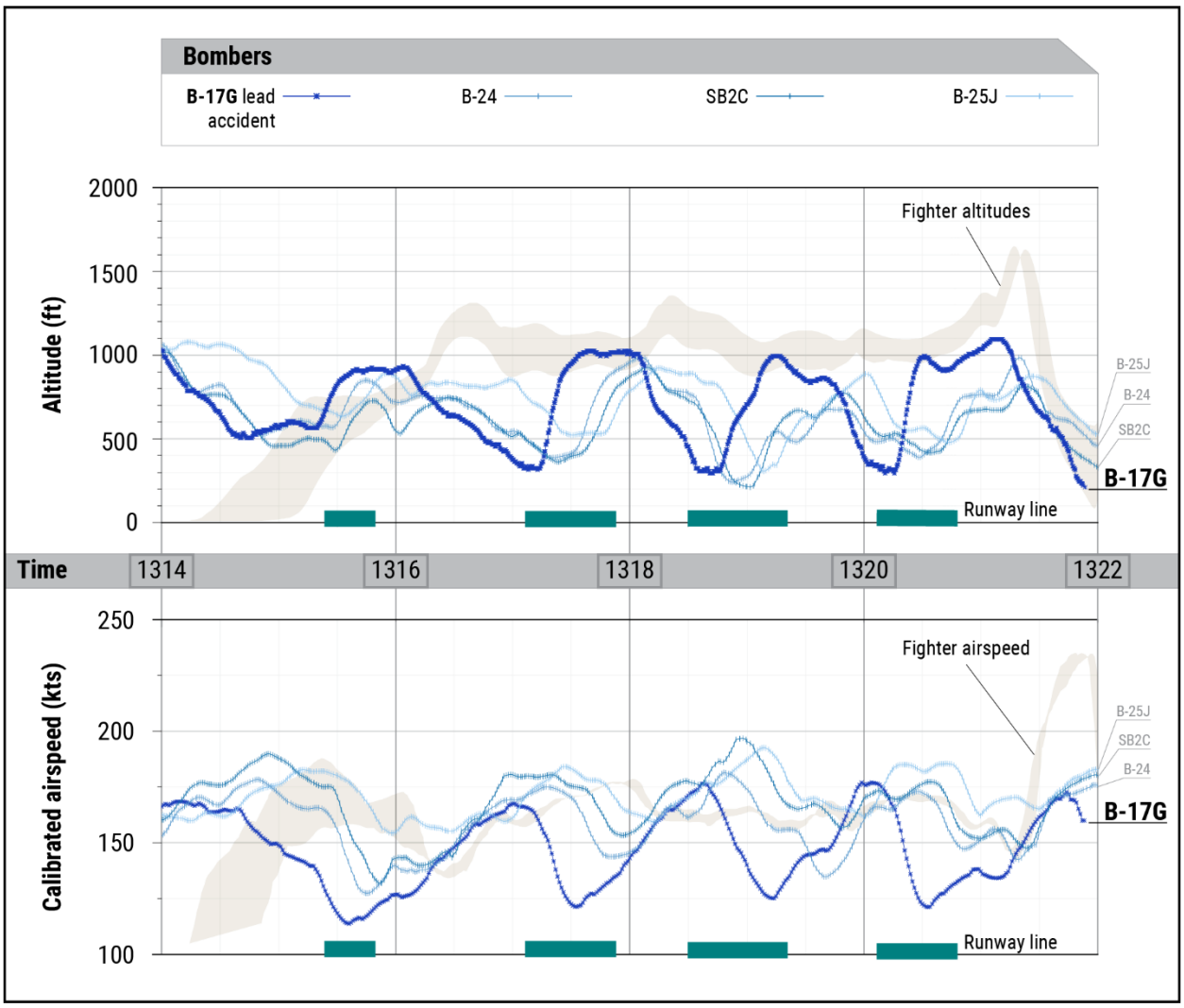

Figure 13. Bomber airplane altitudes and airspeeds from 1314 to 1322.

Note: The times that the bombers performed passes parallel to the runway are noted. (For comparison, the airspeeds and altitudes of the fighter airplanes are shown in gray.)

The pilots in the fighter formation generally flew their airplanes between 800 ft and 1,300 ft agl. Each pilot kept their fighter airplane in close formation with their airspeeds evenly matched and maintained about 100 ft of altitude separation between each fighter airplane throughout most of the performance (with the pilot of the Bell P-63F flying the lowest of the three). While flying with the bomber group, the fighters' airspeeds varied between 150 kts and 170 kts until the final turn for the next intended pass, for which the air boss directed the fighter formation pilots to "get in front of" the bombers (see figure 14).

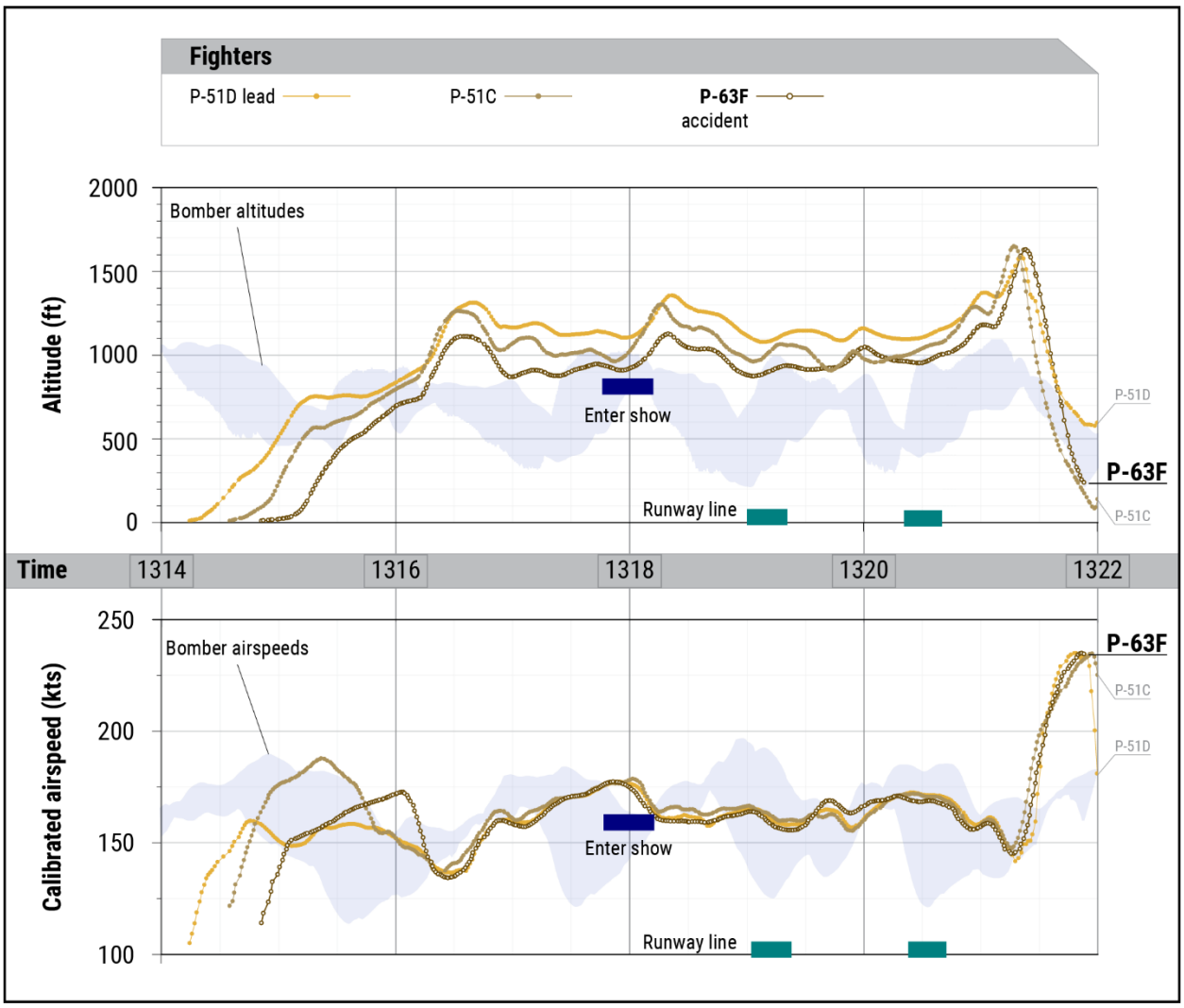

Figure 14. Fighter airplane altitudes and airspeeds from 1314 to 1322.

Note: The times that the airplanes entered the show and performed passes parallel to the runway are noted. (For comparison, the airspeeds and altitudes of the bomber airplanes are shown in gray.)

The study determined that the fighter lead passed left of the Boeing B-17G at 1321:38, at a higher altitude and with about 1,600 ft lateral separation. At the time, the fighter lead was at 880 ft agl and 200 kts, and the Boeing B-17G was at 550 ft agl and 170 kts. The fighter in position 2 passed left of the Boeing B-17G at 1321:45, at a lower altitude and with about 1,000 ft lateral separation. At the time, the position 2 fighter was at 320 ft agl at 220 kts, and the Boeing B-17G was at 425 ft agl and 170 kts.

The Bell P-63F was descending at a rate of 1,500 ft per minute, and its airspeed was just above 230 kts shortly before the collision. The Boeing B-17G was also descending, but at a slower rate, and its flight path was curving toward the 1,000-ft

show line. As stated in section 1.1, the Bell P-63F's flight path closely followed the fighter in position 2 until about 1321:47, when its flight path no longer curved toward the 1,000-ft show line but became somewhat straighter.

1.8.2.2 Visibility Simulation

As stated in section 1.8.1, the aircraft performance study used the video study's estimates of the airplanes' altitudes and roll angles to support a visibility simulation that evaluated what opportunity the pilots of the Boeing B-17G and Bell P-63F may have had to see the other airplane before the collision.[27] The visibility study used flight simulation software to simulate the flights of the two accident airplanes and the other two fighter airplanes from 1321:20 until the collision.

The visibility simulation determined that, at 1321:39 (which corresponds with the time that the air boss asked the Boeing B-17G crew if they could see the fighters in front and off to the left), the simulation showed that the model fighter lead and position 2 fighter were in view through the model Boeing B-17's forward left side window, and the model Bell P-63 was visible through the aft left side window (which, in the Boeing B-17G, would be behind the pilot's left shoulder) (see figure 15).

[27] What a pilot can see from the flight deck of an actual airplane depends on the pilot's stature and positioning. For example, whether the pilot is taller or shorter or leaning forward versus sitting back affects how the airplane structure obscures the outside view.

Figure 15. Simulation view from the flight deck left side windows of the model Boeing B-17 at 1321:39, showing the respective locations of the three model fighters.

From 1321:44 to 1321:52, the view of the model Bell P-63 was obscured by the structure between the model Boeing B-17's forward and aft left side windows.[28] The model Bell P-63 could not be seen again in any view from the model Boeing B-17's flight deck until 1321:53, when it became rapidly visible from the left side windows (see figure 16).

[28] Examination of an exemplar Boeing B-17 flight deck showed that the pilot's seat back was even with the structure between the forward and aft left side windows.

Figure 16. Pilot's forward (top image) and left side (bottom image) simulation views from the model Boeing B-17 flight deck at 1321:53, showing the respective locations of the three model fighters.

The visibility simulation determined that the model Boeing B-17 was visible from the model Bell P-63's flight deck from 1321:22 to 1321:24 (visible through the front window) and from 1321:34 to 1321:50 (visible through the right side window), but it was likely blocked from view from 1321:50 up to the collision at 1321:54 (see figure 17).[29]

Figure 17. Simulation view from the flight deck of the model Bell P-63 at 1321:50, showing the locations of the model Boeing B-17 and the two other model fighters.

The visibility simulation study also considered the accident airplanes' calculated closure rate and their respective azimuth angles to assess the relative motion of the Boeing B-17G at the times corresponding with when the model

[29] Examination of an exemplar Bell P-63 flight deck and a photograph of the accident airplane being taxied showed that the pilot's seat back was about in line with the rear of the side window and the pilot's eyes were level with the side window's upper frame (in the front-to-back center of the side window). This indicates that much of the side window would be in the pilot's peripheral vision such that looking out may require turning the head.

Boeing B-17 was visible from the model Bell P-63's flight deck.[30] (Relative motion of an object in a person's field of view affects whether the object is perceived. An object that moves with the observer such that it remains stationary in their view is less likely to be perceived compared to an object that is moving in the field of view.)

From 1321:22 to 1321:24 (when the model Boeing B-17 was visible through the model Bell P-63's front window), the Boeing B-17G's azimuth angle (position in the observer's field of view) was changing, but the closure rate (how quickly the two airplanes were moving toward each other) was near zero, indicating that it moved through the field of view but did not change size. From 1321:34 to 1321:50 (when the model Boeing B-17 was visible through the model Bell P-63's right side window), the Boeing B-17G's azimuth angle showed little change, indicating little relative motion, but the closure rate was increasing (consistent with the increasing size of the model Boeing B-17 in the simulation).

Further, the simulation determined that the model Boeing B-17 (which was colored the same as the accident airplane's paint scheme), when viewed from above, was difficult to discern against the simulated ground features at times due to the olive-drab color on most of the airplane's upper fuselage and wings.[31]

1.8.3 Audio Recording Timing Correlation

The federal contract tower at KRBD provided a certified copy of the audio recording of the radio communications on the air show radio frequency from 1250 to 1344. The recording consisted of one channel of audio information from the air show radio frequency and one channel of a spoken timecode (in universal coordinated time) every 20 seconds.

An NTSB investigative group's review of the certified recording identified inconsistencies in the time spacing of the recording's timecode, which indicated that, during the production of the recording, long-duration silences had been removed (a

[30] Closure rate is how quickly the airplanes were moving toward each other, and azimuth angle refers to where the airplane is from the observer's field of view. For example, an object directly ahead is at 0° of azimuth, an object to the right is at 90°, directly behind is at 180°, and to the left is at 270° of azimuth.

[31] A pilot's visual acuity and focus greatly affect what is visible. On average, in ideal conditions, a person can see an object that spans at least 0.01° of their field of view when looking directly at the object (Velasco e Cruz 1990, 661). This is also influenced by the person's age and focus, as well as the object's color, contrast with the background, and illumination. At the time that the Boeing B-17G was used in military service, paint schemes that were olive drab above and neutral gray below were used to camouflage airplanes. The olive drab would visually blend with the ground when viewed from above, and the gray would visually blend with the sky when viewed from below.

recording production feature used to condense audio recordings). The investigative group produced a transcript of the communications from the beginning of the recording to just after the accident. The transcript provided recording elapsed time for all communications in sequence and included local time for those communications that could be correlated with the spoken time code.

1.8.4 Electronic Recorder Devices

An impact- and fire-damaged Avidyne IFD540 (flight management system, GPS, and navigator) device was recovered from the Boeing B-17G and examined by the NTSB's recorders laboratory. The laboratory extracted data from the device's internal compact flash card, which included data for the accident flight. The data included groundspeed, ground track, altitude above mean sea level (msl), pressure altitude, and other parameters.

An impact-damaged Garmin GPSMAP 496 (portable GPS with a built-in aviation navigation publications database) was recovered from the Bell P-63F and examined by the NTSB's recorders laboratory. The laboratory extracted data from the device's nonvolatile memory chip and determined that the device's track log recording function had likely been inactive since 2014. No track log data for the accident flight were recorded on the device.

1.9 Organizational and Management Information

1.9.1 Commemorative Air Force

The CAF, headquartered in Dallas, is a 501(c)(3) nonprofit "founded to acquire, restore, and preserve in flying condition a complete collection of combat aircraft which were flown by all military services of the United States, and selected aircraft of other nations, for the education and enjoyment of present and future generations of Americans." The CAF's mission is to "educate, inspire, and honor through flight and living history experiences" and its objectives included using its aircraft to "recreate, remind, and reinforce the lessons learned from the defining moments in American military aviation history" (CAF 2024).

The FAA certificate of waiver for the Wings Over Dallas air show was issued to the CAF as the "event organizer," which the FAA defines as "the person or agency responsible for the organization and conduct of the aviation event" (FAA 2020a, 11). The waiver listed the CAF's air show chairman (see section 1.9.1.3.3) and the air boss (see section 1.9.2) as responsible persons.

At the time of the accident, the CAF had a fleet of more than 175 aircraft across 82 units within the United States, Canada, New Zealand, United Kingdom, France,

and Switzerland. According to the CAF's director of operations, CAF aircraft operations included air show performances, air tour rides, and positioning aircraft for static displays at various locations. The CAF's chief aviation officer and the director of operations were among the CAF's paid staff positions; all CAF pilots were volunteers and CAF members, which required payment of a membership fee.

1.9.1.1 Pilot Standardization and Evaluation

The CAF conducted US operations under 14 *CFR* Part 91. According to the director of operations, most CAF pilots were either current or retired airline or military pilots who had an understanding of and respect for professional aviation training. He said that most held either a commercial or airline transport pilot certificate.

The director of operations maintained all CAF manuals, policies, and procedures online, and all CAF members (pilots, mechanics, and others) had access to them. These included a general operating manual with an appendix that contained CAF guidance on flying in air shows. The CAF's standardization and safety committee monitored pilot performance and adherence to standards and performed recurrent reviews of the policies in their safety program.

The CAF used a specialized software program to continuously track pilot qualifications such as flight times, check rides, and aircraft flown. The CAF's standardization and safety committee used the program as a primary tool for tracking pilot performance and making suggestions for the director of operations to consider, such as recommending pilot upgrades to instructor pilot. The program also tracked aircraft maintenance status.

The chief aviation officer said he attended the International Council of Air Shows Inc. (ICAS) and National Warbird Operators conferences each year to discuss safety topics with air show event organizers and other warbird operators.

1.9.1.2 Safety Program

The CAF's safety program was structured as a voluntary safety management system (SMS) and applied to all CAF members and unit staff officers. The SMS guidance document, dated January 2017, was approved by the CAF president. It described the purpose of the program, how aspects of the program aligned with the four pillars of SMS, the CAF's anonymous flight safety and ground hazard reporting program, and the areas of CAF operations identified as having an increased potential for risk. The chief aviation officer said that CAF pilots were introduced to the CAF's SMS in ground school and that the CAF used periodic safety videos, safety bulletins, presentations, and webinars to communicate safety information.

The chief aviation officer said that he and the director of operations had an open-door policy, and they both routinely fielded calls from CAF units. He said that he received calls at all times of the day and night about various issues, such as maintenance issues with specific aircraft or pilot concerns about policy or other personnel. He said he did not receive any anonymous safety reports in the year before the accident, but he was confident that CAF members were aware of the option to submit such a report.

The chief aviation officer stated that, after the accident, he discovered that four CAF pilots who had flown in the Wings Over Houston air show 2 weeks before the accident (October 29-30, 2022) had safety concerns with directives issued by that air boss.[32] He said he learned that the four pilots had met over dinner and complained to each other about the Wings Over Houston air boss, but they did not voice their concerns to him (the CAF chief aviation officer) until after the Wings Over Dallas accident (see section 1.10.2.1).

According to the vice chairman of the Wings Over Houston air show, he and some other pilots were upset with the Wings Over Houston air boss after participating in that show and experiencing what they felt were "freeform" directives during both days of the air show.[33] The Wings Over Houston vice chairman was also a commercial airline pilot, CAF instructor pilot, and CAF pilot standardization and evaluation committee member.

The Wings Over Houston vice chairman stated that, during Wings Over Houston, he flew in the right seat of a CAF bomber (with the left-seat pilot flying) during a Sunday performance that included multiple bomber and fighter airplanes, some of which were from other museums or privately owned. He stated that, during that performance, the Wings Over Houston air boss instructed the pilot of a privately owned fighter airplane to do a maneuver that he found to be unusual and that the air boss had not discussed during the morning briefing. He stated that the air boss's "freeform" directive resulted in the fighter airplane crossing in front of his crew's airplane and the bomber they were following. He said that he saw the fighter coming from right to left at the same altitude, and he informed the pilot flying that the fighter would be passing in front of their airplane and told him to keep flying his line. He said

[32] He said that the Wings Over Houston air boss was the father, mentor, and air boss company partner of the Wings Over Dallas air boss. The Wings Over Dallas air boss had assisted his father with some aspects of the Wings Over Houston show but did not issue the directives about which the pilots were concerned. In this report, "Wings Over Houston" and "Wings Over Dallas" refer to the air shows conducted in 2022, unless otherwise noted.

[33] He said he did not know the specifics but became aware that some CAF pilots who had flown on Saturday during Wings Over Houston had "expressed extreme displeasure" directly to the Wings Over Houston air boss about "the freeform that took place on Saturday."

he knew that the fighter airplane was not going to collide with their airplane, but he "didn't want [the pilot flying] to be surprised" by it and react by pulling up or doing some other maneuver.

He said that he and other pilots who saw what happened "were not happy," and they talked about it among themselves. When asked if he or any of the other pilots debriefed their concerns to anyone else, he stated that debriefs typically did not occur on the last day of an air show. He said that he did not inform the CAF director of operations or submit an anonymous feedback report and did not inform the CAF chief aviation officer until after the Wings Over Dallas accident. He said that, in retrospect, he wished he would have voiced his concerns to the CAF chief aviation officer sooner. He noted that the two air bosses ran their shows and conducted their preshow briefings similarly.

1.9.1.3 Air Show Operations

CAF pilots participated in various air shows each year, some of which were hosted by other event organizers, held at locations other than an aircraft's base, or included performances that combined CAF-operated aircraft with warbirds operated by other museums or private owners. Numerous CAF pilots were qualified on more than one CAF airplane, and, during some air shows, the same airplanes would be featured in certain performances each day but would be flown by different pilots. Different types of CAF performances were featured at Wings Over Dallas, including air boss–directed performances (like the accident performance) and an approved maneuvers package, which was a defined routine that was flown with no input from the air boss. (Both types of performances are discussed below.)

1.9.1.3.1 Performances Involving Multiple Airplanes Directed by Air Boss

According to one CAF pilot experienced with flying warbirds in air shows, it was not unusual for warbird performances involving multiple airplanes to have a mix of bombers and fighters, and it was not unusual for the bombers to fly racetracks and 90°/270° (dog bone) turns between passes. (This is the same pilot who was also the Wings Over Houston vice chairman, as discussed in section 1.9.1.2.) He said that, typically, the fighters would remain at higher altitudes than the bombers, and the altitudes would be discussed ahead of time with the air boss. He said that, for such performances, "the air boss will provide direction [during the performance], control the timing, [and] resolve conflicts…with other airplanes."

According to the pilot of the Consolidated B-24 bomber in position 2 during the accident performance (who had also flown in numerous air shows in various CAF aircraft), such performances were not particularly complicated to fly. He said that, before the Wings Over Dallas air show, the bomber group pilots for the accident performance discussed what order they should fly in trail, taking into consideration

the mix of aircraft with different airspeeds and performance characteristics. He said it was not difficult to follow another airplane in trail, noting that the considerations involved engine power settings and turn strategies for maintaining spacing.

He said that, generally, during a performance like the accident performance, the air boss did the choreography, and the pilots did what they were told. He said that, during the accident performance, he did not know the fighter formation was going to pass the bomber group until he heard the air boss call for it. He said that, as the position 2 bomber pilot, his focus was on following the Boeing B-17G. He stated that, generally, performers in one group (like the bombers) would maintain general awareness of the directives issued to another group (like the fighter formation) but would not necessarily keep track of the specifics unless the air boss called something to their attention.

1.9.1.3.2 Approved Maneuvers Package

The CAF had one approved maneuvers package, a performance called *Tora! Tora! Tora!*, which was flown earlier on the day of the accident. The performance involved bomber, fighter, and trainer airplanes performing a set of maneuvers that were flown in sequence with no communications from the air boss (other than to direct the performance to start), and it included coordinated pyrotechnics and a scripted narration for the crowd.

According to the CAF director of operations, the approved maneuvers package was rehearsed and performed the same way each time. He said that the performance was very disciplined and that aircraft deconflictions were accomplished by performers flying their airplanes "at particular positions at particular times." He noted that the accident Bell P-63F pilot, who had flown a trainer airplane during the *Tora!* performance earlier on the day of the accident, was a very experienced pilot who was very active with the *Tora!* performances (which were also performed at other air shows, including Wings Over Houston). He said that, during an approved maneuvers package performance, it's very important for the performers to be where they're supposed to be because that's how aircraft separation is maintained.

1.9.1.3.3 Air Show Chairman for Wings Over Dallas

The CAF's air show chairman for Wings Over Dallas had been working with air shows since 2000. Her role involved obtaining the waiver for the air show; hiring the air boss, the announcer, the sound system technicians, and any non-CAF performers; and handling all the logistics for the concessions and anything else needed on the grounds for the event. Her responsibilities also included working with local emergency response personnel (including participating in tabletop exercises), inviting visiting CAF performers who were not local to the area, and arranging for lodging, rental cars, and other needs. She was a CAF member who was compensated

for her work on Wings Over Dallas, which she had chaired four times. She had been on committees or consulted for other air shows numerous times.

The Wings Over Dallas air show chairman said she knew most of the performers, and they were all very experienced. She had known the air boss for a long time and had hired him for at least 10 shows. She said she knew his capabilities, was comfortable with his performance, and liked the way he handled things, noting that he was a "perfectionist." She said that she hired air bosses based on her knowledge of them, their performance, and the feedback that performers provided about them.

She said that, when working with an air boss, she provided him with the list of performers and a schedule of which ones she would like to see flying and when, and he adjusted it and made suggestions, as needed, mindful of keeping the action going for the crowd.

1.9.1.4 Revenue Ride Programs

According to CAF's chief aviation officer, the CAF provided revenue rides under Part 91 through two programs: an LOA, which applied to standard-category airplanes, and an FAA-issued living history flight experience (LHFE) exemption, which applied to limited and experimental category airplanes.[34] The North Texas FAA flight standards district office provided oversight of both programs. The CAF's chief aviation officer stated that the CAF had about 88 airplanes listed on LOA 01147, which included trainer airplanes like the Boeing PT-17. The CAF's LHFE exemption 6802T listed 23 aircraft, including numerous bombers, several fighters, and a few trainer airplanes.

The CAF's chief aviation officer stated that ride flights were a way for different CAF units to generate revenue with their airplanes if they chose to participate, noting

[34] The FAA may grant an LHFE exemption to authorize an operator of certain historically significant, former military aircraft to provide passengers with short in-flight experiences for compensation. The safety of LHFE flight operations and related FAA oversight were the subject of two NTSB safety recommendations issued in 2021, which were supported, in part, by our investigation of a fatal accident in 2019 involving a Boeing B-17G operated as an LHFE flight (NTSB 2021a and case ERA20MA001). Safety Recommendation A-21-9 asked the FAA to develop national safety standards for LHFE and other revenue passenger-carrying operations conducted under Part 91. In response, the FAA stated that it was assessing the feasibility of the recommendation and considering whether rulemaking would meet the applicable cost-benefit guidelines. Safety Recommendation A-21-9 is classified Open—Acceptable Response. Safety Recommendation A-21-11 asked the FAA to develop guidance for inspectors who oversee LHFE operations. In response, the FAA updated its guidance, training, and surveillance activities for inspectors to help inspectors ensure that LHFE exemption holders comply with regulations, the conditions and limitations of the exemptions, and manual systems that apply to their operations. As a result of these responsive actions, the NTSB classified Safety Recommendation A-21-11 Closed—Acceptable Action on July 8, 2024.

that fuel costs alone are high. He said that some units don't have enough pilots or resources to offer revenue rides but that, for those that do, it "helps pay the bills." He said that units are required to submit a percentage of their revenue to headquarters, which helps pay for such things as insurance and personnel costs.

The CAF's chief aviation officer said that he was not in favor of having any rides operating during the Wings Over Dallas air show (that is, during the time that the airspace waiver was active). He further stated that he "acquiesced" to allow them after having received a lot of "pushback" and "pressure from a lot of high-up people," including the Wings Over Dallas air boss, to try to fit in some ride flights during the show.[35] He said that he authorized rides to occur as long as they did not take off or land while another act was flying. The CAF's air show chairman for Wings Over Dallas stated that she was aware that rides would be occurring and that the rides were coordinated through the air boss and briefed.

The CAF's chief aviation officer stated that, after the accident, he saw the video that showed the CAF-operated Boeing PT-17's ride flight touching down at the same time as the collision.[36] He also learned postaccident that another CAF-operated ride flight (the Beechcraft T-34B discussed in section 1.1) landed during the accident performance. He said that those rides were not supposed to be landing while performance acts were flying.

1.9.2 Air Boss

According to FAA guidance, the air boss's responsibilities included the control of air show operations on the active taxiways, runways, and the air show demonstration area; coordination with the jurisdictional air traffic control facility and the FAA inspector-in-charge (IIC) for the air show; establishing the transition of airspace and control of participating and nonparticipating aircraft; and preparing and presenting a daily Air Show Participants Safety Briefing (FAA 2020a, 5 and

[35] He stated that, in years past, air shows were much longer and had long periods of time between acts, and he would allow rides to occur because they could depart, fly around, and return between acts while also giving the crowd something to see. He said that the current air show format (like that of Wings Over Dallas) is much more condensed, such that the air boss has control of the air space the entire time.

[36] He stated that, at first, he thought the ride was a senior pilot ride (part of the CAF endorsement process for a pilot to be approved to fly in an air show) but later found out that it was a revenue ride flight. Based on CAF pilot interviews, both the accident Boeing B-17G and the position 2 bomber from the accident performance also flew revenue rides earlier in the day. It was not clear from the interviews whether those rides took off or landed while any other act was performing.

2019b, 1).[37] The air boss of the accident performance had provided his services for the Wings Over Dallas air show numerous times before. He said that, generally, he received air boss work primarily through referrals but has also met connections at the annual ICAS convention.

1.9.2.1 Air Show Participants Safety Briefing

The air boss began the required safety briefing about 0800, and members of the accident Boeing B-17G crew, the other bomber crews, and all three fighter pilots (including the accident Bell P-63F pilot) attended. (Attendance was mandatory for all single-pilot performers, but members of a crew could have a representative attend.[38]) The FAA IIC of the air show also attended, as required (see section 1.9.3.1).

The air boss used a PowerPoint presentation to provide an overview of the air show that included discussions of the waiver, airfield and airspace, radio frequencies (main and secondary), the performance schedule, and other information. A postaccident review of the presentation revealed that the airspace slides included maps showing traffic flow patterns to the airport depending on wind direction, landmarks along the perimeter of the airspace boundary to use for reference and locations of holding patterns, and the locations of the show lines. One slide showed a satellite map view from one of the boundary markers to the airport and listed distance and times it would take an airplane traveling at various speeds to arrive at the center of the airport.

According to the air boss's Flight Demonstration Sequence sheet, the air show was to start at 1050, and six performances were scheduled to precede the accident performance. The accident performance (listed as "warbirds") was scheduled to begin at 1305 and included "bombers launch," "fighters launch," and "passes per [air

[37] The guidance, FAA Order 8900.1, directs the activities of FAA aviation safety inspectors and other flight standards service personnel. Its primary audience consists of FAA inspectors, their managers, and supervisors, but the aviation industry may use it as a reference (FAA 2022, 1). Previous FAA guidance for "prospective aviation event sponsors and other interested parties" was contained in Advisory Circular (AC) 91-45C, "Waivers: Aviation Events," which was issued in 1990 (FAA 1990). In 2012, the NTSB issued Safety Recommendation A-12-8, which asked the FAA to, in part, revise AC 91-45C to correct inaccurate and incomplete information and reconcile all the differences and inconsistencies between it and FAA Order 8900.1. In 2020, the FAA informed us that it updated the order but canceled AC 91-45C because it was "significantly outdated" (FAA 2020b). We responded that, although the FAA did not revise AC 91-45C as recommended, we believed canceling the AC, along with updating FAA Order 8900.1, represented an acceptable alternate solution. We classified Safety Recommendation A-12-8 Closed—Acceptable Alternate Action on July 13, 2021.

[38] According to the air boss, the accident Boeing B-17G pilot did not attend the entirety of the briefing but the copilot attended. Also, the position 2 bomber flight engineer stated that he did not attend. The fighter lead pilot and position 2 fighter pilot attended the briefing, but their postaccident interview summaries contained no comments about its contents.

boss]."[39] Other performances were scheduled to follow, with the final demonstration planned for 1350.[40]

According to the air boss, his briefing items that morning included broad expectations, such as avoiding the overlying airspace and having performers avoid overflying the area where ride flights were operating.[41] He stated that, generally, for a performance like the accident performance, "the decision on how they're going to fly and how they're going to operate within the airspace once it starts is either decided in the briefing, if they are given rote altitudes and orbits, or they are decided by the air boss while those aircraft are flying in an effort to maximize the entertainment value because you are providing entertainment to people."

The air boss described that the briefing for the accident performance addressed generally that the bomber group and the fighter formation would separate and that the Boeing B-29 (which had not yet departed at the time of the accident) would join as a third element, but the specifics of how that would be executed were beyond the scope of the briefing.

He stated that he discussed in the briefing which direction the Boeing B-29 was going to turn after takeoff, but the decision points for turning the other performers depended on other variables. He said that, for example, depending on how long the Boeing B-29 took to depart, he would have to determine when and where to turn the fighters back, or put them into a hold.

The briefing also included a deconfliction plan for responding to the use of the "knock it off" phrase by the air boss or any participant, which is used to clear the flying display area, such as during an emergency. Per the briefing, in response to hearing that phrase on the radio, the participants were expected to immediately fly their aircraft to their respective prebriefed holding point and await further instruction.

[39] According to the radio communications transcript, the first bombers departed sometime between 1301 and 1310 (the North American B-25J airplanes that were in bomber positions 4 and 5 at the time of the accident), and the other three bombers (including the accident airplane) departed about 1310. The pilots of the two North American B-25J airplanes performed one pass together with coordinated ground pyrotechnics before joining the other bombers in trail about 1313:30, as directed by the air boss.

[40] The sequence sheet included the handwritten note "no tours" next to two of the performances, neither of which was the accident performance.

[41] He said that ride operations were not commonplace during air shows in general but that CAF requested them for Wings Over Dallas and had done them during air shows before. He noted that not all air bosses have the skillset to accommodate such a request. He said many of the pilots and airplanes used in the ride operations were also participating in the show, and he did not consider handling them complex or distracting.

According to the pilot of the Consolidated B-24 bomber in position 2, the air boss discussed with the bomber group pilots what they had in mind for the performance, and the pilots discussed the order of the bombers flying in trail of the Boeing B-17G. He stated that the air boss's briefing included such things as the weather, safety, and performance schedule. He said the air boss presented a map when discussing the locations of the show lines, entry points, exit points, and minimum altitudes. He stated that he had flown in many air shows, including about three with the Wings Over Dallas air boss. He said he considered the air boss's briefing on the day of the accident consistent with what he would expect from any air boss, noting that "all of the air boss meetings I go to are essentially structured the same."

According to the copilot of the bomber in position 2, during the safety briefing, the air boss covered very general principles, including a discussion and display of the general flight patterns. He said that he took notes and that the air boss allowed time for any questions. He said that, after the main briefing, he and some other bomber group pilots (including the Boeing B-17G copilot) met with the air boss to discuss some clarification items related to the air boss's intentions for concluding their performance by bringing all the bombers together for a photo pass to occur after the Boeing B-29's departure. He said he felt the performance was scripted out, and he had no question about what was briefed.

The CAF director of operations and the CAF chief aviation officer also attended the briefing. They voiced no concerns about the content of the briefing but noted that the directive to cross the fighter formation in front of the bomber group was not mentioned during the briefing. A CAF instructor pilot, who was also a commercial airline pilot and was on the CAF standardization and evaluation committee, also attended the briefing.[42] He had flown as copilot of the accident Boeing B-17G on the day of the accident in an earlier performance (before the accident performance) at the Wings Over Dallas air show. He said he recalled nothing unusual about the briefing.

1.9.2.2 Aircraft Separation Strategy for Multiple Aircraft

As stated in section 1.1, during the air show, the air boss stood atop a set of air stairs on the field that provided him with an unobstructed view of the flying display area and beyond. He used a handheld radio and headset to communicate on the air show radio frequency, which included the ability to communicate with the KRBD tower controllers, as needed. In addition, he had a set of binoculars, clipboard, schedule, pen, and a cellular phone, which he used to send text messages to the

[42] This is the same pilot who was also the Wings Over Houston vice chairman, as discussed in sections 1.9.1.2 and 1.9.1.3.1.

performers before their performances, if needed, such as to notify them if the show were running behind schedule. An observer air boss, whose role was to observe the air boss to gain exposure and familiarity with warbird operations at air shows, had attended the air boss's morning briefing and was also on the air stairs.[43]

According to the air boss, air show aircraft separation was typically accomplished through visual, lateral, timing, and altitude deconflictions. Examples included directing one performer to follow another performer's aircraft (visual deconfliction), the use of show lines (lateral deconfliction), having a performer delay entering the flying display area until after another airplane had landed (timing deconfliction), and having aircraft fly at different altitudes. He described the processes as situation-dependent with many variables that required flexibility. He said that it was his belief that assigning altitudes would lead to a loss of needed flexibility, and "altitude isn't always the best or first way to separate aircraft."

When asked about his preference, the air boss stated, "So visual is the rule of the road, right? I do a lot of assignment of responsibility…" He stated that, regarding the instructions he provided during performances, performer compliance was acknowledgement of his instructions. He stated that he trusted the performers because he had worked with them in this environment and with these airplanes before. He also stated that he did not think that the operation of ride flights during the accident performance added to the complexity of the event.

When asked about his radio communications for the accident performance and his use of a phrase similar to "that should work" before the collision, the air boss stated, "That's probably a thought-fulfilling phrase" and not a directive.[44] He said that, to him, that communication meant, "Okay, we're on tempo, that should work, here we go."

He stated that, as the air boss, he had to be a few steps ahead and move on to the next sequence because he had "all these things queued up." He said that, had the

[43] The air boss listed the observer as the "miniboss" on a slide during the morning briefing. A miniboss is obligated to perform duties as assigned by the air boss. However, the air boss clarified during a postaccident interview that the observer air boss was not fulfilling the defined role of miniboss and had "no obligations that day" and that he had used the term as a courtesy only.

[44] The air boss had previously heard the audio recording, but the transcript was not available during the postaccident interview. The phrase discussed during the interview was part of a directive that the air boss provided while the fighters were descending to pass the bombers. Per the transcript (and as discussed in section 1.1), about 24 seconds before the collision, the air boss stated, "Nice job, fighters, you're coming through first. That will work out. B-17 and all the bombers on the 1,000-ft line," before asking, "B-17, you got the fighters in front of you off your left?" There was an unintelligible transmission before the air boss stated (about 10 seconds before the collision), "Nice job, fighters, come on through."

collision not occurred, the next performance sequence he intended (following the accident pass) was for the fighters to climb up, turn right, then perform directed repositioning turns, "and the bombers are going to left [90° turn] out, and they're probably going to go into a racetrack because I'm going to take the [Boeing] B-29 off" from runway 31. He said, "I know where the B-29's going to go because we briefed that. We know how that's going to work. But I don't know how the bombers and fighters exactly are going to interact with that. So that's what I mean by we're ahead and that's kind of what we're building toward."

1.9.2.3 Performers' Perceptions of Air Boss's Directives

The pilot of the Consolidated B-24 bomber in position 2 stated that there wasn't anything fundamentally different between the way the Wings Over Dallas air boss conducted the air show compared to other shows in which he had flown, and he did not recall anything abnormal about the air boss's radio communications. He recalled that, while he was focused on following the Boeing B-17G, he saw two fighters pass it, but never saw the Bell P-63F. He said that, in a "millisecond," the Boeing B-17G erupted into pieces in front of him, and (at the time) he did not know why.

According to the copilot of the bomber in position 2, during the performance, his crew flew as discussed during the morning briefing. When asked about the relative positions of the bombers and the fighter formation during the performance, he stated that his crew's main attention was on the airplane they were following and maintaining the briefed distance.

He said he saw the first two fighters pass his airplane on the left and that he remembered hearing "another transmission from the air boss of something in an uplifting, positive note, like 'good pass' or 'that looks good,' and [he] assumed what [the air boss] meant was people on the ground had a good perspective to take pictures." He said he next saw the Bell P-63F in a banked turn come across and in front of his airplane and make contact with the Boeing B-17G.

According to an interview summary for the position 2 bomber's flight engineer, he felt there was confusion during the performance because there were lots of changes, including turns in both directions instead of just a racetrack pattern. He felt like there was just too much going on. According to an interview summary for the fighter lead pilot, during the performance and before the accident, he did not fully understand the string of instructions the air boss provided, and he asked him to clarify. He said that he believed that the air boss had directed the fighters to the 1,000-ft show line. He said that he put his wingmen (the positions 2 and 3 fighters) in a right echelon until the air boss instructed him to put them in trail. He said that, as he descended and picked up the 1,000-ft line for a pass, everything looked good but, as

he climbed his airplane after the pass, he heard the "knock it off" call from the air boss, knew something was wrong, and proceeded to the holding area.

According to an interview summary for the pilot of the position 2 fighter, he recalled that the air boss had issued a long stream of instructions, but he wasn't really paying attention and was focused on the fighter lead. He recalled that, when the air boss told the fighters to get in front of the bombers, he ensured his airplane had separation from the Boeing B-17G, then he shifted his focus back to the fighter lead. He himself had air boss experience and considered the Wings Over Dallas air boss the best in the business. He stated that he absolutely trusted the air boss and the fighter lead pilot.

1.9.3 Air Show Safety Oversight

1.9.3.1 Federal Aviation Administration

The FAA IIC issued the certificate of waiver for the Wings Over Dallas air show to the event organizer and chairman on November 2, 2022, and performed surveillance activities during the event. The waiver authorized aerobatic performances and flybys within a 5 nautical mile radius of KRBD from the surface to 6,000 ft msl and specified the provisions with which the air show had to comply. The Part 91 rules for maintaining aircraft separation were not listed among the regulations waived. Title 14 *CFR* 91.111(a) specifies that "no person may operate an aircraft so close to another aircraft as to create a collision hazard," and 14 *CFR* 91.113(b) specifies that "vigilance shall be maintained by each person operating an aircraft so as to see and avoid other aircraft….Pilot[s]…may not pass over, under, or ahead of [another aircraft] unless well clear."

FAA Order 8900.1, Volume 3, Chapter 6, "Issue a Certificate of Waiver or Authorization for an Aviation Event," contains guidelines for FAA IICs to use when ensuring that all applicable requirements are met for issuing an air show waiver. Among its provisions, the order:

- Designates FAA guidance for oversight,
- Addresses the airspace in which flying displays are authorized to perform,
- Provides guidance for performers' aerobatic flight and maneuvering,
- Explains performer and essential personnel competencies and credentialing,
- Lists requirements for emergency and incident planning, and
- Provides a timeline indicating when each step in the process should be accomplished.

This section of the order also addresses solo and formation pilot competencies and requirements for certain maneuvers, with a focus on minimum safety distances and altitudes from the spectator areas, pitch and bank angles, and airspeed. It also lists the minimum items that must be covered at the daily Participants Safety Briefing, such as the contact information for key event personnel, weather information, airspace details, a method of coordinating participating and nonparticipating air traffic, a depiction of the aviation event site (including the location of spectator areas, show lines, flying display area, and holding areas), the performance schedule, and other specified topics. The order also provides a sample briefing guide (FAA 2020a, 103-5 and 147-8).

Also, the sample surveillance job aids attached to the order address activities for inspecting aircraft, performers, and parachutists' equipment. The items described in this section of the order that apply to observing an air boss at an air show include a checklist item to "attend participants safety briefing" and a reference to having radios available for the FAA "IIC and, as needed, for other aviation event officials to monitor communications" (FAA 2020a, 4, 18, 20, 96, 159).

FAA Order 8900.1, Volume 5, Chapter 9, Section 6, "Issue/Renew/Reevaluate/Rescind an Air Boss Letter of Authorization," contains guidance for FAA inspectors related to air boss LOAs. Per the order, the FAA has the final authority for the issuance of an air boss's LOA and does so based on a recommendation from the recognized industry organization in accordance with its FAA-accepted Air Boss Recognition Program (ABRP) manual (FAA 2018); at the time of this report, the only recognized industry organization for air bosses was the ICAS. (See the next section.) The FAA has the authority to deny an LOA application or rescind an existing LOA in circumstances such as an applicant (or air boss) being under investigation or subject to a pending action by ICAS (FAA 2020a, 23 and 2019b, 1).

This section of the order states that FAA inspectors "should ensure [that] a person who wishes to provide air boss services at an air show possesses a valid air boss LOA." It does not identify any specific direct surveillance activities for FAA inspectors to perform concerning an air boss at an air show but states that "any time an air boss's actions or inactions give the FAA reason to doubt an air boss LOA holder's ability to serve as air boss, his or her competency to hold an air boss LOA should be reevaluated" (FAA 2019b, 5 and 8).

According to the FAA IIC for Wings Over Dallas, his role involved reviewing the air show event organizer's application for the air show certificate of waiver to ensure all the requirements were met. He said that this section of the order was 166 pages long and that he kept the document open and crosschecked it item by item when going through the application.

He said that, because of the number of aircraft participating in Wings Over Dallas, he requested (and received) two FAA maintenance inspectors to assist with ramp checking aircraft and checking performers' documents. He said that other surveillance he performed included ensuring that all the performers and aircraft met all applicable requirements, attending the Air Show Participants Safety Briefing each day, ensuring that all the performers were on the sign-in sheet, and performing other tasks like walking the air show perimeter and checking the fencing to make sure no spectators or other personnel could enter prohibited areas.

He said that the air boss's Air Show Participants Safety Briefing on the morning of the accident was thorough and the participants were attentive. He did not recall any discussion of specific altitude separations during the general briefing except for the part of the accident performance that was to involve the flight of the Boeing B-29.

He said that, during the air show, he stood directly below the air boss's air stairs and monitored the show, observing no deviations from the waiver. He didn't have a radio with him and could not hear the communications between the air boss and the performers. He did not see the collision but saw the aftermath. He said the emergency response vehicles and personnel were positioned on the taxiway and arrived on scene within about 30 seconds.

An FAA inspector who was in training to provide air show oversight was observing the FAA IIC. This inspector had a radio and was listening on the air boss radio frequency during the accident performance. He recalled that the radio was "busy" because of the multiple airplanes flying, but he said he did not recall any "safety issue" with the communications.

1.9.3.2 International Council of Air Shows Inc.

ICAS is a nonprofit industry organization "dedicated to building and sustaining a vibrant air show industry;" fostering "the highest levels of safety, professionalism, and integrity" among its members; and serving a leadership role on a range of air show–related issues, including safety, industry standards, and best practices (ICAS 2024).

Effective June 30, 2018, the FAA recognized and began accepting the ICAS ABRP manual as meeting the requirement for issuing an air boss LOA. The guidance in FAA Order 8900.1 states that the intent of the ABRP is to ensure that air bosses are properly trained and evaluated before providing air boss services at an air show. Both the order and the ICAS ABRP manual define the role of the Air Boss Evaluator, who is a recognized air boss designated by the ICAS to evaluate air boss applicants.

The ICAS ABRP specifies that an air boss "must be able to prepare and present a quality daily Air Show Participants Safety Briefing; possess a strong working

knowledge of applicable regulations, policy and forms; and have a command and control 'presence'" (ICAS 2018, 1).

According to the ICAS ABRP evaluation form, an air boss must (among other criteria):

- Ensure necessary coordination between pilots,
- Communicate clearly and concisely,
- Maintain situation awareness at all times,
- Provide positive control of the air show,
- Apply good judgment, and
- Maintain effective air show flow (ICAS 2018, appendix B).[45]

For each level of air boss designation, various ICAS ABRP education, testing, and experience criteria, as well as a ground evaluation conducted by an ICAS-recognized Air Boss Evaluator, apply. The "recognized air boss, multiple venue" designator (the highest level, which was held by the air boss of the accident performance) also requires a satisfactory practical evaluation by an Air Boss Evaluator who monitors and provides an objective assessment of the applicant's performance during an air show. The ICAS ABRP manual describes the assessment process and contains a sample evaluation form, and the FAA Order 8900.1 references the general criteria.

Per the ICAS ABRP manual, obtaining a recognized air boss, multiple venues designation required the successful completion of the ICAS ABRP basic experience air show education data sheet, a score of 75% or better on the multiple-choice air boss test, an evaluation conducted by an ICAS-recognized Air Boss Evaluator, and certain experience and recommendation requirements. According to the ICAS ABRP manual, the evaluation begins with the Air Show Participant Safety Briefing for the morning of the air show rehearsal and concludes when the last aircraft has landed on the final day of the show. The manual states that "during that entire time, the performance, knowledge, and demeanor of the applicant will be evaluated" (ICAS 2018, 8).

The air boss LOA renewal process, which occurs every 3 years, has different requirements for each level of air boss. For an air boss to renew a recognized air boss, multiple venue designation, the air boss must submit to the ICAS vice president of safety and operations a renewal application that includes documentation that they have worked as an air boss at that level for at least eight air shows during the previous

[45] The ICAS ABRP manual does not define "positive control" but otherwise discusses the air boss's "primary responsibility for control of air show operations on active taxiways, runways, and the surrounding demonstration area" and providing "appropriate control of the event in his/her capacity as air boss" (ICAS 2018, 4 and 15).

3 years; at least four recommendation letters from specified industry personnel (including other recognized air bosses or air show performers with specified credentials who have experience working with the applicant during the previous 3 years); and documentation of having attended at least one ICAS Air Boss Academy Program, ICAS Air Boss 101 Workshop, or equivalent training program (ICAS 2018, 31).

According to the ICAS vice president of safety and operations, the air show industry had sought to standardize and certify air bosses for about 30 years before the ICAS ABRP obtained FAA acceptance in 2018. He said that the FAA personnel met with ICAS personnel about once a quarter and periodically audited the program's paperwork. He estimated that ICAS had six or seven Air Boss Evaluators, each with decades of air boss experience. He estimated that there were about 60 or 70 ICAS-approved air bosses.

He stated that Air Boss Evaluators followed the guidelines in the ABRP manual when evaluating air bosses, but there was no specific set of training requirements. He said that ICAS had a strict code of ethics and a conflict-of-interest clause in the manual that prohibited evaluators from evaluating family members or close business associates.

The ICAS vice president of safety and operations also said that the ICAS Confidential Reporting System (known as ICARUS) enabled members to anonymously report safety concerns via an online form. He said that ICAS used the submitted reports to perform safety analysis, monitor trends, or take action for any safety issue specific to a certain event. He said that air show pilots, performers, or others could also call to report a safety concern and, per policy, he would investigate and determine what needed to be done to correct the issue. He estimated that ICAS received about 10 ICARUS reports in the last 15 years but that, in the last 2 years, he had taken about 60 calls for various issues, some of which were minor.

1.10 Additional Information

1.10.1 Other Air Show Event Organizers' Aircraft Separation Strategies for Warbird Performances

The NTSB interviewed the event organizers of two other large-scale, complex air shows to better understand how they managed their processes. According to the summary of interviews of representatives for one event organizer, several months before the event, the lead air boss (of eight they employed for the week of the air show) would talk to the warbird community and the air show managers to determine what the plan would be and how they wanted to choreograph their performances. The final choreography would be shared with each performer in the morning briefing

before the show. Air show acts were deconflicted laterally and with a minimum vertical separation of 200 ft. Different flights would operate at different altitudes and the goal was to not have varying speed aircraft flying together. The air boss would put faster aircraft at a higher altitude and on a predetermined flight path.

According to the summary of interviews of representatives for a different event organizer, their expectation was for the air boss to execute the plan without deviation, except for maintenance issues. Acts were to be deconflicted by altitude, airspeed, and aircraft performance, and it was made very clear in the Participants Safety Briefing what was to happen during the show. Examples of styles that were considered inappropriate included changing performances from what was briefed, failing to run the show in accordance with the schedule, and not verifying paperwork pertinent to the safe operation of the air show.

1.10.2 Postaccident Actions

1.10.2.1 Commemorative Air Force Procedures Changes

As discussed in section 1.9.1.2, the CAF's chief aviation officer did not find out that some CAF pilots who had flown in the Wings Over Houston air show 2 weeks before the accident had safety concerns about some "freeform," unbriefed directives but did not report them until after the Wings Over Dallas accident. He said that getting CAF members to use the CAF's SMS feedback mechanism would take education.

He said that, after the accident, he made it clear to the CAF members that, "from now on, if you see something, say something and speak up, and if you're afraid, that's OK. Tell me, and I'll do it." He considered it an improvement that the pilots involved in the Wings Over Houston event reached out to him after the Wings Over Dallas accident, stating that 5 or 6 years ago, people were more reluctant to talk because they perceived that they could lose their privileges of flying the airplanes in air shows. He said that the pilots now realized that safety transcends that right.

Also, effective April 20, 2023, the CAF issued new revisions to the air show guidance appendix in its procedures manual that stated that all aircraft in a parade flight should be of like performance, maintain altitude separation from parades of multiple, dissimilar aircraft, and fly only racetrack patterns in one direction.[46] The guidance also prohibited dog bone patterns and crossing maneuvers unless part of

[46] The guidance defined a parade flight as a group of aircraft at the same altitude flying a racetrack pattern with in-trail spacing (more than 500 ft). Dissimilar aircraft are those with differences in performance characteristics and may also differ in class and weight.

an approved maneuvers package and stated that, when passing other aircraft in the demonstration area, pilots must ensure a minimum of 500 ft vertical separation.

The CAF also implemented updates to its safety program, revising its SMS manual in November 2023 and again in January 2024.[47] The most recent revision of the manual included a "History" section that described the CAF's efforts to align its safety program with SMS models, stating that it compared its program with FAA materials, evaluated the available tools, and implemented those tools that worked best for its organization. The revised manual included a "Risk Management" section that listed the CAF's anonymous flight safety and ground hazard reporting program and stated that the CAF's chief aviation officer, staff, and safety committees "evaluate risk assessment of day-to-day operations and analysis of reported risk. Risk mitigations are explicitly implemented to reduce risk and are incorporated into CAF policies and procedures."

1.10.2.2 Safety Alert for Operators: Mass Aircraft Demonstrations

On July 15, 2024, the FAA issued Safety Alert for Operators (SAFO) 24005, "Mass Aircraft Demonstrations at Aviation Events," to recommend proactive risk mitigation strategies for the pilots, air bosses, and event organizers of civilian air shows that include mass aircraft demonstrations, particularly those involving multiple, dissimilar aircraft that are not part of an approved maneuvers package.

The SAFO recommended distributing to the pilots a detailed written plan for the performance; conducting mandatory preflight briefings and postflight debriefings that review all aspects of normal and emergency procedures; using aircraft deconfliction strategies characterized by complete geographical, lateral, and time separation; and flying simple racetrack patterns to avoid complex maneuvering and loss of visual separation. It also stated that "following the briefed plan for operational execution is of critical importance. Deviations from the plan, [such as] ad hoc instructions or maneuvers can contribute to confusion and loss of separation." It also stated that simultaneous flight operations involving nonparticipating aircraft should not be conducted.

The SAFO provided a link to a new ICAS best practices document, effective July 20, 2024, that contained guidance for drafting and implementing a performance plan and conducting preflight briefings and postflight debriefings. It also contained an example of a "stack plan" strategy that can be used to standardize air show structure, execution, and terminology and provide altitude and lateral separation to simplify aircraft deconfliction. The guidance included a diagram of racetrack flight

[47] The November 2023 revisions included a note from the CAF president, a publications management and revisions guide, a definitions page, and appendixes for the CAF's emergency action program, aircraft contingency plan, and hazard reporting.

patterns with different 300-ft altitude blocks (separated from each other by a 500-ft buffer) and unique names, as well as an exemplar form that the air boss can fill out to assign different aircraft to different patterns and altitude blocks. It provided an example of how the plan was used by Warbirds of America at a recent large air show that featured multiple warbirds, the coordination and planning for which began months before the show.[48]

[48] Warbirds of America is a division of the Experimental Aircraft Association dedicated to promoting and encouraging "the preservation and operation of World War II and other such aircraft that are representative of military aviation operations" and educating its members and other interested persons "in methods and safe operation and maintenance" of these aircraft (EAA 2024).

2. Analysis

2.1 Introduction

The accident occurred when two CAF-operated warbird airplanes, a Boeing B-17G bomber and a Bell P-63F fighter, collided in flight during an air boss–directed warbird performance that included multiple, dissimilar aircraft at the CAF's Wings Over Dallas air show. The analysis discusses the accident sequence and evaluates the following safety issues:

- The factors that limited the ability of the Boeing B-17G pilot and the Bell P-63F pilot to see and avoid each other's aircraft, and the inherent limitations of the see-and-avoid concept for collision avoidance (section 2.2.1).
- The air boss's ineffective aircraft deconfliction strategy for the accident performance (section 2.2.2).
- The lack of adequate air show safety oversight, including the requirements for the contents of the air show Participants Safety Briefing (section 2.3.1), the need for administrative controls and documented safety risk assessments (section 2.3.2), and the need for air boss oversight, including recurrent evaluations, standardized communications, and FAA surveillance (section 2.3.3).
- Air show safety culture issues, including evidence that CAF pilots did not report observed safety concerns, and the limited ability of the ICAS to influence culture in an industry composed of various operators, individual performers, and individual air bosses (section 2.4).

Having completed a comprehensive review of the circumstances that led to the accident, the investigation determined that none of the following were factors:

- *Flight crew qualification*s. The Boeing B-17G pilot, copilot, and flight engineer and the Bell P-63F pilot were certificated in accordance with federal regulations and were current and qualified in accordance with CAF requirements.

- *Airplane mechanical condition*. Maintenance records for both airplanes indicated that each was maintained and inspected in accordance with its respective applicable maintenance requirements. Photographic and video evidence that captured imagery of both airplanes during the performance showed that both were intact and maneuvering in a manner consistent with controlled flight before the collision. Examination of the wreckage of both

airplanes identified no evidence of any precollision anomaly or failure that would have precluded their normal operation.

- *Flight crew medical fitness*. The Boeing B-17G pilot, copilot, and flight engineer and the Bell P-63F pilot possessed valid and current FAA medical certificates appropriate for the flight operations. The NTSB reviewed their FAA medical certification information and the autopsy and toxicology reports for all personnel on board both airplanes. Considering the autopsies' limitations (due to the severity of some injuries) and the operational circumstances of the accident, our evaluation determined the following:

    - The Boeing B-17G pilot and the Bell P-63F pilot each had coronary artery disease. No autopsy evidence indicates that either pilot experienced a sudden cardiac event; however, such an event does not reliably leave autopsy evidence if it occurs just before death (Schoen 2005, 555–618).[49] The flight paths of both airplanes were consistent with controlled flight (see section 2.2.1), and neither pilot (nor any other crew on board the Boeing B-17G) made a distress call over the radio. Thus, the accident circumstances were not consistent with either pilot having experienced a sudden cardiac event.

    - Toxicological results for the Boeing B-17G pilot and flight engineer indicated that both had used the potentially impairing antihistamine medication meclizine. However, the precise timing of their antihistamine use and whether they were experiencing related impairment (such as mild sedation) cannot be determined from the available results. Regardless, as stated above, operational evidence indicates that the pilot maneuvered the airplane in accordance with the air boss's directives. Further, the investigation determined (see section 2.2.1) that the Boeing B-17G crew had very limited opportunity to see (and react to) the Bell P-63F before the collision. Given these circumstances, it is unlikely that the effects of antihistamine use by the crewmembers contributed to the accident.

    - The Boeing B-17G copilot and flight engineer each had one postmortem tissue specimen that tested positive for ethanol and

[49] Coronary artery disease increases the risk of a sudden impairing or incapacitating cardiac event such as abnormal heartbeat or heart attack. Even severe coronary artery disease is often asymptomatic (Bild et al. 2005, 1313–20; Wong and Harvey 2002, 3–5).

multiple other specimens that tested negative. This indicates that the detected ethanol was likely from sources other than consumption.[50]

- Neither of the two individuals serving as scanners on board the Boeing B-17G had (and were not required to have) an FAA medical certificate. Although CAF's chief aviation officer stated that the scanners' role during the air show included looking for traffic, per the CAF's loadmaster operations manual and training agenda, their primary in-flight responsibilities involved monitoring engine and tailwheel operations, and there were no procedures or training specified for assisting with collision avoidance. Although the toxicology results for one scanner indicated that he had used multiple medications that were potentially impairing or that might indicate potentially impairing underlying medical conditions, given his limited role on the accident flight, it is unlikely that any impairment, if present, could have affected the flight's outcome.[51]

Thus, the NTSB concludes that no pilot qualification deficiency or airplane malfunction or failure was identified, and there is no evidence that any flight crewmember's medical condition or use of medications contributed to the accident.

2.2 Accident Sequence

As part of the performance, the Boeing B-17G was in the first position of five historic bomber airplanes flying as multiple solo aircraft in trail, and the Bell P-63F was in the last position of three historic fighter airplanes flying in formation. Generally, the pilots in each group (bombers and fighters) flew multiple passes parallel to runway 13/31 at KRBD and completed repositioning turns on the south side of the extended show lines to set up for each respective pass, as directed by the air boss.

The air boss provided directives based on his continuous, real-time assessment of all the variables associated with the performance, including the respective positions of the airplanes. The airplanes' altitudes and airspeeds varied throughout the performance, which included descending passes from the bomber group, fighter formation maneuvers, the coordinated detonation of ground pyrotechnics, and a

[50] For the flight engineer, this included a negative ethanol result in vitreous, which is typically least susceptible to postmortem microbial ethanol production (Kugelberg and Jones 2007, 10–29).

[51] Although the scanners' respective seating locations on board the accident airplane (right or left door position) were not known, given the rapid approach of the Bell P-63F from behind and above the Boeing B-17G, there would likely have been insufficient time for either scanner to observe its approach, recognize it as a threat, and communicate that to the flight crew, and for the flight crew to react.

real-time narration from an air show announcer on the ground. In addition, the air boss coordinated the flight of CAF-operated Boeing PT-17, which was providing a revenue passenger ride during the performance, and the taxiing of a CAF-operated Boeing B-29 that was positioning for takeoff to join the performance. The air boss, who stood atop a set of air stairs on the field, directed all these activities via radio on the air show radio frequency.

Position data were available for seven of the eight airplanes in the performance (all but the bomber in position 5) and the Boeing PT-17 ride flight. The data showed that, in the 2 minutes before the accident, the bomber group and the fighter formation completed a pass in front of the crowd from show right to left (that is, from right to left from the crowd's perspective), heading southeast, parallel to runway 13. The airplanes were setting up for the next pass when the accident occurred.

Recorded radio communications and airplane position data showed that, as the fighter formation was entering the pass that preceded the accident, the air boss issued directives to the bomber group and the fighter formation about the pass, the subsequent repositioning turns, and the next pass. The air boss's directives for the fighter formation included directing them to "walk" their way up to the Boeing B-17G, informing them that he was going to "break" them out "left" after they "follow the bombers to the right 90 out, and then…roll back in left and be on the 500-ft line…to set up for an echelon for a break…[and] get in trail." Following those directives, the fighter lead pilot asked for clarification, and the only directive repeated (by the air boss) and confirmed (by the fighter lead pilot) related to the direction of the echelon break.

After completing the pass that preceded the accident, the pilots of all eight airplanes performed repositioning turns (a 90° right turn followed by a 270° left turn) on the south side of the extended show lines to set up for the next pass, as directed by the air boss. Based on the radio communications, the next pass was intended to be from show left to right in front of the crowd (heading northwest, parallel to runway 31); the air boss directed the fighter formation to pass the bomber group and fly the 500-ft show line, and he directed the bombers to fly the 1,000-ft show line. Compliance with this directive required the fighter formation to pass off the left side of the bomber group, then cross laterally in front of the Boeing B-17G. (Figure 5 shows the beginning of this maneuver.)

The position data showed that the flight path for the fighter lead and position 2 fighter airplanes passed the bomber group airplanes off the bombers' left side then crossed in front of the Boeing B-17G, as directed, but subsequently aligned with the 1,000-ft show line (instead of continuing farther across to the assigned 500-ft show line). The position data showed that the flight path of the Boeing B-17G (with the other bombers in trail) aligned with the 1,000-ft show line. (Figure 6 shows this alignment.)

Based on an interview summary with the fighter lead pilot, he mistakenly believed that the air boss had directed the fighters to the 1,000-ft show line. The fighter lead pilot said that, as he descended and picked up the 1,000-ft line, everything looked good. According to an interview summary for the pilot of the position 2 fighter, he recalled that the air boss had issued a long stream of instructions, but he was primarily focused on his spacing with the fighter lead. He recalled that, when the air boss told the fighters to get in front of the bombers, he visually ensured his airplane had separation from the Boeing B-17G, then he shifted his focus back to the fighter lead.[52] (Air boss communications are discussed further in section 2.3.3.2)

Thus, the NTSB concludes that, although the fighter lead pilot was confused by the air boss's unclear directives, the fighter lead pilot and the position 2 fighter pilot visually ensured separation from the bomber group airplanes when passing and crossing in front of the Boeing B-17G before mistakenly aligning with the incorrect show line. The position data showed that the Bell P-63F's flight path closely followed the fighter in position 2 until about 7 seconds before the collision, when its flight path no longer curved toward the 1,000-ft show line but became somewhat straighter, possibly toward the 500-ft show line, which would be consistent with the air boss's directive. Regardless of which show line the Bell P-63F pilot may have intended to fly, alignment with either show line required him (like the other pilots in the fighter formation) to pass the bomber group airplanes off the bombers' left side then cross in front of the Boeing B-17G. Video and photographic evidence captured by witnesses on the ground showed that the Bell P-63F was in a descending, left-banked turn when it struck the left side of the Boeing B-17G near the trailing edge of the left wing, then both airplanes broke apart in flight.

2.2.1 Pilots' Limited Ability to See and Avoid

Although the fighter lead and position 2 fighter pilot aligned their airplanes with the incorrect show line, both pilots were able to visually ensure separation between their airplanes and the bomber airplanes. For the accident airplanes, the NTSB performed a visibility simulation to evaluate the opportunities the pilots of the accident airplanes had to see and avoid each other.

As the Bell P-63F descended toward the show line, it approached the Boeing B-17G from above, behind, and to the left. The simulation showed that, during that

[52] Basic formation flying guidance emphasized the need for the pilots of trailing aircraft to closely monitor the lead aircraft. It stated that precise, smooth formation flying included recognizing "slight motion" in relation to the lead aircraft and making "small, prompt corrections" as soon as they perceive they are out of position. The guidance stated that "the easiest way to detect motion is by closely monitoring fixed references on the lead aircraft" (FAST 2016, 14).

time, the view of the model Bell P-63 from the flight deck of the model Boeing B-17 bomber was likely obscured until just before the collision by a window structure.

Further, based on the Bell P-63F's flight path and bank angles, the simulation's model Boeing B-17 was visible from the model Bell P-63's flight deck from about 32 seconds to 4 seconds before the collision, but it was likely blocked from view afterward. The simulation also determined that the model Boeing B-17 (which was colored the same as the accident airplane's paint scheme), when viewed from above, was difficult to discern against the simulated ground features at times due to the olive-drab color on most of the airplane's upper fuselage and wings. Thus, it is likely that, even when the Boeing B-17G was within the Bell P-63F pilot's view, its olive-drab color may have blended with the ground features, making it more difficult to visually detect.

The see-and-avoid concept as a means of collision avoidance relies on a pilot to look through the cockpit windows, visually acquire and identify other aircraft, determine if that aircraft poses a threat, and take the appropriate action to avert a collision, if necessary. Limitations to this concept include any obscuration that detracts from the field of view and the limitations of human attention, particularly when operating in a highly dynamic environment in which high workload is likely.

Even in a relatively calm environment, a pilot is likely to spend only 30% to 35% of their time monitoring the outside environment (Wickens and McCarley 2008). This percentage decreases when the pilot is otherwise engaged in additional tasks, thus reducing how well a pilot can visually detect outside traffic. The higher the workload, the higher the demand for task accomplishment, thus reducing what cognitive ability is left to manage and sustain situation awareness (Vidulich and Tsang 2012, 243–73).

In this accident, the NTSB visibility simulation showed that the opportunities for the pilots of the Bell P-63F and the Boeing B-17G to see and avoid each other were limited. Further, the Bell P-63F pilot's ability to visually acquire the Boeing B-17G and implement evasive action would have been even further diminished because, as the pilot of the position 3 airplane in trail of two other fighters, his immediate focus would have been on maintaining appropriate distance and airspeed to stay with the formation and ensuring his flight path aligned with the assigned show line. Likewise, part of the Boeing B-17G flight crew's focus would be on maintaining flight along the assigned show line.

Thus, the NTSB concludes that the ability of the Bell P-63F and the Boeing B-17G pilots to see and avoid each other was limited due to flight path geometry, out-the-window view obscuration by aircraft structures, the limitations of human performance that can make it difficult to see another aircraft, and the attention demands associated with maintaining flight along the assigned show lines and, for the Bell P-63F pilot, as a trailing aircraft in a formation.

The NTSB has repeatedly highlighted the inadequacy of see and avoid, most recently in our investigative report on an in-flight collision between a float-equipped de Havilland DHC-2 and a float-equipped de Havilland DHC-3 that took place about 10 miles north of Ketchikan, Alaska, during clear day weather conditions in May 2019 (NTSB 2021b). All 5 people on board the de Havilland DHC-2 and 1 of the 11 people on board the de Havilland DHC-3 were fatally injured. Both airplanes were operating as air tours in a geographic area known for its high concentration of air tour traffic, and our investigation cited the inherent limitations of the see-and-avoid concept as directly causal to the accident.[53]

Thus, the NTSB concludes that the circumstances of this accident underscore the inherent limitations of the see-and-avoid concept for collision avoidance.

2.2.2 Ineffective Aircraft Deconfliction Strategy

By definition, an air boss has primary responsibility for the control of air show operations and is expected to maintain situation awareness, ensure necessary coordination between pilots, communicate clearly and concisely, and provide positive control of the air show operations.

According to the Wings Over Dallas air boss, he typically accomplished aircraft separation through visual, lateral, timing, and altitude deconflictions. He described these processes as situation-dependent with many variables that required flexibility. For example, he could direct one performer to follow another performer's aircraft (visual deconfliction), assign performers different show lines (lateral deconfliction), have a performer delay entering the flying display area until after another airplane lands (timing deconfliction), or assign aircraft to fly at different altitudes.

Within the air show environment, there is mutual trust between the air boss and the performers. The air boss trusts that the performers will follow directives, maintain situation awareness, and ensure adequate separation between their aircraft and others, as required by 14 *CFR* 91.111(a) and 91.113(b), which specify, respectively, that "no person may operate an aircraft so close to another aircraft as to create a collision hazard" and that "vigilance shall be maintained by each person

[53] In the Ketchikan accident report, the NTSB determined that the de Havilland DHC-2 pilot had no opportunity to see and avoid the other airplane because it was obscured by aircraft structure. Further, the de Havilland DHC-3 pilot's ability to see and avoid the de Havilland DHC-2 was limited, in part, due to the little apparent motion of the de Havilland DHC-2 as the two airplanes converged at a relatively constant angle for about 3 minutes before the collision. The report noted that the lack of apparent motion reduced the likelihood that the de Havilland DHC-3 pilot would see the other airplane in his periphery, citing a study stating that human ambient vision (a component of the human visual system that processes information in a peripheral field of view) is more sensitive to motion than to fine detail (NTSB 2021b, 33).

operating an aircraft so as to see and avoid other aircraft….Pilot[s]…may not pass over, under, or ahead of [another aircraft] unless well clear."

Likewise, the performers trust that the air boss will ensure necessary coordination between pilots, communicate clearly and concisely, maintain situation awareness, provide positive control, and apply good judgment.[54] This relationship is similar to that of an air traffic controller and a pilot conducting flight under visual flight rules. In the air traffic control environment, although it is incumbent upon pilots to remain vigilant about their surroundings as the rules of operational right-of-way dictate, the controller shares responsibility to ensure separation from other aircraft when issuing instructions to that pilot.[55]

While under the direction of an air boss, a performer reasonably expects that the air boss would not issue directions that would put aircraft in conflict, or that the air boss would issue corrective instructions if a performer unintentionally maneuvers an aircraft into a position where a conflict might occur.

According to the Wings Over Dallas air boss, his intent for the next pass was for the fighter formation (which was composed of faster airplanes than the bomber group) to pass the bomber group off the bombers' left side, such that he expected the fighters to be past all of the bombers before transitioning to their assigned 500-ft show line and for all performers to maintain visual separation. However, the position data for the airplanes showed that the Bell P-63F was not yet past the lead bomber when the Bell P-63F began to move toward the assigned 500-ft show line, on a converging path with the Boeing B-17G. Thus, the NTSB concludes that the air boss's deconfliction strategy for the accident performance, which relied on his real-time, predictive assessment of airplane locations and the ability of the pilots to see and avoid other airplanes, was ineffective because the flight paths of the Boeing B-17G and the Bell P-63F converged as each pilot maneuvered toward their respective assigned show lines.

2.3 Air Show Safety Oversight

CAF pilots participated in various air shows each year, some of which were hosted by other event organizers, held at locations other than an aircraft's base, or included performances that combined CAF-operated aircraft with warbirds operated

[54] The ICAS ABRP evaluation form listed each of these as air boss responsibilities.

[55] FAA guidance related to pilot and controller roles and responsibilities stated that "to maintain a safe and efficient air traffic system, it is necessary that each party fulfill their responsibilities to the fullest. The responsibilities of the pilot and the controller intentionally overlap in many areas providing a degree of redundancy" (FAA 2024a, 5.5.1).

by other museums or private owners. According to experienced CAF air show pilots, warbird performances commonly involved multiple solo airplanes, including a mix of bombers and fighters, and such performances were not particularly complicated to fly. However, one pilot said that, typically, the fighters would remain at higher altitudes than the bombers, and the altitudes would be discussed ahead of time with the air boss, during the participants safety briefing.

2.3.1 Participants Safety Briefing Requirements

The air boss briefed general aspects of the accident performance with the participants during the required Air Show Participants Safety briefing. According to the FAA IIC for Wings Over Dallas, the air boss's briefing addressed all the required items listed in the FAA Order 8900.1 guidance for FAA inspector surveillance of air shows. Further, none of the briefing attendees interviewed postaccident, which included the FAA IIC, the FAA inspector trainee, the observer air boss, CAF management personnel, and CAF performers, voiced any concern about the air boss's briefed plan for the accident performance.

Further, the FAA certificate of waiver for the air show, FAA Order 8900.1 guidance, and the ICAS ABRP manual did not specify any required procedures for maintaining separation between multiple, dissimilar aircraft operating within the same flying display area and not part of an approved maneuvers package, as was the case with the accident performance. Also, none of these materials specified a requirement for air show event organizers or air bosses to perform a documented risk assessment for each air show performance.

The NTSB notes that such risk assessments could help determine what hazards are present and then determine a plan for applying effective mitigations to address them. In an air show environment, two of the most significant hazards to mitigate are the potential for aircraft contact with the spectators and aircraft contact with one another.

Significant regulatory improvements for ensuring the safety of spectators at air shows and air races (including defined parameters for show line distances from the crowd) resulted from the NTSB's investigation of a September 16, 2011, accident involving an airplane that crashed during an air race in Reno, Nevada (NTSB 2012). However, no specific requirements exist for performing documented risk assessments to mitigate risks for air show performances involving multiple, dissimilar aircraft, and neither the CAF nor the air boss had a documented safety risk assessment process for the accident performance.

Thus, the NTSB concludes that FAA and ICAS guidance did not adequately address the need to better mitigate the collision risks associated with air boss–

directed performances involving multiple, dissimilar aircraft. The following section discusses controls that can be put in place to alleviate some of the risks associated with air boss–directed performances.

2.3.2 Need for Administrative Controls and Risk Assessment

For an air boss–directed performance (like the accident performance) that lacks a definitive maneuvers plan before its execution, the participants involved may not have a clear, shared mental model of what is to occur. For example, the pilot of the position 2 bomber in the accident performance stated he did not know that the fighter formation was going to pass and cross in front of the bomber group until he heard the air boss call for it on the radio.

A team functions best when the team members have a shared understanding of what a task encompasses and how it is to be performed (Jonker, van Riemsdijk, and Vermeulen 2010, 132–51). To facilitate an effective shared mental model, team members should discuss and agree upon the desired course of action, what goals should be achieved, and how they intend to achieve them, well before the execution phase.

Air boss–directed performances (like the accident performance, which involved multiple solo, dissimilar aircraft) differ from an approved maneuvers package, which is a defined, coordinated sequence of maneuvers that the participants know and rehearse ahead of time and perform with no input from the air boss. An approved maneuvers package inherently includes controls for ensuring aircraft separation because it involves a set routine to which the performers train and from which they do not deviate, thus minimizing the risk of aircraft contact with each other.

Thus, the NTSB concludes that, compared to an approved maneuvers package, an air boss–directed performance involving multiple, dissimilar aircraft represents an increased workload for both the air boss and the pilots, as the air boss bears the cognitive load of having to create the performance sequence in real time and then issue directives, and the pilots must anticipate, understand, and comply with the directives while maintaining visual separation from other aircraft.

Administrative controls establish work practices that reduce the duration, frequency, or intensity of exposure to hazards. They maximize coordination and ensure reliability and predictability of behavior. They can take the form of training, procedure, policy, or design changes that lessen the threat of a hazard to an individual (CDC 2024). Because operating in an air show has an inherent level of associated risk, administrative controls are necessary for continued safe operations.

The NTSB interviewed the event organizers of other large-scale complex air shows to better understand how they managed the process. One large event

organizer said that, several months before the event, the lead air boss (of eight they employ) would talk to the warbird community and with the air show managers to establish respective plans and determine how they wanted to choreograph their performances. The final choreography would be shared with each performer during the morning briefing. When asked about safety measures that were built into the choreography, the team stated that they deconflicted acts laterally with a minimum vertical separation of 200 ft. Different flights would operate at different altitudes, and the goal was to not have varying speed aircraft flying together. The air boss would put faster aircraft at a higher altitude and on a predetermined flight path.

The lateral, altitude, and airspeed separations the event organizers and air bosses agreed upon are an example of administrative controls at work. A different event organizer stated that they expected the air boss to execute the plan with no deviations except for maintenance issues. Acts were to be deconflicted by altitude, airspeed, and aircraft performance, and it was made very clear in the Participants Safety Briefing what was to happen during the show so that a shared mental model was assured.

As described in section 2.2.2, the air boss stated that his deconfliction strategies included using lateral, altitude, timing, and visual options. However, at no time before or during the accident performance did he set designated altitudes or airspeeds for the pilots to fly, and the directive he issued for the fighter formation to cross laterally in front of the bomber group relied entirely on his real-time, predictive assessment that the fighter formation would arrive at the show line first and that the pilots would see and avoid each other. As discussed in the previous section, this strategy presents a higher workload in terms of communication and information processing and an increased demand for situation awareness for both the air boss and each pilot.

Thus, the NTSB concludes that a lack of administrative controls, such as a prebriefed aircraft separation plan with defined lateral, altitude, and timing deconflictions directly contributed to the in-flight collision.

The NTSB notes that after this accident, on July 15, 2024, the FAA issued SAFO 24005, "Mass Aircraft Demonstrations at Aviation Events," to recommend proactive risk mitigation strategies for the pilots, air bosses, and event organizers of civilian air shows that include mass aircraft demonstrations, particularly those involving multiple, dissimilar aircraft that are not part of an approved maneuvers package (FAA 2024c). The SAFO recommended distributing to the pilots a detailed written plan for the performance; conducting mandatory preflight briefings and postflight debriefings that review all aspects of normal and emergency procedures; using aircraft deconfliction strategies characterized by complete geographical, lateral, and time separation; and flying simple racetrack patterns to avoid complex maneuvering and loss of visual separation.

The SAFO provided a link to an ICAS best practices document that contained guidance for drafting and implementing a performance plan, recommended preflight briefings and postflight debriefings, and included examples of a separation strategy that has proven effective for the event organizer of a recent large air show that featured multiple warbirds. However, it did not include guidance for developing effective risk assessment strategies, ensuring that debriefings are performed after every day of the air show, or establishing a mechanism by which any safety deficiencies identified during the debriefings are communicated to the FAA and the ICAS to help improve future guidance and policy. (One CAF volunteer stated that debriefings typically did not occur on the last day of an air show. See section 2.4.1 for more information.)

The NTSB believes that, although the new guidance materials contain helpful information, as guidance materials—rather than standard operating procedures—they still allow for disparity in how different event organizers or air bosses may choose to manage aircraft separation, and they do not adequately address risk assessment or debriefing strategies to be applied to every performance.

Thus, the NTSB concludes that a documented safety risk assessment for each performance would allow air show event organizers and air bosses to identify hazards and determine and apply effective mitigations, such as establishing administrative controls to ensure aircraft deconfliction for performances involving multiple, dissimilar aircraft.

Therefore, the NTSB recommends that the FAA work with ICAS and the warbird community to establish standard operating procedures for air show event organizers and air bosses that include: 1) applying administrative controls to ensure that multiple, dissimilar aircraft not operated as part of an approved maneuvers package remain deconflicted; 2) performing a safety risk assessment for each performance to determine hazards and apply effective mitigations, including consideration for any revenue ride flights conducted during air show operations; and 3) completing a daily debriefing that includes continuous feedback to the FAA and the ICAS to address any identified deficiencies.

Further, the NTSB recommends that the ICAS work with the FAA and the warbird community to establish standard operating procedures for air show event organizers and air bosses that include: 1) applying administrative controls to ensure that multiple, dissimilar aircraft not operated as part of an approved maneuvers package remain deconflicted; 2) performing a safety risk assessment for each performance to determine hazards and apply effective mitigations, including consideration for any revenue ride flights conducted during air show operations; and 3) completing a daily debriefing that includes continuous feedback to the FAA and the ICAS to address any identified deficiencies.

2.3.3 Need for Air Boss Oversight

2.3.3.1 Recurrent Evaluations

Effective June 30, 2018 (less than 4 years before the accident), the FAA accepted and recognized the ICAS ABRP manual as meeting the requirement for issuing an air boss LOA. Per this arrangement, the FAA will issue an air boss LOA based on a recommendation from ICAS, relying on ICAS subject matter experts to provide objective feedback. Although ICAS administers the ARBP, the FAA is the only authority for the issuance of air show certificates of waiver and the final authority for the issuance of an air show air boss LOA.

The air boss of the accident performance held a valid FAA-issued air boss LOA with a recognized air boss, multiple venue designation, which is the highest, most experienced level. The process for obtaining the LOA for this level designation required the air boss to successfully complete various testing and experience requirements, as well as an evaluation conducted by an ICAS-recognized Air Boss Evaluator, as specified in the ABRP manual. The LOA process for the basic and standard air boss designations do not require an evaluation, and, for the recognized air boss, single venue designation, the applicant may choose either an evaluation or a specified education, interview, and recommendation process.[56]

The LOA renewal process, which occurs every 3 years, does not require an observation by an Air Boss Evaluator for any level of air boss LOA. Further, the guidance for FAA inspectors who provide oversight for air shows does not provide specific surveillance activities or criteria to reference when observing an air boss's performance during air show operations beyond ensuring that the Air Show Participants Safety Briefing contains the required items. Thus, once an air boss attains the highest level recognized air boss designation, no further objective assessments of the air boss's performance by ICAS or the FAA are required. Although a highest-level air boss must submit four recommendation letters as part of the LOA renewal process, these letters can be from other recognized air bosses or air show performers who have previously worked with the air boss (rather than an Air Boss Evaluator or FAA personnel).

This lack of required recurrent evaluation of an air boss's performance is in stark contrast to the requirements that apply to certificate holders like pilots and air traffic controllers. To maintain currency to exercise the privileges of their certificates,

[56] The ICAS ABRP manual states that an applicant for recognized air boss, single venue designation may choose to complete either an evaluation by an Air Boss Evaluator or meet other specified requirements, including participating in a written, in-house training program, an interview with an Air Boss Evaluator, and providing six recommendation letters from specified industry personnel (ICAS 2018, 20–24).

pilots and controllers are subject to mandatory recurrent training requirements and periodic mandatory proficiency checks performed by the FAA or an FAA designee. Such requirements are necessary for pilots and air traffic controllers because they have others' lives entrusted to them. Thus, the NTSB concludes that recurrent evaluations of air bosses as part of the LOA renewal process would provide objective and ongoing assessments of their performance to help ensure the safety of air show operations.

Therefore, the NTSB recommends that the FAA require recurrent air boss evaluations as part of the LOA renewal process.

2.3.3.2 Standardized Communications

As discussed in section 2.2, the fighter lead pilot misunderstood the air boss's directive related to which show line to fly. Although the fighter lead pilot asked the air boss to clarify the directives because he did not fully understand the string of instructions provided, the air boss clarified only the directive related to the direction of the echelon break. The position 2 fighter pilot also described the air boss's directives as lengthy, and one of the bomber pilots stated that he felt there was confusion because there were so many changes in direction.

Effective communication ensures that all parties involved convey and receive information clearly and decreases the likelihood of error due to misunderstanding. It also encourages trust between the parties. Although air shows typically include defined and prebriefed show lines and landmarks to designate specific spaces within the flying display area, there is no standardized naming convention for the lines or phraseology guidance for other directives. The NTSB notes that, throughout the performance, the air boss used terms such as "walk your way up," "that will work out," and "come on through," which could be interpreted differently by different performers or not in the way the air boss intended.

Basic FAA guidance for pilots emphasizes the importance of clarity and brevity for ensuring understanding in radio communications, providing a glossary that defines standard terms and noting that "good phraseology enhances safety" and that "jargon, chatter, and…slang" should not be used (FAA 2024d). Although this guidance addresses communications between pilots and air traffic controllers, the NTSB believes the same principles can be applied to enhance safety in the air show environment.

Thus, the NTSB concludes that standardized phraseology for references to show lines and other safety considerations that avoids the use of ambiguous terms could help prevent confusion and ensure the clarity and brevity of air boss–provided directives while minimizing radio congestion.

Therefore, the NTSB recommends that the FAA work with ICAS and other air show industry stakeholders to develop standardized, unambiguous terms to help ensure that the directives that air bosses provide performers, such as those related to show lines, are clear and brief.

The NTSB also recommends that ICAS work with the FAA and other air show industry stakeholders to develop standardized, unambiguous terms to help ensure that the directives that air bosses provide performers, such as those related to show lines, are clear and brief.

2.3.3.3 Federal Aviation Administration Surveillance

The guidance in FAA Order 8900.1 for FAA inspectors is focused primarily on ensuring that the requirements for the certificate of waiver are met but does not include specific surveillance requirements or job aids. According to the FAA IIC for Wings Over Dallas, in accordance with the guidance specified in FAA Order 8900.1, his oversight and surveillance activities for the air show included ensuring that all the performers and aircraft met all applicable requirements, attending the briefings and ensuring that all the performers were on the sign-in sheet, and performing other tasks like walking the air show perimeter to ensure that spectators and other personnel were being kept out of prohibited areas.

During the accident performance, the FAA IIC stood at the base of the air stairs beneath the air boss but did not listen in on the air boss radio frequency, which is not defined as a required surveillance activity in FAA Order 8900.1. A second FAA inspector, who was in training to provide air show oversight and surveillance, was also at the base of the air stairs and used a headset and radio to listen in on the air boss radio frequency. The second FAA inspector stated that he did not recall any "safety issue" with the air boss's communications.

The NTSB recognizes that, given the lack of guidance or surveillance tasks in FAA Order 8900.1 related to air bosses' radio communications, it may be difficult for an inspector to identify whether a safety issue was evident in the communications. However, as discussed previously, during the accident performance, the air boss issued directives that, due to their length, wording, or variations, confused some performers, and the real-time directive he issued for the fighters to cross in front of the bombers (which, ultimately, placed the Bell P-63F and the Boeing B-17G on converging flight paths) had not been discussed during the morning briefing.

Thus, the NTSB concludes that the lack of guidance and required surveillance tasks for FAA inspectors assigned to air shows related to the direct observation of an air boss's performance represents a missed opportunity for inspectors to detect performance-related safety issues and provide debriefing feedback to address these

issues, such as unclear directives, inadequate aircraft deconfliction strategies, or deviations from a previously briefed plan.

Therefore, the NTSB recommends that the FAA revise FAA Order 8900.1 to provide guidance and a job aid for FAA inspectors who evaluate an air boss's performance and require the FAA IIC of an air show to observe an air boss's performance visually and on the air boss radio frequency and provide appropriate feedback during the air show debriefing.

2.4 Air Show Safety Culture

2.4.1 Commemorative Air Force

The CAF's chief aviation officer and the director of operations each had an open-door policy. Both routinely fielded calls from CAF units about various issues that came in "at all times of the night" and varied in subject from maintenance issues with specific aircraft to pilot concerns about policy or other personnel. Also, the CAF's voluntary SMS included an anonymous flight safety and ground hazard reporting program that members and performers could use to log their concerns or feedback; however, the chief aviation officer said he received zero anonymous reports (through this system) in the year before the accident.

Although the CAF senior leadership expressed confidence that CAF members were aware of the option to anonymously submit reports, the NTSB notes that having zero reports is not necessarily indicative of an environment that is without issue but rather may be indicative of a process that is not as robust as it should be.[57] Managing feedback by "open door" or "open line" policy has its advantages, but its effectiveness requires diligence in documenting every interaction that occurs via open door or a phone call and tracking and assessing negative trends that could be precursors to a more serious event.

For example, evidence indicates that some CAF volunteers observed safety concerns but failed to report them. One CAF volunteer, who was a commercial airline pilot, CAF instructor pilot, and the vice chairman of the Wings Over Houston air show that occurred 2 weeks before Wings Over Dallas, stated that he and other CAF pilots were upset after experiencing what they felt were "freeform" directives by the Wings Over Houston air boss. He stated that, during one performance involving multiple bomber and fighter airplanes, the Wings Over Houston air boss instructed the pilot of

[57] Research has shown that, for every serious accident, multiple minor accidents and even more near misses likely preceded it as precursors to the accident (Heinrich 1930, 83–92).

a fighter airplane to do a maneuver that had not been briefed and that resulted in a fighter airplane crossing in front of his bomber at the same altitude.

When asked whether he or any of the other pilots debriefed their concerns to anyone else, he stated that debriefs typically did not occur on the last day of an air show. He stated that he was aware of the available CAF options for providing feedback, but he did not debrief the CAF director of operations or submit an anonymous feedback report, and he did not inform the CAF chief aviation officer until after the Wings Over Dallas accident. The NTSB is concerned that this CAF volunteer, who, as an experienced commercial airline pilot, was likely trained on and familiar with the importance of communication and feedback in supporting safe flight operations, did not immediately voice his concerns via any of the ways afforded to him through the CAF safety program.

Research has shown that a key feature of a healthy safety culture is continuous commitment from everyone within the organization to emphasize safety over competing goals. Underlying this commitment are shared interests and meaningful relationships among members of an organization. An organization's culture can become unhealthy if motivational factors exert influence that turn it into something colloquially known as "don't rock the boat" syndrome.

In such environments, individuals may be unwilling to use the tools available to them for fear of retribution or reprisal. They may also avoid pointing out errors or issues that might draw negative attention in an attempt to avoid being perceived as a non-team player or a troublemaker (Paul and Townsend 1996, 149–61; McIntosh et al. 2019, 171–210; and Probst, Babaranelli, and Pettita 2013, 383–402). Also, an appeal to tradition is a common form of bias and complacency that can negatively affect an organization. Such an appeal relies on the argument that an approach, policy, or idea is correct or superior largely because it has been applied for the longest amount of time (Michaud 2018, 121–4). In such cases, individuals may also be reluctant to point out their concerns or might even shrug them off as being "the way it has always been done."

Applying this lens to a largely volunteer organization with a membership fee like the CAF, where the primary incentive for lending one's time and energy working for the organization is the ability to work in and around legacy military aircraft, a member's reluctance to do anything that they perceive might jeopardize their access would be understandable. The CAF's chief aviation officer stated that, after the accident, he made it clear to the CAF members that they needed to speak up with any safety concerns. He said that he considered it an improvement that the pilots involved in the Wings Over Houston event reached out to him after the Wings Over Dallas accident, stating that 5 or 6 years ago, people were more reluctant to talk because they perceived that they could lose their privileges of flying the airplanes in air shows. He said that the pilots now realized that safety transcends that right.

However, the investigation found another example of an organizational goal that was allowed to compete with safety policy. Although the CAF's chief aviation officer was not in favor of having any revenue passenger rides operating during an air show, he authorized rides to occur during Wings Over Dallas as long as they did not take off or land while a performance was in progress. He said he "acquiesced" after having received a lot of "pushback" and "pressure from high-up" people, which he said included the air boss.

The NTSB is concerned that the CAF's chief aviation officer was influenced by pressures to compromise his preferred safety procedure, effectively agreeing to allow paying passengers to be exposed to a higher risk than would be present if the rides were limited as he originally intended. Further, despite his subsequent limitation on when rides could occur, this limitation was not documented or enforced, and two CAF-operated revenue passenger rides landed on the runway in the flying display area during the accident performance. The second of the two ride airplanes, a Boeing PT-17, landed at nearly the same time as the midair collision and narrowly avoided being hit by falling debris.

The NTSB is also concerned that the air boss advocated to include the operation of ride flights, which represented a nonessential extra element within the flying display area. Although the air boss stated that he did not think that his handling of ride flights added complexity to the event, the NTSB believes that an air boss's attention should be solely focused on the air show performers.

These issues raise questions about the efficacy of the CAF's safety risk assessment process. As discussed in section 2.3, there is a regulatory and guidance vacuum for how air bosses accomplish preshow deconfliction plans and risk assessments for air boss–directed performances involving multiple solo, dissimilar aircraft. In the absence of such requirements, the CAF, as the event organizer and operator of the involved aircraft, should ensure that its safety standards are met or exceeded.

Risk assessment is a key element to having continued safe operations. By identifying which hazards pose the most risk to safe operations and establishing trends to better inform the mitigation decision-making process, operators can decrease the likelihood of an accident happening. Although the CAF had a safety program in place that was structured to incorporate aspects of a voluntary SMS, it was an immature product that did not incorporate operational safety risk assessment as a component.

For example, as discussed previously, the CAF did not have a documented safety risk assessment process for the accident performance or for the chief aviation officer's limitations on when revenue ride flights could be operated. Further, the selection of the air boss for Wings Over Dallas was not informed by a documented

safety risk assessment of his performances but rather the air show chairman's history of working with him. Although the air show chairman said that she had hired the air boss for at least 10 previous air shows, was comfortable with his performance, and liked the way he handled things, the investigation found no evidence that CAF conducted any routine observation and assessment of the performance of air bosses to gather information to inform future decisions.

Thus, the NTSB concludes that the CAF's lack of a strong, clearly defined safety risk assessment plan resulted in air show production decisions that were not systematically developed to determine acceptable levels of risk and were susceptible to influences unrelated to safety, including pressures to deviate from the intended limitations on when revenue passenger rides could be conducted during air show operations.

The NTSB notes that, since the accident, the CAF has continued to develop its safety program. The most recent revision of the CAF's SMS manual (dated January 2024) described the CAF's efforts to align its safety program with SMS models, stating that it reviewed FAA materials and implemented the tools that it believed worked best for its organization. Although the revised manual stated that the CAF's chief aviation officer, staff, and safety committees "evaluate[d] risk assessment of day-to-day operations" and implemented risk mitigations into CAF policies and procedures, the manual did not identify how these processes would be applied to its air show operations or how safety hazards would be tracked and trend data routinely assessed.

The NTSB notes that, on May 21, 2024, the FAA issued updated Advisory Circular) 120-92D, "Safety Management Systems for Aviation Service Providers," which included new guidance and implementation strategies to assist aviation organizations of all types and sizes with developing and implementing SMS.[58] The NTSB believes that this revised guidance can assist the CAF in continuing to improve its safety program. Therefore, the NTSB recommends that the CAF, using the guidance provided in AC 120-92D, establish a safety risk assessment process for identifying and mitigating risks, tracking safety hazards, and routinely assessing trend data to include policies and procedures that specifically address the unique aspects of air show operations, such as considerations for serving as event organizer; participating in air boss–directed performances involving multiple, dissimilar aircraft; and ensuring the safety of revenue passenger rides.

[58] The revisions the FAA published in AC 120-92D resulted from NTSB Safety Recommendation A-22-15, which asked the FAA to develop guidance for small operators for scaling an SMS that includes implementation methods and techniques. Safety Recommendation A-22-15 was classified Closed—Acceptable Action on July 24, 2024.

2.4.2 Role of International Council of Air Shows Inc.

As discussed in section 2.3.3, ICAS managed the ABRP and was responsible for delineating the requirements for a person to obtain an LOA to assume the role of air boss. The organization and its ABRP are accepted by the FAA, but the ICAS has no regulatory authority.

Throughout multiple interviews, CAF pilots, other air show performers, and other event organizers described some facets of warbird operations and air boss styles that they considered unacceptable, such as changing performances from what was briefed, failing to run the show in accordance with the schedule, and not verifying paperwork pertinent to the safe operation of the air show. In such cases, the performance can become more about thrilling the crowd, sometimes to the detriment of aviation safety. While some air show event organizers have actively worked to apply administrative controls to preclude such performances, the circumstances of this accident suggest that, for some parts of the warbird community, it may persist.

Although the ICAS does not have an SMS, it does have a Confidential Reporting System, called ICARUS, that, like CAF's reporting system, does not seem to garner much use. The ICAS largely relies on its annual convention and the same open line policy that CAF uses to disseminate and collect information. If negative feedback should come in, ICAS has different committees organized by subject to manage the report. However, ICAS's role does not involve actively monitoring air shows or air boss performance, and it is not staffed to do active monitoring.

The challenge then becomes determining who should be responsible for assessing warbird safety culture and establishing guidance and effective mitigation to ensure the highest level of safety. Warbirds that are featured in different air shows may be owned by different organizations and individuals who may be performing together for the first time. Air show event organizers and air bosses may vary from one venue to another. Not all air shows incorporate warbirds, and not all air bosses work with warbirds. In short, there is a gap in regulation and observation of warbird air show performance and safety culture.

The ICAS must rely on passive measures such as word of mouth and air boss observational periods (which are not required for air boss LOA renewals) to determine how successful an air boss is in the field or how successful an air show has been. The organization has no real means to proactively identify or assess risk in the air show environment, and its lack of authority over air shows and air bosses hampers its ability to determine or affect air show safety culture.

Thus, the NTSB concludes that, although ICAS was responsible for administering the FAA-accepted program that specified the requirements for a

person to obtain an air boss LOA, its role did not involve actively monitoring air shows or the performance of air bosses, underscoring the need for the FAA to address the regulatory void related to recurrent evaluations of air bosses and direct surveillance of their performance at air shows. Safety Recommendations A-24-31 through -34 recommend that the FAA address these issues.

3. Conclusions

3.1 Findings

1. No pilot qualification deficiency or airplane malfunction or failure was identified, and there is no evidence that any flight crewmember's medical condition or use of medications contributed to the accident.

2. Although the fighter lead pilot was confused by the air boss's unclear directives, the fighter lead pilot and the position 2 fighter pilot visually ensured separation from the bomber group airplanes when passing and crossing in front of the Boeing B-17G before mistakenly aligning with the incorrect show line.

3. The ability of the Bell P-63F and the Boeing B-17G pilots to see and avoid each other was limited due to flight path geometry, out-the-window view obscuration by aircraft structures, the limitations of human performance that can make it difficult to see another aircraft, and the attention demands associated with maintaining flight along the assigned show lines and, for the Bell P-63F pilot, as a trailing aircraft in a formation.

4. The circumstances of this accident underscore the inherent limitations of the see-and-avoid concept for collision avoidance.

5. The air boss's deconfliction strategy for the accident performance, which relied on his real-time, predictive assessment of airplane locations and the ability of the pilots to see and avoid other airplanes, was ineffective because the flight paths of the Boeing B-17G and the Bell P-63F converged as each pilot maneuvered toward their respective assigned show lines.

6. Federal Aviation Administration and International Council of Air Shows Inc. guidance did not adequately address the need to better mitigate the collision risks associated with air boss–directed performances involving multiple, dissimilar aircraft.

7. Compared to an approved maneuvers package, an air boss–directed performance involving multiple, dissimilar aircraft represents an increased workload for both the air boss and the pilots, as the air boss bears the cognitive load of having to create the performance sequence in real time and then issue directives, and the pilots must anticipate, understand, and comply with the directives while maintaining visual separation from other aircraft.

8. A lack of administrative controls, such as a prebriefed aircraft separation plan with defined lateral, altitude, and timing deconflictions, directly contributed to the in-flight collision.

9. A documented safety risk assessment for each performance would allow air show event organizers and air bosses to identify hazards and determine and apply effective mitigations, such as establishing administrative controls to ensure aircraft deconfliction for performances involving multiple, dissimilar aircraft.

10. Recurrent evaluations of air bosses as part of the letter of authorization renewal process would provide objective and ongoing assessments of their performance to help ensure the safety of air show operations.

11. Standardized phraseology for references to show lines and other safety considerations that avoids the use of ambiguous terms could help prevent confusion and ensure the clarity and brevity of air boss–provided directives while minimizing radio congestion.

12. The lack of guidance and required surveillance tasks for Federal Aviation Administration inspectors assigned to air shows related to the direct observation of an air boss's performance represents a missed opportunity for inspectors to detect performance-related safety issues and provide debriefing feedback to address these issues, such as unclear directives, inadequate aircraft deconfliction strategies, or deviations from a previously briefed plan.

13. The Commemorative Air Force's lack of a strong, clearly defined safety risk assessment plan resulted in air show production decisions that were not systematically developed to determine acceptable levels of risk and were susceptible to influences unrelated to safety, including pressures to deviate from the intended limitations on when revenue passenger rides could be conducted during air show operations.

14. Although the International Council of Air Shows Inc. was responsible for administering the Federal Aviation Administration (FAA)-accepted program that specified the requirements for a person to obtain an air boss letter of authorization, its role did not involve actively monitoring air shows or the performance of air bosses, underscoring the need for the FAA to address the regulatory void related to recurrent evaluations of air bosses and direct surveillance of their performance at air shows.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of the accident was the air boss's and air show event organizer's lack of an adequate, prebriefed aircraft separation plan for the air show performance, relying instead on the air boss's real-time deconfliction directives and the see-and-avoid strategy for collision avoidance, which allowed for the loss of separation between the Boeing B-17G and the Bell P-63F airplanes. Also causal was the diminished ability of the accident pilots to see and avoid the other aircraft due to flight path geometry, out-the-window view obscuration by aircraft structures, attention demands associated with the air show performance, and the inherent limitations of human performance that can make it difficult to see another aircraft. Contributing to the accident were the lack of Federal Aviation Administration (FAA) guidance for air bosses and air show event organizers on developing plans and performing risk assessments that ensure the separation of aircraft that are not part of an approved maneuvers package and the lack of FAA requirements and guidance for recurrent evaluations of air bosses and direct surveillance of their performance.

4. Recommendations

4.1 New Recommendations

As a result of this investigation, the National Transportation Safety Board makes the following new safety recommendations.

To the Federal Aviation Administration:

Work with the International Council of Air Shows Inc. (ICAS) and the warbird community to establish standard operating procedures for air show event organizers and air bosses that include: 1) applying administrative controls to ensure that multiple, dissimilar aircraft not operated as part of an approved maneuvers package remain deconflicted; 2) performing a safety risk assessment for each performance to determine hazards and apply effective mitigations, including consideration for any revenue ride flights conducted during air show operations; and 3) completing a daily debriefing that includes continuous feedback to the Federal Aviation Administration and the ICAS to address any identified deficiencies. (A-24-31)

Require recurrent air boss evaluations as part of the letter of authorization renewal process. (A-24-32)

Work with the International Council of Air Shows Inc. and other air show industry stakeholders to develop standardized, unambiguous terms to help ensure that the directives that air bosses provide performers, such as those related to show lines, are clear and brief. (A-24-33)

Revise Federal Aviation Administration (FAA) Order 8900.1 to provide guidance and a job aid for FAA inspectors who evaluate an air boss's performance and require the FAA inspector-in-charge of an air show to observe an air boss's performance visually and on the air boss radio frequency and provide appropriate feedback during the air show debriefing. (A-24-34)

To the International Council of Air Shows Inc.:

In collaboration with the Federal Aviation Administration and other air show industry stakeholders, develop standardized, unambiguous terms to help ensure that the directives that air bosses provide performers, such as those related to show lines, are clear and brief. (A-24-35)

In collaboration with the Federal Aviation Administration (FAA) and the warbird community, establish standard operating procedures for air show event organizers and air bosses that include: 1) applying administrative controls to ensure that multiple, dissimilar aircraft not operated as part of an approved maneuvers package remain deconflicted; 2) performing a safety risk assessment for each performance to determine hazards and apply effective mitigations, including consideration for any revenue ride flights conducted during air show operations; and 3) completing a daily debriefing that includes continuous feedback to the FAA and the International Council of Air Shows to address any identified deficiencies. (A-24-36)

To the Commemorative Air Force:

Using the guidance provided in Advisory Circular 120-92D, "Safety Management Systems for Aviation Service Providers," establish a safety risk assessment process for identifying and mitigating risks, tracking safety hazards, and routinely assessing trend data to include policies and procedures that specifically address the unique aspects of air show operations, such as considerations for serving as event organizer; participating in air boss–directed performances involving multiple, dissimilar aircraft; and ensuring the safety of revenue passenger rides. (A-24-37)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

JENNIFER HOMENDY
Chair

MICHAEL GRAHAM
Member

THOMAS CHAPMAN
Member

ALVIN BROWN
Member

J. TODD INMAN
Member

Report Date: December 4, 2024

Appendixes

Appendix A: Investigation

The National Transportation Safety Board was notified of this accident on November 12, 2022, and members of the investigative team arrived on scene November 13, 2022. Investigative groups were formed to develop a transcript of the air boss's air show audio recording, evaluate operational factors and human performance, and examine aircraft airworthiness. Also, specialists were assigned to perform an airplane performance study and a video study, review maintenance records, examine recovered electronic recorder devices, review the flight crewmembers' medical records and reports, and provide aerial imagery of the accident scene. The Federal Aviation Administration, Commemorative Air Force, and International Council of Air Shows Inc. were parties to the investigation.

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-24-31
Work with the International Council of Air Shows Inc. (ICAS) and the warbird community to establish standard operating procedures for air show event organizers and air bosses that include: 1) applying administrative controls to ensure that multiple, dissimilar aircraft not operated as part of an approved maneuvers package remain deconflicted; 2) performing a safety risk assessment for each performance to determine hazards and apply effective mitigations, including consideration for any revenue ride flights conducted during air show operations; and 3) completing a daily debriefing that includes continuous feedback to the Federal Aviation Administration and ICAS to address any identified deficiencies.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.3 Air Show Safety Oversight, specifically subsection 2.3.2 Need for Administrative Controls and Risk Assessment. Information supporting (b)(1) and (b)(2) can be found on pages 62-64. Although (b)(3) is not applicable to the accident, postaccident actions are described in section 1.10.2.1 Commemorative Air Force Procedures Changes, pages 50-51, and section 1.10.2.2 Safety Alert for Operators: Mass Aircraft Demonstrations, pages 51-52.

A-24-32
Require recurrent air boss evaluations as part of the letter of authorization renewal process.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.3.3 Need for Air Boss Oversight, specifically subsection 2.3.3.1 Recurrent Evaluations. Information supporting (b)(1) and (b)(2) can be found on pages 65-66, and (b)(3) is not applicable.

A-24-33
Work with the International Council of Air Shows Inc. and other air show industry stakeholders to develop standardized, unambiguous terms to help ensure that the directives that air bosses provide performers, such as those related to show lines, are clear and brief.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.3.3.2, Standardized Communications. Information supporting (b)(1) and (b)(2) can be found on pages 66-67, and (b)(3) is not applicable.

A-24-34
Revise Federal Aviation Administration (FAA) Order 8900.1 to provide guidance and a job aid for FAA inspectors who evaluate an air boss's performance, and require the FAA inspector-in-charge of an air show to observe an air boss's performance visually and on the air boss radio frequency and provide appropriate feedback during the air show debriefing.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.3.3 Need for Air Boss Oversight, specifically subsection 2.3.3.3 Federal Aviation Administration Surveillance. Information supporting (b)(1) and (b)(2) can be found on pages 67-68, and (b)(3) is not applicable.

To the International Council of Air Shows Inc.

A-24-35
In collaboration with the Federal Aviation Administration and other air show industry stakeholders develop standardized, unambiguous terms to help ensure that the directives that air bosses provide performers, such as those related to show lines, are clear and brief.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.3.3.2, Standardized Communications. Information supporting (b)(1) and (b)(2) can be found on pages 66-67, and (b)(3) is not applicable.

A-24-36
In collaboration with the Federal Aviation Administration (FAA) and the warbird community establish standard operating procedures for air show event organizers and air bosses that include: 1) applying administrative controls to ensure that multiple, dissimilar aircraft not operated as part of an approved maneuvers package remain deconflicted; 2) performing a safety risk assessment for each performance to determine hazards and apply effective mitigations, including consideration for any revenue ride flights conducted during air show operations; and 3) completing a daily debriefing that includes continuous feedback to the FAA and the International Council of Air Shows to address any identified deficiencies.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.3 Air Show Safety Oversight, specifically subsection 2.3.2 Need for Administrative Controls and Risk Assessment. Information supporting (b)(1) and (b)(2) can be found on pages 62-64. Although (b)(3) is not applicable to the accident, postaccident actions are described in section 1.10.2.1 Commemorative Air Force Procedures Changes, pages 50-51, and section 1.10.2.2 Safety Alert for Operators: Mass Aircraft Demonstrations, pages 51-52.

To the Commemorative Air Force

A-24-37
Using the guidance provided in Advisory Circular 120-92D, "Safety Management Systems for Aviation Service Providers," revise your safety risk assessment process for identifying and mitigating risks, tracking safety hazards, and routinely assessing trend data to include policies and procedures that specifically address the unique aspects of air show operations, such as considerations for serving as event organizer; participating in air boss–directed performances involving multiple, dissimilar aircraft; and ensuring the safety of revenue passenger rides.

Information that addresses the requirements of 49 *USC* 1117(b), as applicable, can be found in section 2.4 Air Show Safety Culture, specifically subsection 2.4.1 Commemorative Air Force. Information supporting (b)(1) and (b)(2) can be found on pages 68-71, and (b)(3) is not applicable.

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