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NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

AIRCRAFT ACCIDENT REPORT

MIDAIR COLLISION OF
U.S. ARMY U-21A, ARMY 18061,
AND SACHS ELECTRIC COMPANY
PIPER PA-31-350, N60SE
INDEPENDENCE, MISSOURI
JANUARY 20, 1987

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16. Abstract On January 20, 1987, about 1228 central standard time, a U.S. Army Beech U-21A airplane, Army 18061, and a Sachs Electric Company Piper PA-31-350, N60SE, collided at 7,000 feet msl over the Lake City Army Ammunition Plant, Independence, Missouri, about 5 miles east of the eastern boundary of the Kansas City Terminal Control Area. The U-21 was level at 7,000 feet and en route to Fort Leavenworth, Kansas, in accordance with instrument flight rules. The PA-31 was climbing eastbound to an unknown cruise altitude, having departed the Kansas City Downtown Airport in accordance with visual flight rules, en route to Saint Louis, Missouri. The airplanes collided nearly head-on in daylight and visual meteorological conditions. Although both airplanes were equipped with operating mode-C transponders, the radar controllers in communication with the U-21 did not observe and were not alerted to the conflict. Therefore, traffic advisories were not provided. As a result of the accident two pilots and one passenger aboard the U-21 and the pilot and two passengers aboard the PA-31 were fatally injured. Both airplanes were destroyed.

The National Transportation Safety Board determines that the probable cause of the accident was the failure of the radar controllers to detect the conflict and to issue traffic advisories or a safety alert to the flightcrew of the U-21; deficiencies of the see and avoid concept as a primary means of collision avoidance; and the lack of automated redundancy in the air traffic control system to provide conflict detection between participating and nonparticipating aircraft.

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EXECUTIVE SUMMARY

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The major safety issues addressed by the report are limitations in the ability of pilots and air traffic controllers to detect midair collision threats in time to avert inflight collisions between flying aircraft under instrument flight rules and visual flight rules.

As a result of this accident and others, safety recommendations addressing these issues were made to the Federal Aviation Administration, the National Business Aircraft Association, and the Aircraft Owners and Pilots Association.

NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C. 20594

AIRCRAFT ACCIDENT REPORT

Adopted: February 3, 1988

MIDAIR COLLISION OF U.S. ARMY BEECH U-21A, ARMY 18061, AND SACHS ELECTRIC COMPANY PIPER PA-31-350, N60SE INDEPENDENCE, MISSOURI JANUARY 20, 1987

1. FACTUAL INFORMATION

1.1 History of the Flight

On January 20, 1987, about 0745 central standard time, a Piper PA-31-350, N60SE, operated by the Sachs Electric Company, departed Spirit of Saint Louis Airport, St. Louis, Missouri, en route to Kansas City International Airport, Kansas City, Missouri. The purpose of the flight was to transport company executives to Kansas City where they were to conduct company business. The pilot of N60SE obtained a preflight weather briefing and filed an instrument flight rules (IFR) flight plan before departure. The Federal Aviation Administration (FAA) flight service station (FSS) employee who provided the weather briefing and copied the flight plan information also offered to copy the information required to provide the pilot an IFR flight plan for a return flight planned for later that day. The pilot of N60SE declined the offer saying he would file for the return flight later that day.

There were no reported airplane descrepancies during the flight to Kansas City and the airplane arrived without incident. The flight was conducted in visual meteorological conditions. The pilot landed at Kansas City International Airport and dropped off one of his passengers; then he flew to Kansas City Downtown Airport where he deplaned the other passenger and awaited the completion of their business in the Kansas City area. While awaiting the return of his passengers, the pilot made preparations for the return flight to St. Louis.

Although the pilot had advised the St. Louis FSS that he would file an IFR flight plan for the return flight, there was no record to indicate that he obtained a weather briefing in Kansas City or that he filed a flight plan for the return flight to St. Louis. Under applicable FAA rules, the pilot was not required to file a flight plan for the subsequent visual flight rules (VFR) flight. N60SE was not refueled at Kansas City but had sufficient fuel reserves to complete the planned return flight.

N60SE departed from runway 19 at Kansas City Downtown Airport at 1221 in accordance with VFR. The pilot advised the local controller that he would make a left turn to the east after departure. The pilot's acknowledgement of the controller's approval of the left turn was the last known radio transmission from the flight.

The track of the flight of N60SE was reconstructed from Kansas City International Airport Terminal Radar Approach Control (TRACON) and Kansas City Air Route Traffic Control Center (ARTCC) recorded secondary (transponder) radar data. According to the radar data, N60SE turned to an easterly heading after departing Kansas

City, toward the Napoleon VORTAC. 1/ The onboard transponder was transmitting code 1200 and mode C (altitude) information. The radar data showed that the airplane did not enter the Kansas City Terminal Control Area (TCA), but remained beneath its 5,000-foot 2/ base until outside the 20-mile arc which defined the perimeter of the TCA. The secondary radar, mode-C target, was detected by the TRACON's ASR-8 radar equipment at 1222:48 when the target was near the Downtown Airport at an indicated 1,600 feet. The target tracked eastbound at a near constant rate of climb until the target was lost near the Lake City Army Ammunition Plant, Independence, Missouri, at 1227:58 and 7,000 feet.

At 0944 on January 20, 1987, a Beech U-21A airplane, operated by the U.S. Army and using the call-sign "Army 18061," departed Calhoun County Airport, Anniston, Alabama, en route to Sherman Army Airfield (AAF), Fort Leavenworth, Kansas. The purpose of the flight was to transport an Army general officer to Fort Leavenworth. The flightcrew checked the forecast weather and was briefed before departure regarding the mission. No discrepancies were noted during the preflight inspection of the airplane. The IFR flight plan route was direct Muscle Shoals VOR, direct Dyersburg VOR, direct Maples VOR, direct Napoleon VOR, and direct Sherman AAF at an assigned altitude of 8,000 feet.

The flight progressed routinely at 8,000 feet. At 1218, Kansas City ARTCC cleared Army 18061 to descend to 7,000 feet and provided the Kansas City altimeter setting. Army 18061 was level at 7,000 feet at 1221 when Kansas City ARTCC handed off the flight to the Kansas City TRACON East Radar controller. The East Radar controller advised Army 18061 to expect a visual approach to runway 33 at Sherman AAF and provided the following Sherman AAF weather: sky clear, visibility 10, wind from 260 at 7 knots, and altimeter 30.26.

At 1222:34 Army 18061 was instructed to proceed directly to the Kansas City VOR and to depart the VOR heading 310 degrees. The crew acknowledged the clearance with "wilco," indicating that they understood and would comply with the clearance. At 1225:09, Army 18061 was advised of traffic (identified by the East Radar controller as a twin Cessna) at the flight's 12 o'clock position, 5 miles distant, at 8,000 feet, IFR, and southwest bound. At 1225:23 the Army flightcrew reported the traffic in sight. There were no further radio transmissions from the flight. Radar contact with the flight was lost about 1228.

Examination of the radar data confirmed that the traffic advisory to Army 18061 did not pertain to N60SE, and Army 18061 was well clear of that reported traffic when it collided with N60SE about 1228. The radar data indicated that Army 18061 did not alter its heading noticeably after it turned toward the Kansas City VOR and the airplane maintained 7,000 feet until radar contact was lost following the collision.

After the radar target was lost, the air traffic controller's computer attempted to predict the position of the airplane from previous track and ground speed history. The computer identified the target shown on the controller's radarscope as a "coast"target and attempted to re-acquire the target. The computer was unable to

1/ A collocated very high frequency omni range station and ultra-high frequency tactical air navigation aid providing azimuth and distance information to the user.
2/ All altitudes herein are reported in mean sea level (msl) unless otherwise specified.
3/ Coast targets are exhibited on a controller radarscope for a short period of time after radar information on a tracked target is lost, based on the tracking history of the previous target and computer calculations of the probable location of the target.

re-acquire the transponder generated secondary 4/ radar target associated with Army 18061. About the same time that the track went into coast, the Kansas City ARTCC radar began to display multiple primary 5/ radar returns in the area where the secondary targets of N60SE and Army 18061 had been previously presented.

Army 18061 and N60SE collided in visual meteorological conditions over the Lake City Army Ammunition Plant, Independence, Missouri, at 7,000 feet msl. Both airplanes fell to the ground within the confines of the ammunition plant. Two pilots and one passenger aboard the Army airplane were fatally injured, as were the pilot and two passengers aboard the Piper. Ground damage was limited to trees and electrical wires. There were no injuries to persons on the ground. The accident occurred at 39 degrees 06' N latitude and 094 degrees 16' W longitude.

The Safety Board interviewed 15 persons who had reportedly witnessed the collision. Thirteen of these persons were on the grounds of the Lake City Army Ammunition Plant at the time of the collision; none observed the airplanes inflight before the collision. Some of the witnesses described the U-21 falling to the ground, apparently out of control, and debris falling to the ground after the collision. None of the witnesses observed the PA-31 airplane following the collision.

At the time of the accident the East Radar position at the Kansas City TRACON was staffed by an area supervisor and a developmental air traffic control specialist. The supervisor was providing on-the-job training (OJT) to the developmental controller. Both controllers reported that they did not see primary or secondary radar information or an Automated Radar Terminal System (ARTS) III limited data block associated with any aircraft in the vicinity of Army 18061 on their radarscope. They had not provided any traffic advisories relevant to the PA-31.

The area supervisor had assumed the responsibilities of the East Radar position 7 minutes before the collision and had provided the Kansas City weather, the direct routing to the Kansas City VOR, and the traffic advisory regarding the twin Cessna to Army 18061. The developmental controller had been working at the position for about 1 minute at the time of the collision and had not communicated with the Army airplane. She had been briefed by the area supervisor regarding traffic in the sector before she signed on at the position. After her briefing, she made manual adjustments to her radarscope, but she had not made any keyboard entries at the time of the accident.

1.2 Injuries to Persons

	Crew	Passengers	Total
Fatal	3	3	6
Serious	0	0	0
Minor/None	0	0	0
Total	3	3	6

4/ Secondary radar target information presented on a controller scope is generated from transponder information received by the associated radar.

5/ Primary radar target information presented on a controller scope is representative of the radar perceived image of an aircraft or other object (based on reflected radio energy) and is not dependent on receipt of transponder information.

1.3 Damage to Aircraft

The Army U-21 was destroyed by the collision, ground impact, and the effects of a postcrash fire. The Piper PA-31 was destroyed by the collision and ground impact. The wreckage of the PA-31 was not involved in a postcrash fire.

1.4 Other Damage

Three 1/2-inch-diameter high voltage powerlines were broken when the fuselage of the U-21 fell through the wires before ground impact. The only other ground damage involved trees which were struck by falling debris.

1.5 Personnel Information

The pilot of the PA-31 was properly certificated and was adequately trained and experienced to conduct the flight. He had been employed by the Sachs Electric Company as the company's chief pilot. The pilot was currently qualified in the airplane and was quite familiar with it. A review of the pilot's training and certification records did not reveal any history of flight safety violations or aircraft accidents. The pilot was familiar with the Kansas City area including the TCA. He had no known life situational stress problems or unusual resting or eating habits. He smoked about one pack of cigarettes daily. His most recent first class airman medical certificate listed no limitations. His medical examination report indicated that he had 20/20 uncorrected vision in both eyes and normal field of vision. (See appendix B.)

The PA-31 pilot did not allow his nonpilot corporate passengers to occupy the right front (pilot) seat. He explained to his associates that his policy prevented passengers from interfering with the controls or distracting him from his pilot duties. The right pilot seat of the PA-31 was not occupied on the accident flight.

The U-21 was flown by an Army pilot who performed copilot duties and a civilian pilot employed by the Department of the Army who operated the flight controls. The civilian pilot occupied the left pilot seat; the Army pilot occupied the right pilot seat. Both pilots were properly certificated and were current and qualified in the airplane according to FAA and U.S. Army standards. Review of the pilot training records revealed no major weaknesses in the proficiency of either pilot. Neither pilot had any known life situational stress problems or unusual resting or sleeping habits. Neither pilot had any history of flight safety violations or aircraft accidents. Both pilots held current second class airman medical certificates without limitation. Their medical examination reports indicated that both pilots had 20/20 uncorrected vision in both eyes and normal field of vision. (See appendix B.)

The air traffic controllers at the Kansas City International TRACON, East Radar position were qualified to assume the responsibilities of their respective positions. The area supervisor was a full performance level controller, qualified on all control positions in the TRACON. He was an experienced terminal controller who had instructed at the FAA Air Traffic Control (ATC) Academy in the terminal controller option. The controller receiving OJT on the East Radar position was a developmental controller. She was qualified on two positions in the TRACON, but she had not yet qualified on the remaining radar positions. Examination of the controller training records did not reveal any deficiencies. Interviews of the controllers did not reveal any deficiencies with respect to their knowledge of relevant ATC radar procedures or policies. (See appendix B.)

1.6 Aircraft Information

The Piper PA-31, N60SE, was owned and operated by Sachs Electric Company and used for corporate business. The airplane was certificated, equipped, and maintained in accordance with FAA regulations. A review of the available airplane maintenance records did not reveal any discrepancies relevant to the circumstances of the accident flight. The airplane was issued a standard certificate of airworthiness on February 10, 1983. The most recent recertification of the altimeter and pitot static system was logged on January 29, 1985. The most recent annual inspection of the airplane was completed at Kansas City Aviation Center, Olathe, Kansas, on December 23, 1986, at 861 total airframe hours. The airplane was operated only 30 hours from the date of the inspection until the accident. The airplane was equipped with navigation lights and anticollision strobe lights. The strobe lights were examined and repaired in December 1986 as a consequence of the annual inspection. The airplane was painted off-white with two-tone brown trim.

The Beech U-21 airplane (similar to the Beech A90 King Air), Army Serial No. 67-18061, call sign Army 18061, was maintained in accordance with U.S. Army regulations. Review of the airplane logbook and maintenance and historical records revealed nothing of significance to the accident. All applicable Modification Work Orders had been applied. Army 18061 was not equipped with anticollision strobe lights; however, it was equipped with rotating anticollision beacons. The landing lights of the U-21 were capable of being illuminated at any speed. However, the operating instructions for the airplane did not require that the lights be illuminated until the landing checklist was conducted before landing. There was no Army policy or requirement for the landing lights to be illuminated to improve airplane conspicuity during or following descent of the airplane from its cruise altitude. The airplane was painted dark green and white.

1.7 Meteorological Information

At the time of the accident, the weather conditions in the Kansas City area were characterized by high scattered clouds and excellent visibility. The weather observations at Kansas City International Airport, about 25 miles west northwest of the accident location, were:

> 1147, Surface Aviation: 25,000 feet thin scattered; visibility--20 miles; weather--none; temperature--26 degrees F, dew point--11 degrees F; wind--230 degrees at 11 knots; altimeter--30.26 inHg.
>
> 1242, Special: 25,000 feet thin scattered; visibility--20 miles; temperature--28 degrees F, dew point 14 degrees F; wind--240 degrees at 13 knots; altimeter--30.22 inHg; remarks--aircraft mishap.

Based on winds aloft reports, it was determined that the wind at 7,000 feet was from about 307 degrees at 32 knots.

The position of the sun relative to the accident site at the time of the accident was determined to have been 180 degrees (true) in azimuth and 31 degrees in elevation. The sun would have been more than 90 degrees from each pilot's zero reference point. 6/

6/ Zero reference point assumes an average pilot eye reference point for a given seat position and refers to the center of that pilot's viewing area.

1.8 Aids to Navigation

Not applicable.

1.9 Communications

There were no reported communications difficulties. Interviews with the controllers assigned to the TRACON East Radar position did not reveal any communication difficulties.

The East Radar position controllers were in communication with five aircraft at the time of the accident. Based upon volume and complexity, they judged their workload to be light at the time of the accident.

1.10 Aerodrome Information

Not applicable.

1.11 Flight Recorders

Cockpit voice recorders and flight recorders were not installed and were not required in either airplane.

1.12 Wreckage and Impact Information

Wreckage and debris from the two airplanes were located at two main impact sites, 3,700 feet apart, within the confines of the Lake City Army Ammunition Plant. The accident site and surrounding area were snow covered. Other debris from the airplanes was scattered over a 2-mile path. One main wreckage site consisted of the U-21 forward fuselage, its wings, and its engines. The empennage and the aft fuselage were remote from that site. The other main wreckage site contained most of the wreckage of the PA-31; however, the left wing and both engines were remote from that site. The U-21 wreckage was largely consumed by the effects of a postcrash fire. The PA-31 wreckage did not burn. A wreckage distribution chart is in appendix C.

Piper PA-31, N60SE.--The PA-31 main wreckage was in a wooded area adjacent to the firing range of the ammunition plant. The forward fuselage was deformed as a result of impacting a tree. The fuselage was split open forward of the entry door on the left side of the cabin. The lower left side of the fuselage was torn away. The left windshield frame was in one piece; the right was partially torn away at the bottom.

A section of forward fuselage structure with the left windshield wiper attached was found 2,200 feet southeast of the main wreckage site. The top of the fiberglass nosecone cover was intact; the lower third of the nosecone was crushed and separated from the larger top section. The right side of the fuselage was crushed inboard at the midcabin window area and aft of that area. An imprint in that area contained black scuff marks. A parallel black scuff was noted on the outboard side of the right engine nacelle, starting at the juncture between the front wing spar and the nacelle and continuing rearward and upward, 45 degrees to the airplane longitudinal axis. A clean slice through the cabin floor and carpet was noted on the right side of the cabin and opposite the cabin door. The slice was oriented from outboard to inboard (as viewed looking rearward). A styrofoam and plastic ice chest about 12 inches high, normally placed at that location in the airplane by Sachs Electric Company employees, was also cleanly slashed. The inside of the cabin was substantially distorted. A piece of the vertical stabilizer structure of the U-21 was found inside the PA-31 cabin.

The left wing was separated from the fuselage at the wingroot and came to rest 580 feet southwest of the main wreckage site The fractures associated with the wing separation revealed no evidence of preexisting damage. The upper surface of the left wing revealed no obvious collision damage. However, the lower surface contained gouges, scrapes, and a slice through the lower surface. The slice through the lower surface was 3 inches wide and 28 inches long. It began about 7 feet outboard of the fuselage and 30 inches aft of the wing leading edge. The slice progressed rearward at an angle 10 degrees from that of the wing spar. Several scrape marks swept rearward and outboard (about 30 inches) from the inboard leading edge of the wing lower surface, at an angle 20 degrees from the fuselage centerline. The left flap position was up, and the left landing gear was retracted.

The left engine was separated from the wing and was found partially buried in the ground in a wooded area. A clean slice, similar to the one found in the lower surface of the left wing, was present in the bottom of the engine cowl, almost perpendicular to the airplane's normal line of flight. The slice had penetrated through the cowl and into the engine oil pan, several inches inside the cowl. The slice had progressed through the oil pan from the No. 3 cylinder to the No. 4 cylinder of the engine. Two propeller tips were missing and the third was scraped and had deep nicks on the leading edge at 3.5 and 4.5 inches from the tip.

The right wing was in one piece and partially attached to the fuselage structure. The leading edge of the wing outboard of the nacelle was crushed aft and inboard from the leading edge. The crushing extended rearward to the front wing spar, which was broken and deformed rearward. Pieces separated from this area of the wing exhibited crushing deformation in the aft and inboard directions. The crushing along the wing leading edge extended about 4 feet outboard from the nacelle. A shallow dent which contained black scuff marks extended upward and aft from the crush area and along the outboard side of the nacelle. This damage appeared to be aligned with other deformation on the right side of the fuselage cabin. The right engine and propeller did not reveal evidence of having contacted the U-21.

The empennage was still attached to the fuselage. The left horizontal stabilizer and elevator were largely undamaged. The vertical stabilizer and rudder were attached but were resting atop the right horizontal stabilizer. A piece of flight control counterweight, from the left elevator of the U-21, was found inside a hole in the right side of the vertical stabilizer 32 inches above the base of the stabilizer. The outboard end of the right horizontal stabilizer was bent upward.

The cockpit of the PA-31 was fragmented and distorted by collision and ground impact forces. The recognition and strobe light switches in the cockpit were found in the on position. The Safety Board was not able to determine whether the strobe lights were in operation at the time of the accident. A fragment of a Nomex flightsuit with the nametag of the left seat pilot of the U-21 was found embedded left side of the cockpit of the PA-31.

Beech U-21, Army 18061.--The main wreckage of the U-21 came to rest at the edge of a blacktop road about 50 feet northeast of Building 64A of the Lake City Army Ammunition Plant. Three 1/2-inch-diameter high voltage power lines, normally suspended 30 feet above the ground, were broken above the wreckage. Portions of the cabin roof and the fuselage, aft of the airstair (main cabin) door, were scattered about the wreckage path remote from the main wreckage. The wreckage and debris at the main wreckage site was severely fire damaged. The airplane pieces and other debris along the wreckage path were not burned. The extensive postcrash fire damage at the U-21 main wreckage site prevented identification of scratch or scrape marks, propeller slash marks, or other evidence of the angle of impact.

The cockpit area was extensively damaged by impact forces and fire. Most of the instruments on the control panel were separated, exhibited severe impact damage, and/or were severely burned. The control trim positions could not be determined. Fire damage precluded a positive determination regarding the operation of the rotating beacon or landing light at the time of the collision. The flap control lever was in the flaps up position and the flap indicator indicated that the flaps were up. Both flap actuators (in the wings) were found in positions corresponding with fully retracted flaps. The landing gear was determined to be in the retracted position.

The leading edge of the right wing was crushed rearward. The outboard 8 to 10 feet of the right wing exhibited multidirectional shearing. The left engine spinner, hub, and propeller blades were found about 1,500 feet north of the U-21 main wreckage.

The fuselage, aft of the airstair door, was disintegrated and the pieces were scattered about the wreckage path. The tops of the airstair and cargo doors had been sheared off below the fuselage window line, in a rearward direction. Cabin roof pieces, scattered about the wreckage path, were crushed and battered in a rearward direction.

The empennage was fragmented and pieces were scattered about the wreckage path. The largest piece consisted of the right horizontal stabilizer with elevator and trim tab attached. The outboard end of the right horizontal stabilizer and elevator was sheared off. The right elevator counterweight was intact. The left horizontal stabilizer was more highly fragmented than the right. The pieces which could be identified exhibited rearward deformation. The outboard tip of the left elevator was recovered with a fragmented portion of counterweight attached. The fragmented piece matched the control counterweight piece found in the PA-31 vertical stabilizer. The vertical stabilizer and rudder were battered and fragmented. The pieces were deformed rearward and to the right.

The right engine propeller blades remained with the engine but were heavily damaged. The propeller dome was broken apart. Its component parts were missing. However, all three blades were twisted and the propeller blade angles were consistent with high rotational speed at impact. One blade was cut and gouged in the outboard 7 inches with 1 inch of the tip missing. A second blade was twisted severely; the third blade was broken off but was bent into an S-shape. The left engine propeller spinner had a large dent between two propeller blades. The outboard 16 inches of one blade was broken into two pieces. A second blade was bent into an S-shape; the third blade was in a low-pitch position with chordwise scatches on the blade.

The examination of the wreckages of the airplanes did not reveal any evidence of precollision failure or malfunction of control systems or the airplane powerplants.

1.13 Medical and Pathological Information

The postmortem examinations of the pilots were performed by the Jackson County, Missouri Medical Examiner and the Armed Forces Institute of Pathology. The examinations disclosed no evidence of disease processes which would have had any bearing on the pilots' ability to operate an airplane. The cause of death of all of the victims was attributed to multiple severe traumatic injuries as a result of the airplane accident.

Toxicological testing was performed on the remains of the pilots. The tests were negative for drugs. The tests for alcohol revealed a low level of alcohol which was attributed to postmortem factors, not ingestion. The air traffic controllers assigned to the Kansas City International TRACON East Radar position voluntarily submitted urine samples for toxicology. Those samples were negative for drugs.

1.14 Fire

There was no evidence of inflight fire involving either airplane.

The Lake City Army Ammunition Plant Fire Department responded to the postcrash fire at the main wreckage site of the U-21 arriving about 5 minutes after the crash and extinguishing the fire within about 15 minutes. Local fire department and other emergency response vehicles were not permitted on the plant grounds to respond to the fire. The Army Ammunition Plant personnel and equipment were adequate and effective in responding to the emergency and in extinguishing the postcrash U-21 fire.

1.15 Survival Aspects

The accident was not survivable. The occupiable space of both airplanes was compromised and the airplanes were rendered uncontrollable as a result of the inflight collision. There was no evidence that any of the victims survived the collision and ground impact.

1.16 Tests and Research

The Safety Board examined the performance of the airport surveillance radar associated with the Kansas City International TRACON and the capability of the TRACON equipment to display the secondary radar information relevant to N60SE and Army 18061. The Safety Board also examined the collision geometry of the two airplanes and studied the factors that would have affected the visibility of each airplane as viewed from the cockpit of the other.

1.16.1 Kansas City International TRACON

The Kansas City International TRACON provides ATC services including traffic advisories to IFR aircraft operating in the vicinity of the Kansas City TCA and provides traffic advisories to participating VFR aircraft. The TRACON uses the ARTS III computer tracking system to detect, track, and predict the positions of secondary (transponder derived) aircraft targets. The targets are displayed by computer-generated symbols and alphanumeric characters depicting aircraft location, identification, altitude, ground speed, and flight plan data. Aircraft tracked by the ARTS and displaying this information are termed tracked targets; the computer symbology providing the target identification information is termed a full data block (FDB). Those secondary radar derived targets which are not tracked by the ARTS are displayed on the controller scope as limited data blocks (LDB) with computer symbology overlying a received transponder target return. The Safety Board was advised that, at the Kansas City TRACON, 1200-code (VFR) target symbology cannot be supressed by controllers. They are depicted automatically on controller scopes with a computer-generated triangle over the primary and secondary targets for nonmode C targets. Mode-C transponder targets are depicted by a computer-generated square over the primary and secondary targets and also display the transponder-indicated altitude in a three-digit code attached to the square by a leader line about 1/4 inch long.

A review of the FAA records for January 20, 1987, revealed that there were no reported problems with the Kansas City TRACON ASR-8 radar, transponder equipment, or ARTS equipment before the accident. The records indicated that the East Radar scope was removed from service for a maintenance check after the accident, was found to be operating normally, and was returned to service 21 minutes later.

A review of TRACON records, dated December 1, 1986, to January 21, 1987, revealed numerous entries citing false transponder targets on controller radar scopes. The facility air traffic manager (ATM) stated that false targets were reported in the southwest, north, and south quadrants but were not reported in the sector monitored by the East Radar controller. Although the problem was causing false targets to be added to controller scopes, there were no known incidents where tracked or other known targets disappeared from controller scopes for any reason. On the weekend of March 7-8, 1987, a new transponder beacon antenna with a planar array antenna was installed to eliminate the false target problem. The ATM reports that the new antenna has made a significant improvement and eliminated almost all of the false targets. Other action was planned to eliminate the remaining occasional false returns.

On January 21, 1987, a postaccident flight inspection of the ASR-8 radar system and associated TRACON radio frequencies was conducted by an FAA flight inspection airplane which was vectored along a track similar to that of the PA-31 accident airplane. The flight inspection pilots reported that they found the radar and radio frequency operation to be satisfactory. Their report listed no discrepancies. The flight inspection was monitored by a senior, full performance level air traffic controller, and the radar progress of the flight was recorded by the ARTS III computer. During the flight inspection, the controller recorded and graded the primary target return quality; he observed but did not evaluate the quality of the secondary radar returns of the flight inspection airplane. The controller reported that the transponder returns were good and that the mode C readouts were consistent with pilot-reported altitudes during the inspection. The radar data was automatically evaluated by the ARTS computer for validity of the data and for target strength. The extracted radar data showed that target data was presented 99.9 percent of the time during the evaluation period. Only one of the 1,472 returns recorded was graded less than the maximum validity, and mode-C information was presented whenever target information was presented. Target strength was normal during the flight inspection.

1.16.2 Retrack

Since the controllers at the East Radar position reported that they did not observe the eastbound transponder targets of the PA-31 or any other aircraft in the vicinity of the Army U-21, the Safety Board requested that the FAA playback the relevant recorded Kansas City TRACON ARTS III radar data from the East Radar position at the FAA Technical Center, Atlantic City, New Jersey, using their Retrack Program Computer. The retrack program can, through the use of recorded data from the Kansas City TRACON, display ARTS III alphanumeric symbology like that shown on the East Radar controller's display. The retrack program does not currently display raw radar returns (primary returns or ground clutter), analog beacon control slashes, or video maps since this information is not recorded. Therefore, the retrack program cannot replicate the entire radar portrayal on a controller display; it replicates only the alphanumerics generated by the ARTS III program and its associated logic. In this retrack display, control settings such as the alphanumeric gains, character size, and leader length used by the Kansas City TRACON East Radar controllers were incorporated.

On April 17, 1987, the Kansas City TRACON ARTS III recording medium was inserted into the FAA's Retrack Program Computer. The computer had been programmed with the Kansas City TRACON ARTS III program and control settings. The retrack program produced the alphanumeric symbols generated by the ARTS III for Army 18061 and for N60SE. It also revealed the symbology for N12060, which was the overflight traffic identified by the East Radar controller, as traffic for Army 18061 a few minutes before the accident. The display exhibited the alphanumeric symbols of the other airplanes generated by the ARTS III system.

Investigators viewed the retrack three times using different alphanumeric character sizes including character size "2," which was reportedly used by the East Radar controller. The FDB of Army 18061 appeared on the scope at 1221:40 and remained on the scope until the collision. The FDB for Army 18061 was offset to the northeast or southeast relative to the alphanumeric "E" tracking symbol that represented the airplane's position. The LDB associated with N60SE appeared on the scope about 1222:45 and remained on the scope until the collision. The LDB was offset to the northeast of the square symbol representing the airplane's position for the entire viewing. Presentation of data blocks representing both accident airplanes appeared consistent during the viewing, except that on the last three radar antenna sweeps, the FDB for Army 18061 indicated a coast status. The LDB associated with N60SE did not appear on the scope during the last three sweeps. The last presentation, showing both airplanes, had the position tracking symbols nearly overlapped with their 7,000-foot mode C indicated altitudes reading nearly as one presentation.

The Safety Board, viewing the retrack presentation, noted that the offset of the FDBs associated with Army 18061 and N12060 shifted between northeast and southeast, varying due to the automatic offset feature of the ARTS III. The automatic offset feature was designed to preclude FDB information from overlapping and obscuring other FDB radar target information. The Safety Board noted that the FDBs of the tracked targets did not obscure the LDB associated with N60SE at any time during the observed retrack.

The ARTS III system at Kansas City TRACON included "conflict alert" capability, a subprogram that alerts radar controllers to potentially hazardous proximities between tracked aircraft. The aural and visual alerts, associated with the conflict alert system, are based on projected positional and velocity data for tracked mode-C targets. A controller could not be alerted by the system if either of the involved aircraft was not tracked, even if it was equipped with an operating mode-C transponder. Communication with a controller or operating a mode-C transponder on a VFR flight would not provide a pilot with the protection offered by the conflict alert system. However, a controller's positive response to a pilot's request for VFR flight-following services would result in the radar controller tagging up the target and automatically initiating the track needed by the conflict alert system. When controller workload is high, it may not be possible for the controller to provide flight-following or other air traffic services to VFR aircraft. Denial of a pilot's request for flight-following services under these circumstances is not unusual.

To evaluate the potential usefulness of the conflict alert system in alerting controllers to impending collisions between tracked and untracked mode-C radar targets, the Safety Board manually "tagged" the LDB associated with N60SE at the beginning of the third retrack viewing. This caused an FDB to be associated with the radar target of N60SE and a track to be started automatically. With no further input, the FDB continued to be displayed for N60SE until the radar target merged with that of Army 18061. After the time of the collision, the track associated with N60SE displayed a coast status. The Safety Board noted that the conflict alert visual and aural alarms activated during the simulation at 1227:20, more than 40 seconds before the actual collision. The conflict alert feature continued until the radar targets entered coast status.

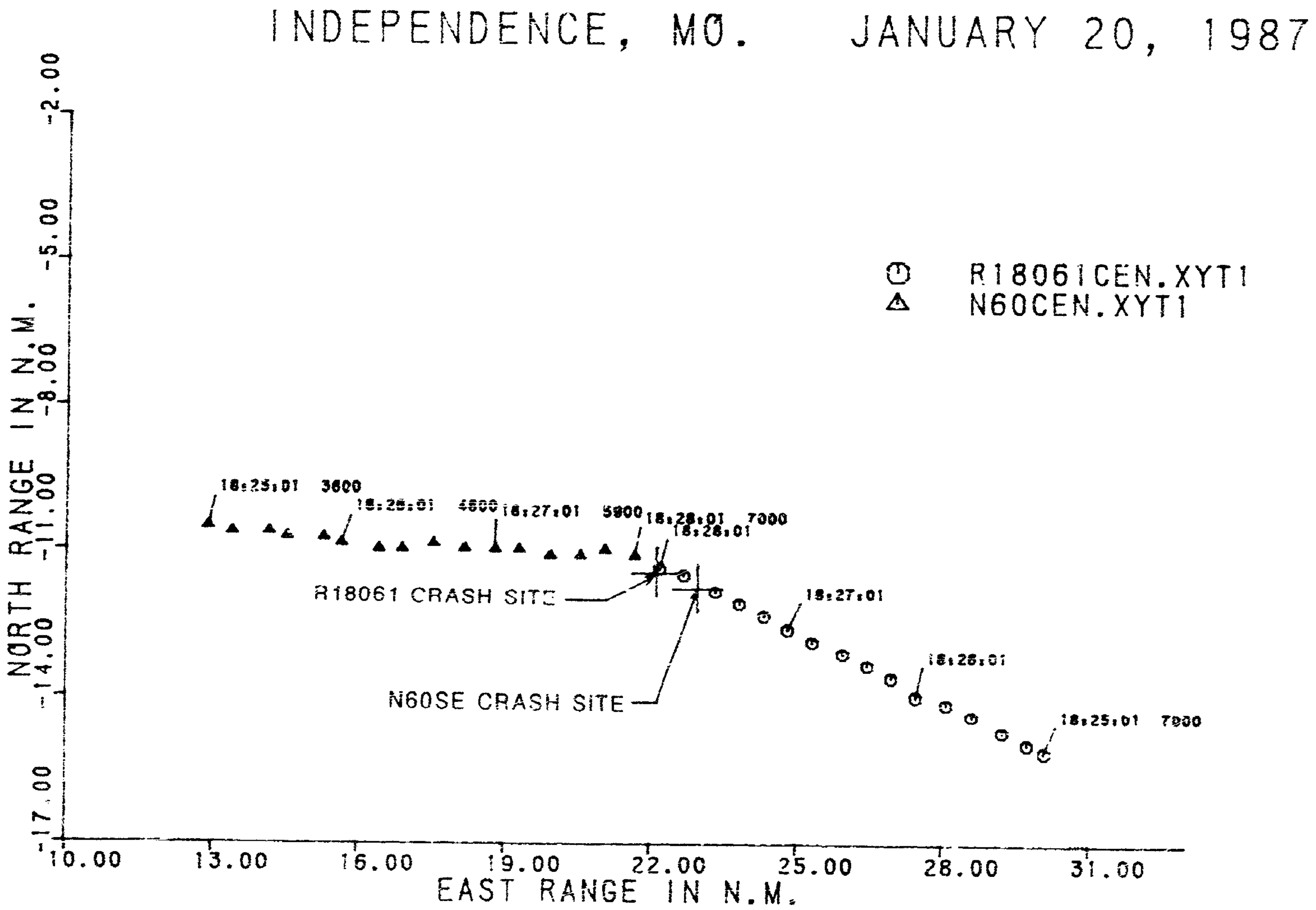

Figure 1.--Tracks of N60SE and Army 18061
plotted from Kansas City ARTCC radar data.

1.16.3 Airplane Performance Calculations

The Safety Board examined the recorded radar data to determine the positions, altitudes, velocities, and flightpaths of both airplanes in the last minutes of the flight. Based on the radar data, it was determined that the accident occurred about 1228:07.

The Kansas City TRACON radar data were originally formatted in range and azimuth from the ASR-8 radar antenna site used by the ARTS III equipment. The data were converted to X-Y coordinates in nautical miles and were reoriented to true north alignment. The radar data were smoothed and evaluated at 5-second intervals to allow the calculation of average airplane performance before the moment of impact. Thus, it was revealed that N60SE maintained an average rate of climb of 1,066 feet per minute (fpm) over the last several minutes of the flight.

The smoothed radar data were used as input data for a National Aeronautics and Space Administration (NASA) computer program (MANAT) that is used to calculate performance parameters such as airspeed, ground speed, roll angles, and acceleration loads. This program is useful for calculating long term motion of the airplane, but short term (abrupt) maneuvers cannot be reconstructed using this program. The MANAT program revealed that there were no significant changes in airspeeds or ground tracks over the last several minutes of the flights. N60SE was maintaining about 140 knots indicated airspeed (KIAS) on a ground track of 093 degrees true and a heading of about 086 degrees true. Army 18061 was maintaining about 190 KIAS on a ground track of about 296 degrees true. N60SE was climbing at about 1,066 fpm and Army 18061 was level at 7,000 feet msl. The tracks of the airplanes, plotted from Kansas City ARTCC radar data, are shown in figure 1. Figure 2 shows the radar tracks and also primary target information which was recorded by Kansas City ARTCC after the collision.

1.16.4 Cockpit Visibility Study

A cockpit visibility study was conducted to determine the location of each airplane with respect to the field of vision of the pilot(s) in the other airplane. A binocular camera, owned and operated by the FAA Technical Center, Atlantic City, New Jersey, was used to photograph the cockpits of two airplanes with structurally identical cockpit visibility to the accident airplanes. 7/ The camera uses two 65 mm wide-angle lenses with angular coverage of 88.5 degrees simulating the lenses of the human eye. The lenses were 2.5 inches apart, the average human interocular distance. The camera rotates about a vertical axis that is normally 3.5 inches from the lenses, approximating the distance between the front of the eye and the odontoid process or pivot point about which the head rotates. The camera produces a continuous strip of film to produce a panoramic view of the window configuration. Horizontal and vertical grid lines are measured and superimposed on the photographs. The resulting photographs show the outline of the cockpit windows as seen by a crewmember rotating his head from side to side. Monocular obstructions within the window, such as windshield or door posts, are also defined by the photographs.

7/ Binocular photographs specific to the PA-31-350 and the U-21 were not available. Binocular photographs of a PA-31 and a Beech 99 were substituted since the cockpits of those airplanes are structurally identical to the accident airplanes according to the manufacturers of the airplanes.

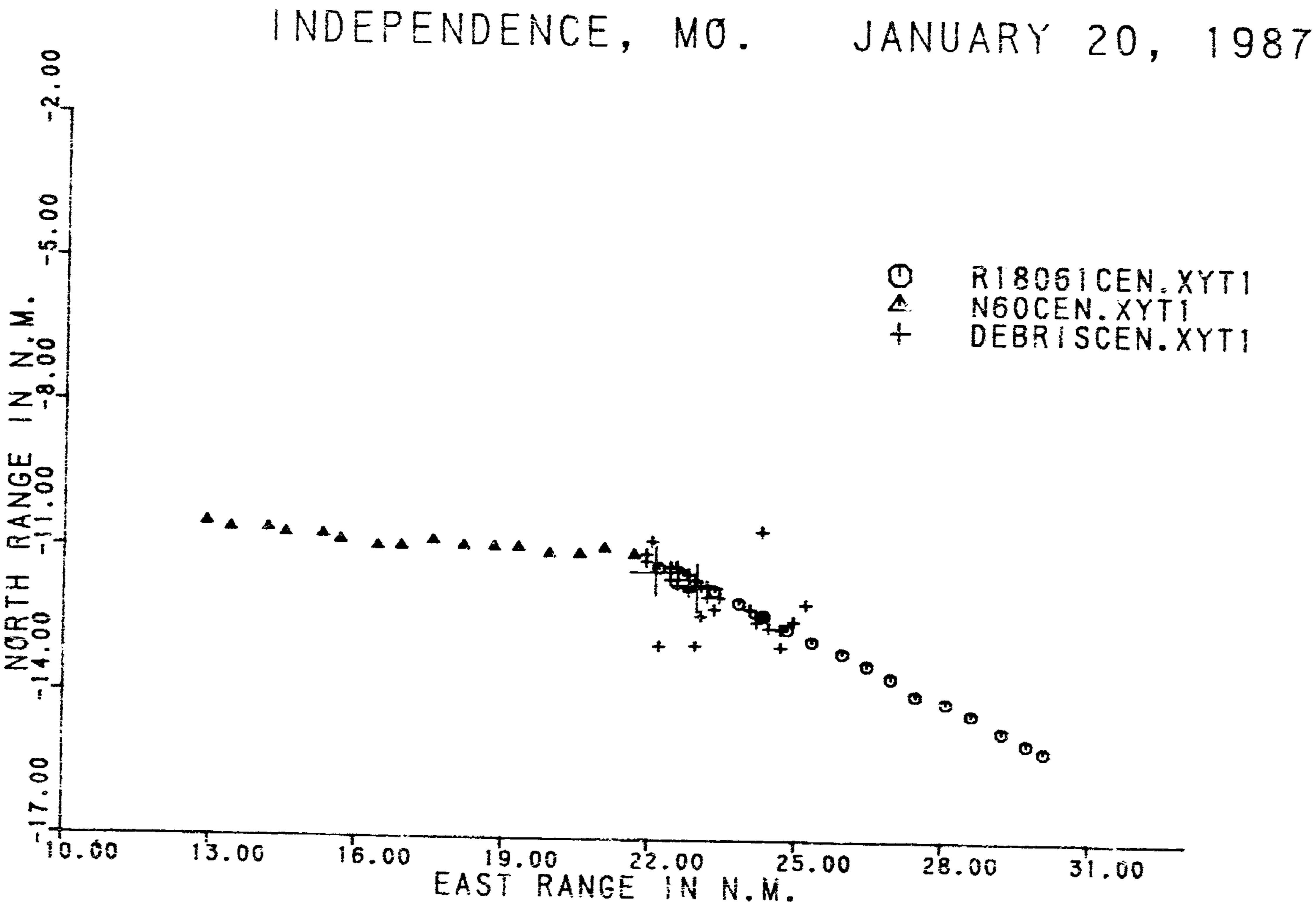

Figure 2.--Radar tracks and primary target information recorded by Kansas City ARTCC.

The binocular photographs were taken with the camera located at a pilot's design eye reference point. The view from the opposite pilot seat was determined by reversing the photographic image.

The ARTS III radar and MANAT data showed that both airplanes maintained a very stable flightpath in the last minutes of the flights. These data revealed that there was negligible target 8/ movement in the pilot fields of vision for more than 60 seconds before the collision.

The cockpit visibility study revealed that:

1. The PA-31 would have appeared about 13 degrees left and 2 degrees below the U-21 pilot eye reference points. Since the U-21 was in level flight, the horizontal axis of the eye reference point was the horizon. There were no cockpit obstructions that would have obstructed the view of the PA-31 from either pilot seat. (See field of vision plots in appendix D.)

2. The U-21 would have appeared about 18 degrees to the right of the PA-31 pilot eye reference point and about 2 degrees above the horizon. However, it would have appeared about 3 degrees below the PA-31 pilot eye reference point due to the PA-31 pitch attitude in the climb. The center windshield post would not have completely obstructed the pilot's view of the U-21, but it would have restricted the pilot to a monocular (left eye) view of the U-21 (assuming no head movement). Movement of the pilot's head forward or to the left would have restored a binocular view of the U-21. The view of the U-21 would not have been obstructed from the right pilot seat.

3. The sun was not in the normal field of vision of the pilots of either airplane.

1.17 Additional Information

1.17.1 U.S. Army Procedures and Practices

The U.S. Army Safety Center reports that the U.S. Army uses several procedures and practices that are intended to reduce the risk of midair collisions.

1. Pilots are obligated to conduct crosscountry flights under IFR whenever possible. Exceptions are authorized when there are excessive ATC delays, when hazardous weather makes IFR flight inadvisible, or when mission requirements dictate.

2. Utility aircraft (U designator) are normally crewed by two pilots on crosscountry flights, even when the applicable flight manual does not require two pilots. For example, the U-21 flight manual requires only one pilot.

3. Effective scanning technique, to reduce the risk of midair collisions, is taught in basic flight training and is reviewed and re-emphasized in annual refresher training of Army pilots.

8/ Targets in the cockpit visibility study refer to the center of the target airplane image and are not representative of its size or shape.

4. Utility and larger transport type airplanes are equipped with mode-C transponders.

5. The Army has participated in the evaluation and testing of airborne collision avoidance systems.

1.17.2 Sachs Electric Company Practices

The Sachs Electric Company operated a small flight department that under the direction of the chief pilot provided corporate flight services for the company. At the time of the accident, the company was operating only one airplane, N60SE, and the chief pilot was their only full-time pilot. It held no air carrier certificates, and therefore, was not obligated to meet the provisions of rules more stringent than those of Part 91 of the Federal Aviation Regulations. The company relied on the chief pilot to make decisions regarding the necessity or advisability of flying in accordance with VFR or IFR. Consequently, some flights were conducted under VFR and some were conducted under IFR. The company had not established a written policy with regard to operation under IFR or the use of flight-following services on VFR flights.

The company normally did not provide two pilots for corporate flights. They deferred to the judgement of the chief pilot with regard to keeping nonpilots from occupying a pilot seat.

1.17.3 ATC Procedures

FAA Order 7110.65D, "Air Traffic Control," (herein referred to as the Handbook), prescribed the air traffic controller procedures and phraseology which were in use at the time of the accident. The Handbook was recently reissued as FAA Order 7110.65E. Paragraph 1-1 of the Handbook requires air traffic controllers to be familiar with the provisions of the Handbook and to exercise their best judgment when confronted by situations not covered by it. Paragraph 2-2 of the Handbook establishes controller priorities. It requires controllers to give first priority to separating traffic and issuing safety alerts. Additional services are to be provided to the extent possible, contingent only on higher priority duties and other factors. A note which follows paragraph 2-2 states, in part:

> The primary purpose of the ATC system is to prevent a collision between aircraft operating in the system and to organize and expedite the flow of traffic. The ability to provide additional services is limited by many factors, such as volume of traffic, frequency congestion, quality of radar, controller workload, higher priority duties, and the pure physical inability to scan and detect those situations that fall into this category. The provision of additional services is required when the work situation permits.

"Traffic advisories" are distinguished from "safety alerts" although both are issued to pilots to advise them of hazardous traffic situations. Safety alerts are a top controller priority because they are issued when in a controller's judgment, an aircraft is in unsafe proximity to another aircraft, terrain, or obstructions. Traffic advisories are given when the situation is less critical.

Paragraph 2-21 of the Handbook states, in part,

> Issue traffic advisories to all aircraft (IFR or VFR) on your frequency when in your judgment their proximity may diminish to

> less than the applicable separation minima. Where no separation minima applies, such as for VFR aircraft outside an ARSA [Airport Radar Service Area], TRSA [Terminal Radar Service Area], or TCA, issue traffic advisories to those aircraft on your frequency when in your judgment their proximity warrants it.

For radar identified aircraft, the traffic advisory should include the direction and distance to the traffic, direction of travel or relative movement of the traffic, and the type aircraft, if known. If requested by the pilot and if able, the controller should provide radar vectors to assist the pilot in avoiding the traffic. However, traffic advisories are additional services and are provided, workload permitting.

Close proximity of conflicting traffic could require the controller to issue a safety alert. Controller recognition of situations of unsafe proximity between aircraft may result from pilot reports, observations on the radarscope or from conflict alert. Paragraph 2-6 of the Handbook requires the controller to issue a safety alert when the controller becomes aware that the aircraft is at an altitude which places it in unsafe proximity to other aircraft. Further alerts are not required if the pilot reports that action is being taken to resolve the conflict. Once the controller recognizes a situation of unsafe aircraft proximity to terrain, obstacles, or other aircraft, the issuance of a safety alert becomes a top priority to the controller. The Handbook encourages the controller to remain vigilant for such situations at all times and to issue a safety alert whenever the situation is recognized. Paragraph 2-6b, Aircraft Conflict Alert, states, "Immediately issue/initiate an alert to an aircraft if you are aware of another aircraft at an altitude which you believe places them in unsafe proximity. If feasible, offer the pilot an alternate course of action."

Paragraph 5-71 of the Handbook states, in part, that the controller shall apply radar separation:

> a. Between the centers of primary radar targets; however, do not allow a primary target to touch another primary target or a beacon control slash.
>
> b. Between the ends of beacon control slashes.
>
> c. Between the end of a beacon control slash and the center of a primary target.

VFR aircraft do not normally receive air traffic separation services from controllers unless those services are specifically requested. Under most circumstances, VFR aircraft are not required to maintain communication with ATC facilities during the en route phase of flight. The pilot of N60SE was not obligated to request air traffic services or to be in communication with either the Kansas City TRACON or the ARTCC at the time of the accident. Separation of IFR and participating VFR aircraft from other participating aircraft is the first priority of the ATC system, along with providing safety alerts.

1.17.4 See and Avoid

The responsibility for pilots to maintain an adequate outside scan to assure that they are able to "see and avoid" other aircraft is mandated by Title 14 Code of Federal Regulations (CFR) 91.67, which requires:

> When weather conditions permit, regardless of whether an operation is conducted under IFR or VFR, vigilance shall be maintained by each person operating an aircraft so as to see and avoid other aircraft, in compliance with this section.

Operation of a flight under IFR but in visual meteorological conditions does not relieve a pilot of the responsibiliy to see and avoid other aircraft. Neither would the receipt of traffic advisories relieve participating VFR pilots of their responsibilities to see and avoid other traffic.

Nonetheless, many physical, physiological, and psychological constraints have been shown to reduce the human ability to exercise the required degree of vigilance. These limitations include target characteristics, size, color, task variables such as workload and time at task, observer characteristics such as age and fatigue, and environmental parameters such as weather, clouds and glare.

Research data indicate that the human eye (with 20/20 vision) is capable of identifying letters of the alphabet if these letters subtend a visual angle 9/ of at least 0.08 degree or 5 minutes of arc. Letters are considered highly discriminable whereas target identification can be more complex. Humans are capable of recognizing a target when it subtends about 1.2 minutes of arc, if the subject is alerted to search for the target. However, research shows that targets should subtend at least 0.2 degree (12 minutes of arc) to ensure reasonably accurate recognition. 10/

Reaction time after visual acquisition of a target is also a factor in avoiding a collision. FAA Advisory Circular (AC) 90-48C provides military-derived data on the time necessary for a pilot to recognize a potential inflight target and to execute an evasive maneuver. AC 90-48C indicates that the total time required to see an object, to perceive the collision threat, and to take evasive action is 12.5 seconds. About 6.4 seconds are required to complete the evasive maneuver after the collision threat is perceived. (See table 1 and appendix F.)

Table 1.--Reaction Time

	Specific (seconds)	Cumulative (seconds)
See object	0.1	0.1
Recognize	1.0	1.1
Perceive collision course	5.0	6.1
Decision to turn left or right	4.0 ⎫	10.1
Muscular reaction	0.4 ⎬ 6.4	10.5
Airplane lag time	2.0 ⎭	12.5

9/ An angle subtended at the eye by the viewed object. Visual angle is a function of both the size of the object measured perpendicularly to the line of sight and the distance of the object from the eye. The angle is directly proportional to the size of the object and inversely proportional to the distance of the object.

10/ Van Cott, H. and Kinkade, R.,"Human Engineering Guide to Equipment Design," Revised Edition, American Institute for Research, Washington, D.C., 1972.

> When weather conditions permit, regardless of whether an operation is conducted under IFR or VFR, vigilance shall be maintained by each person operating an aircraft so as to see and avoid other aircraft, in compliance with this section.

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Decision to turn left or right	4.0	6.4	10.1
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Airplane lag time	2.0		12.5

9/ An angle subtended at the eye by the viewed object. Visual angle is a function of both the size of the object measured perpendicularly to the line of sight and the distance of the object from the eye. The angle is directly proportional to the size of the object and inversely proportional to the distance of the object.

10/ Van Cott, H. and Kinkade, R.,"Human Engineering Guide to Equipment Design," Revised Edition, American Institute for Research, Washington, D.C., 1972.

Finally, there is a concept known as diffusion of responsibility which describes a tendency on the part of pilots in some circumstances to relax their vigilance. A NASA study on near midair collisions indicated that an inappropriate sense of shared responsibility may occur when an airplane is under ATC radar control. That is, a pilot relegates a portion of his vigilance responsibility for seeing and avoiding to the controller. The study states, in part, "If ASRS [Aviation Safety Reporting System] reports are representative, many pilots under radar control believe that they will be advised of traffic that represents a potential conflict and behave accordingly. They tend to relax their visual scan for other aircraft until warned of its presence." 11/

1.17.5 Human Performance Research

Studies and research indicate that physical limitations do not constitute a major deterrent to sighting targets on a radarscope; however, the studies do indicate that physiological and psychological factors can influence target acquisition on the radar scope. Perception, stress, and motivational research studies indicate that there is a relationship between workload and operator performance. With an increase in workload, there is an initial increase in performance, to some extent, because irrelevant task cues are not being attended to. With further increases in workload, optimum and even maximum performance can be attained. At some point, workload can increase so that it physiologically and psychologically overloads the operator; relevant cues are not being attended to or are disregarded and task performance deteriorates. This results in a tunneling or narrowing of operator perception or attention. It has been demonstrated repeatedly that primary or priority tasks will be maintained or focused on during increased workload, and performance on secondary tasks will deteriorate. This narrowing of the attention field has been found to occur in conjunction with many other factors, including time at task, alcohol, and excessive noise. 12/

2. ANALYSIS

2.1 General

Both airplanes were equipped and maintained in accordance with applicable rules and directives. The examination of the wreckages of the airplanes did not reveal any evidence of precollision failure or malfunction of control systems or the airplane powerplants. There was no evidence that an airworthiness problem or equipment malfunction had any bearing on the accident.

The flightcrews of both airplanes were qualified for the flights. There was no apparent weather involvement or sun factor that would have restricted the flightcrews' ability to see one another. Nor was there any known medical problem that would have impeded their ability to avoid the collision.

The area supervisor and the developmental controller assigned to the Kansas City TRACON East Radar position were qualified to perform their respective functions and to provide the required ATC services. Although the developmental controller was not qualified on the East Radar position, she was receiving OJT from and was directly supervised by a controller (her supervisor) who was qualified on that position. The Safety

11/ Billings, C., Grayson, R., Hecht, W., and Curry, R., "A Study of Near Midair Collisions in U.S. Terminal Airspace," NASA Technical Memorandum 81225, 1980.
12/ Duffy, E., "The Psychological Significance of the Concept of Arousal or Activation," Psychological Review, 1957.

Board believes that her qualification on two other radar positions and training received on the East Radar position attests adequately to her knowledge of ATC radar procedures, even though she was not yet qualified on the East Radar position. It was not inappropriate for a developmental controller to be receiving OJT from her immediate supervisor. The area supervisor who briefed the developmental controller on the position and then monitored her performance was appropriately experienced and qualified to perform the OJT function. The Safety Board is aware that the area supervisor was obligated to monitor the training progress of the developmental controller and, based on satisfactory performance, to eventually certify her on the position. The Safety Board is concerned, nonetheless, that the area supervisor, because of his preoccupation with the briefing of the developmental controller, may not have given appropriate attention to the East Radar position in the moments before the accident.

The accident occurred outside the boundaries of the Kansas City TCA. Therefore, the applicable rules and the safety benefits associated with that protected airspace are not relevant to this accident.

The collision occurred in airspace where ATC separation services were provided to IFR aircraft and traffic advisories were provided to VFR aircraft receiving flight-following services. Except for the fact that under Federal aviation rules, VFR aircraft were obligated to remain in visual meteorological conditions and to see and avoid other aircraft operating in that same airspace, VFR aircraft were authorized to operate in the airspace outside of a TCA without receiving ATC services. Since visual meteorological conditions were prevalent, it was not inappropriate for both airplanes to have been operating in the airspace where the collision occurred.

Thus, the Safety Board's analysis first examined the collision geometry to evaluate the potential for the pilots to see and avoid each other. The collision geometry was reconstructed from the physical evidence found in the wreckage of the airplanes and from ARTCC and ARTS III radar data. The Safety Board also examined pilot and ATC procedures, limitations of the "see and avoid" concept, and limitations of the ATC system that negatively affect the ability of controllers to provide safety alerts, even when both airplanes involved are transponder- and mode-C-equipped.

2.2 Analysis of the Collision Geometry

The collision occurred at 7,000 feet as N60SE was eastbound and climbing and while Army 18061 was in cruise, heading northwest. Flight tracks plotted from the ARTS III radar data indicated that the PA-31 was tracking about 093 degrees true and the U-21 was tracking about 296 degrees true before the collision yielding an approach angle of 157 degrees between the tracks. Relative to head-on, the U-21 was approaching the PA-31 from 23 degrees to the right. Conversely, the PA-31 was approaching the U-21 from 23 degrees to the left as the airplanes converged.

Since the wind at 7,000 feet was from about 307 degrees at 32 knots and the U-21 was flying nearly directly into the wind, it was assumed that a small drift correction was applied by the pilot to maintain his track. The PA-31 wind drift correction for the assumed wind would have been about 7 degrees; thus a heading of about 086 degrees (true) would have been maintained to keep the PA-31 on its 093 degrees track.

Although the U-21 was extensively damaged by ground impact forces and postcrash fire, its wreckage still revealed useful information from which to evaluate the collision geometry. The shearing of the cabin roof at the top of the pilot's windshield in a level plane revealed that the PA-31 had contacted the top of the U-21 windshield with a fuselage reference angle approximately equal to that of the U-21. This evidence was supported by the propeller slice across the bottom of the PA-31 left engine cowl. The penetration depth of the propeller blade into the cowl was determined to have been about 4 inches. In level flight, the top of the windshield of the U-21 would have been about even with the bottom of the PA-31 when the U-21 right engine propeller arc was aligned with the 4-inch-deep slice through the P/-31 left engine cowl. Although the fuselage reference angle consistent with a cli ıb rate of 1,066 fpm (about 18 feet per second) would have been al ut ? degrees nose high, contact between the bottom of the PA-31 and the top of the U-21 would have reduced that angle, consistent with that indicated by the destruction of the U-21 cabin roof.

In addition to the cabin roof, the entire aft fuselage and empennage of the U-21 was separated from the forward cabin area in the collision. This was evidenced by the disintegration of the empennage and the scatter of the aft fuselage and empennage debris. Contact between the PA-31 cabin or right wing, as the PA-31 rode over the top of the U-21, would have caused such damage. The recovery of a piece of the vertical stabilizer from the U-21 in the PA-31 cabin showed that the vertical stabilizer had contacted or passed through the PA-31 cabin. (See figure 3.)

There were numerous scratch marks on the bottom of the left wing of the PA-31 that swept rearward at a 20-degree angle relative to the longitudinal axis of the airplane. These marks were indicative of the relative motion between the two airplanes as they made initial contact. Consistent with the direction of the scratch marks were the locations of two consecutive propeller strikes on the bottom of the left engine cowl and wing of the PA-31. The centers of the two propeller strikes were along a line which swept aft about 20 degrees relative to the longitudinal axis of the PA-31.

Using the scratch angle of 20 degrees, the ground speeds of the airplanes (based upon radar data), and the calculated drift angle and true airspeeds, the collision angle between the two airplanes was determined by vector analysis to have been 158 degrees. The closure rate was 350 knots or 591 feet per second. (See figure 4.)

The near equivalence of the approach angle of 157 degrees, derived from the radar data, and the collision angle of 158 degrees, derived from the wreckage by vector analysis, shows that the airplanes collided at approximately the same angle as they converged. This evidence reveals that either no evasive action was taken or that evasive action was initiated too late to prevent the collision. The PA-31, which had been climbing, actually passed in front of and was rising above the cockpit of the U-21 as the airplanes collided. The wreckage of the airplanes (and the occupant injuries) revealed conclusively that both airplanes were disabled by the collision and that some of the occupants were fatally injured as the airplanes collided.

2.3 Analysis Based on Cockpit Visibility Study

The cockpit visibility study showed that the PA-31 was visible through the windshields of both U-21 pilots. Neither pilot's view would have been obstructed by windshield or door posts, windshield wipers, or other airplane equipment. There was no need to attempt to view the PA-31 by looking outside the viewing area associated with normal outside scanning. The sun should not have produced any abnormal glare on the windshield.

The study showed that the U-21 would have been positioned near the center windshield post of the PA-31 pilot's windshield. If the pilot kept his head motionless, the U-21 would have been sufficiently obscured by the windshield post that the pilot would

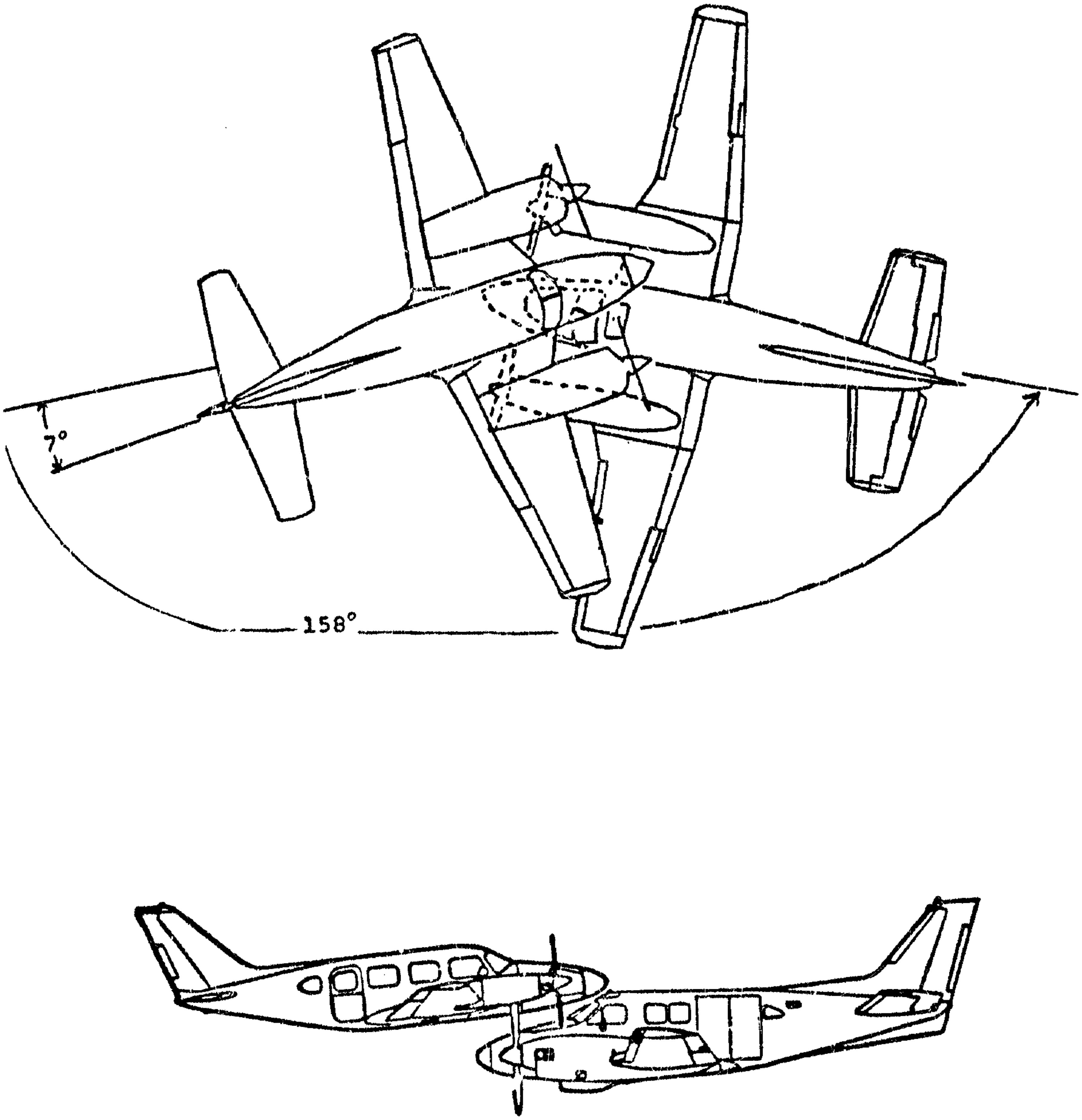
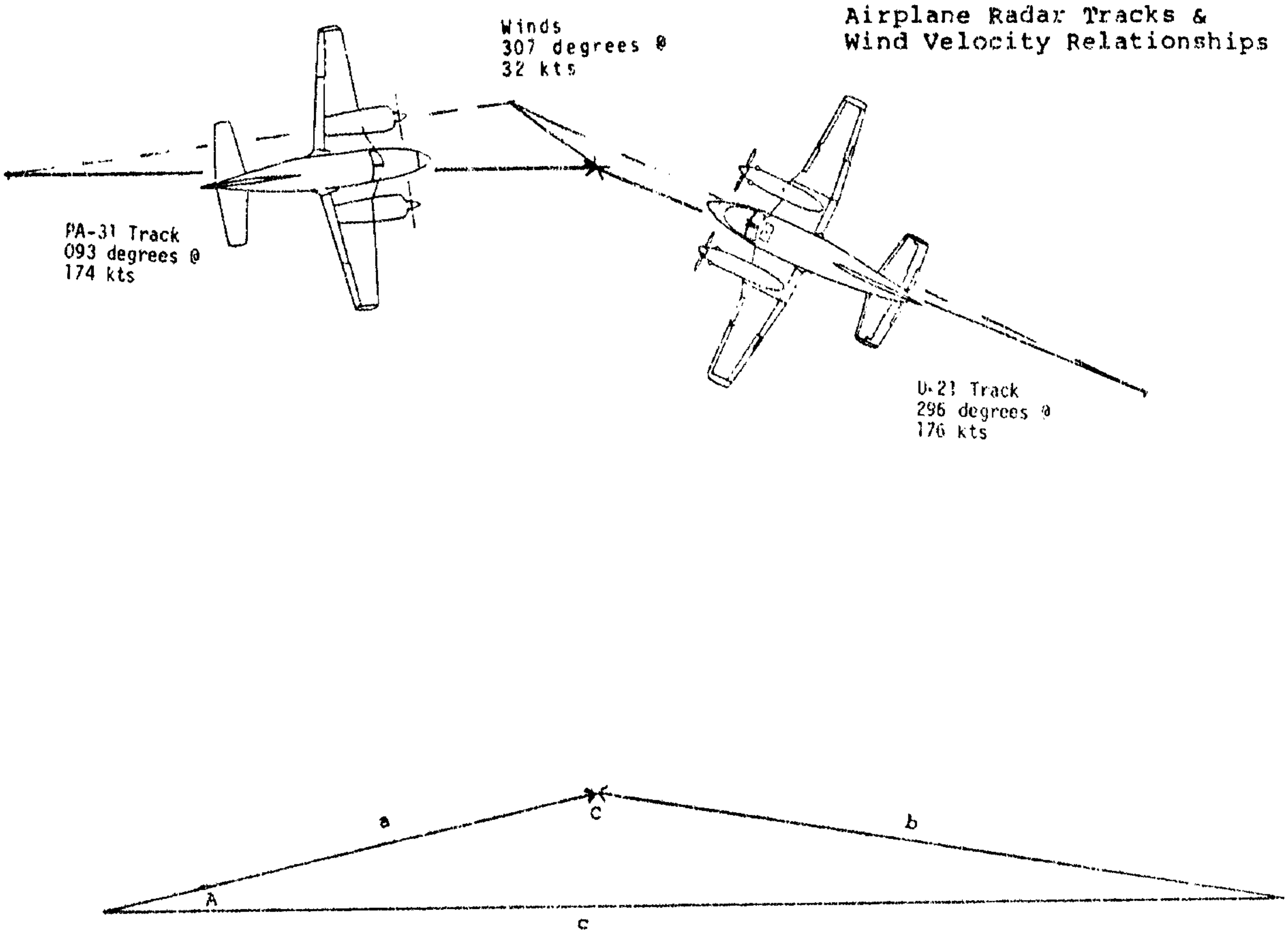


Figure 3.--Horizontal and vertical relationship of the airplanes at impact.



Knowns
Angle A = Scratch Angle - Drift Angle =(20-7)= 13 degrees
Side a = PA-31 True Airspeed = 150 kts
Side b = U-21 True Airspeed = 207 kts

Resultants
Angle C = Collision Angle = 158 degrees
Side c = Closure Speed = 350 kts

Figure 4.--Triangular relationship of the airplanes at impact.

have seen the U-21 only with one eye. However, if the pilot moved his head forward or to the side as he scanned, it would have been possible for him to view the U-21 with both eyes.

The Safety Board believes that a person with the experience of the PA-31 pilot should have employed a scanning technique which included head movement in addition to eye movement. However, it is apparent that the pilot's scanning technique did not result in identification of the collision threat posed by the U-21 in time to prevent the collision. The sun should not have been a factor limiting the pilot's ability to see the U-21; the U-21 target was 76 degrees from the position of the sun.

Since limits in cockpit visibility did not effectively explain why the pilots of each airplane did not see the other airplane in time to take evasive action, the Safety Board considered the closure rate, the relative sizes of the targets, and other factors that could have influenced the pilots' ability to see the other airplane in time to avoid the collision.

2.4 Limitations of the See and Avoid Concept

Since both pilots were clear of clouds, each was responsible, according to 14 CFR 91.67, to maintain vigilance "so as to see and avoid other aircraft." The fact that the U-21 was operated in accordance with IFR was irrelevant, as IFR pilots are also obligated by the rule to see and avoid when in visual meteorological conditions. However, with the airplanes converging from nearly head-on and with a 350 knot (591 feet per second) closure rate, each pilot was presented with a frontal view of the opposing airplane and a rate of closure which, in combination with other factors, may have prevented acquisition and identification in time to recognize the threat of a midair collision and to take appropriate evasive action. The application of the research cited in the See and Avoid section of this report reveals that there was little likelihood of either pilot maneuvering his airplane in time to avert the collision unless they were alerted to the presence and the threat represented by the other airplane.

Initially assuming that the pilots would perceive the collision threat and be able to react to the opposing airplane when the wingtip to wingtip view subtended a 0.2 degree arc, the Safety Board calculated the time before collision at which that angle would be achieved. The PA-31 pilot would have had such a view of the U-21 at a distance of 14,000 feet about 24 seconds before the collision. The U-21 pilots would have had such a view of the somewhat smaller PA-31 at 11,000 feet about 19 seconds before the collision. If the PA-31 pilot's view of the U-21 was partially obstructed by his airplane's center windshield post, the U-21 airplane and collision threat probably would not have been perceived by the PA-31 pilot until the airplanes were much closer than 14,000 feet.

It is uncertain and perhaps unlikely that the pilots would have been able to perceive the collision threat at the precise time when the opposing airplane first subtended the 0.2 degree arc, because the wingtips and other details that would have been needed by the pilots to define and determine the relative motion of the other airplane probably would have been indistinguishable at those distances. If it was assumed that the pilots would perceive the opposing airplane collision threat when the frontal view of the fuselage of the other airplane first subtended a 0.2 degree arc, the collision threat would not have been perceived until the last 3 to 4 seconds before impact. That close to impact, the pilots would not have had time to have completed an evasive maneuver before impact because about 6.4 seconds would have been required to make the appropriate evasive maneuver decision, to apply the control input, and to have the airplane react (after target acquisition and perception of the collision threat). (See table 1 in the See and Avoid section of this report.)

The preceding analysis is based on laboratory evidence derived from perception experiments. The predictions from that research correspond closely to those made from a recent study involving the air-to-air visual acquisition capabilities of actual pilots when applied to the visual circumstances of this accident. The analysis was conducted by the Massachusetts Institute of Technology, Lincoln Laboratory and is contained in appendix E of this report. The Lincoln Laboratory analysis is based on a mathematical model of visual acquisition that was developed during FAA-sponsored flight tests of collision avoidance systems. 13/ The model was extended to unalerted search (i.e., visual search without a traffic advisory) through a series of flight tests in which general aviation pilots in a Beech Bonanza were evaluated with respect to their ability to detect the collision threat presented by a Cessna 421 airplane under actual flight conditions. The pilot subjects whose performance were evaluated had been told they would be participating in an evaluation of workload management techniques of VFR pilots. Although they were told to call out all traffic as soon as they saw it, they were not told that they would be evaluated on the basis of their traffic call outs. Thus, researchers were able to gather insight into workload devoted to visual search as opposed to tasks within the cockpit. Since none of the pilot subjects detected that the Cessna 421 airplane was involved in the test until after the third intercept, the pilot acquisition performance during the test was thought to reasonably approximate the performance to be expected of general aviation pilots in single-pilot VFR flight under low workload conditions.

Basic characteristics associated with the visual target such as closure rate, target aircraft size, and meteorological visual range were explicitly accounted for in the Lincoln Laboratory model. A model parameter (beta) was adjusted to accurately reproduce the observed performance of the pilots of the test flights. Beta is representative of the demonstrated search efficiency. The model did not attempt to model the physiological or mental processes underlying pilot performance. Such factors are incorporated in the search efficiency parameter.

The model was employed to predict the probabilities of visual acquisition of the pilots of the U-21 and PA-31 as the two airplanes converged before the collision. Input into the model were the speeds of both airplanes, headings, the area profile at the presentation angle, the number of pilots in each airplane engaged in the search, and visual range. The Lincoln Laboratory analysis indicated that the predicted probability of target acquisition would not have been high until the last few seconds before the collision. The model indicated only a .27 (27 percent) probability that the PA-31 pilot would see the U-21 at 12 seconds before the collision. Similarly, the model predicted only a .33 probability that either of the U-21 pilots would see the PA-31 at 12 seconds before the collision. These results assume a relatively low-pilot workload (as was the case in the Lincoln Laboratory research) and unobstructed view of the opposing airplane. Increasing the pilot workload, distraction or occupation with other cockpit duties, or obstructions to a clear view of the other airplane would have reduced the probability of acquisition at a given time, and therefore, would have reduced the time available for the pilots to react to the collision threat when it was perceived.

Further application of the Lincoln Laboratory research demonstrated that had any of the pilots been alerted to the impending collision, his probability of acquisition would have been improved significantly. These results were based on studies of pilot performance when alerted with traffic warnings provided by an onboard collision avoidance device. Based on the Lincoln Laboratory model it was determined that the probabilities of acquisition of the other airplane (12 seconds before the collision) by the PA-31 pilot and by the pilots of the U-21 would have been improved to .91 and .96,

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13/ Andrews, J.W., "Air-to-Air Visual Acquisition Performance with TCAS II," ATC-130, DOT/FAA/PM-84-17, Lincoln Laboratory, Massachusetts Institute of Technology, 1984.

respectively, if those pilots had been alerted by such an advisory. Any form of alert provided to the pilots would have improved the probability of acquisition of the other airplane before the collision.

One of the most effective means available to pilots to reduce the potential for involvement in midair collisions is the maintenance of a vigilant lookout by constantly scanning the sky for potential collision threats. Effective outside-the-cockpit scanning is equally important to VFR and IFR pilots because in visual meteorological conditions both are responsible for seeing and avoiding other airplanes. AC 90-48C, last updated in 1983, emphasizes effective scanning techniques and operational procedures to reduce the potential for midair collisions. For example, the AC notes that:

(1) Pilots must remain constantly alert to all traffic movement within their fields of vision, periodically scanning the entire visual field outside the cockpit, to assure the earliest possible detection of collision threats.

(2) Pilots should shift their glances about the viewing area, refocusing at intervals and preventing the eyes from focusing at a fixed distance, because it may take several seconds for the eyes to refocus.

(3) Effective scanning is accomplished by using a series of short, regularly spaced eye movements that bring successive areas of sky into the pilot's central visual field. Each movement should not exceed 10 degrees, and each area should be observed for 1 second to enable detection.

(4) Back and forth eye movements are an effective scanning technique.

(5) Peripheral vision is extremely important to effective scanning because apparent movement of a target is almost always the first perception of a collision threat and that threat is frequently detected first by a pilot's peripheral vision, particularly at night.

(6) Notwithstanding this, pilots should be aware that when a target appears to have no relative motion, it is likely to be on a collision course with the observer's aircraft. Immediate evasive action should be taken when an observed target appears to be increasing in size but has no apparent relative motion.

(7) Pilots should keep their heads moving while scanning to allow searching around door or windowposts to reveal any concealed target.

(8) Pilots should execute gentle banked turns (clearing turns) to the left and right during climbs and descents to permit continuous visual scanning of airspace that might otherwise be obscured by the nose of the aircraft.

The degree to which the pilots of N60SE and Army 18061 were alert and scanning outside their airplanes could not be determined. The radar data showed that the pilot of N60SE did not perform clearing turns as he climbed toward his intended cruise altitude. His failure to perform clearing turns may have effectively limited his ability to detect the presence of a collision threat, particularly in combination with other factors such as his center windshield post that partially obstructed his vision in the direction of the Army airplane. Since the conflict was not resolved by the pilots of either airplane in time to complete evasive action, there is reason to believe that the pilots of both airplanes were not effectively scanning the sky for other airplanes before the collision. While the Safety Board is aware that many other factors may have negatively influenced the ability of the pilots to see and avoid in time to prevent the accident, the Safety Board is convinced that "see and avoid" remains a viable concept, and despite its limitations, it remains the most effective means of collision avoidance for certain kinds of aircraft operations. Thus, the Safety Board endorses the FAA's continuing effort to educate pilots regarding the importance of the "see and avoid" concept and effective scanning to avoid midair collisions.

The Safety Board is concerned that many VFR pilots of transponder-equipped (with or without mode C) aircraft have the mistaken impression that the ATC system routinely monitors or tracks their flights and provides traffic advisories regarding their flights to IFR and participating VFR flights. This accident and others recently investigated by the Safety Board convincingly illustrate that VFR flights are not tracked routinely unless the pilot requests and the ATC system provides flight-following services. VFR pilots cannot be assured that simply operating an airplane equipped with a mode-C transponder on VFR flights provides any guarantee of separation from VFR or IFR airplanes.

AC 90-48C urges VFR pilots to take advantage of air traffic advisory services as a means of assisting them in seeing and avoiding other aircraft, but not substituting for the pilots' own visual scanning. The AC was issued before the conflict alert feature was in widespread use in the U.S. ATC system. Although the Safety Board concurs with the emphasis that the AC places on pilots scanning effectively to avoid midair collisions, the Safety Board believes that AC 90-48C should be updated to alert pilots to the significant additional safety benefits accruing from conflict alert when flight-following services are provided to VFR pilots.

In addition to the factors already discussed, the Safety Board considered other factors that could have influenced the pilots' ability to effectively scan the sky for potential midair collision threats. Those factors included conspicuity of the target, task variables, distractions including occupation with other crew duties, visibility restrictions due to environmental conditions (including snow cover on the ground) and the condition of the windshield glass, pilot fatigue, and empty field myopia (a tendency for the human eye to focus at arms length until objects are identified at a greater distance). It was considered probable that decreased vigilance on the part of the U-21 flightcrew, who had been at the controls for nearly 3 hours, and occupation with normal cockpit duties on the part of the pilots of both airplanes may have reduced the degree of outside scanning that was occurring as the airplanes converged. The condition of the windshield glass was not known. Any of these factors would have reduced the time in which the pilots were actively or effectively attempting to "see and avoid."

Since it is uncertain at exactly what point the pilots could have visually acquired the other airplane, the Safety Board is unable to state with certainty that the pilots could not have avoided the collision. However, the Safety Board believes that this case demonstrates limitations of the "see and avoid" concept that would have impeded significantly the pilots' collective ability to avoid the collision. The Safety Board believes that the see and avoid concept alone may not have been sufficient to avert this accident and that an additional safeguard in the form of automated ATC system redundancy is needed to prevent such midair collision accidents.

2.5 ATC Services

The procedures contained in the controller's Handbook require controllers to set priorities on the services they provide to aircraft with first priority given to the separation of IFR airplanes and the provision of safety alerts. The Handbook states that traffic advisories, distinguished from safety alerts by their lesser urgency, are provided as an additional service, "workload permitting" and "contingent upon higher priority duties." In this case, workload should not have impaired the ability of the controllers to provide additional services; the traffic was light and the operational situation was not complex. Even so, the controllers at the East Radar position reported that they never observed any target in the vicinity of Army 18061 in the minutes before the collision. Obviously, if the information related to N60SE did not appear or was not perceived on their radarscope, traffic advisories or a safety alert would not have been provided to the pilot of the Army airplane. The Kansas City TRACON was not in communication with N60SE; thus, there was no opportunity to provide traffic advisories to that airplane.

The East Radar controllers reported that if they had seen the radar target of an aircraft that represented a threat to Army 18061, they would have provided the appropriate traffic advisories. However, review of the recorded radar data and TRACON communications revealed that in the 7 minutes before the accident, traffic advisories were only provided to aircraft presenting an FDB on the controllers' scope; such advisories were only provided regarding traffic represented on the radar screen by an FDB. The Safety Board was unable to establish that the controllers would have overlooked traffic represented by an LDB or that they would have unintentionally given a lower priority to traffic represented by an LDB. However, the recorded radar data and data from the retrack program suggested that the radar information relevant to N60SE was recorded, processed, and presented on the controllers' scope.

The maintenance records, a postaccident ground check, and a flight check of the East Radar equipment and radarscope did not reveal any indication of a discrepancy that would have prevented the presentation of the LDB of N60SE on the East Radar controller scope at the time of the accident. Therefore, the Safety Board concludes that the radar target of N60SE was displayed on the East Radar controller scope; yet both controllers failed to perceive it and the collision threat represented by it in the minutes before the accident. This failure elevates the concerns of the Safety Board that ATC system redundancy in the form of VFR conflict alert programming is needed to assist in the prevention of such midair collision accidents.

As a result of this and three other midair collision accidents, on July 27, 1987, the Safety Board recommended that the Federal Aviation Administration:

A-87-98

> Take expedited action to add visual flight rules conflict alert (mode C intruder) logic to Automated Radar Terminal System (ARTS) III A systems as an interim measure to the ultimate implementation of the Advanced Automation System.

The timing and completeness of the position relief briefing given to the developmental controller by her area supervisor shortly before the accident may have been of critical importance in this accident. It was important to the developmental controller to be fully aware of the details of the briefing including all of the information relevant to the aircraft being controlled by that sector, because she needed the information to perform her controller duties properly, and because she would be graded on her ability to gather, access, and use the information.

A position relief briefing is routinely conducted before transferring controller duties, to fully inform the relieving controller of the operational situation, even when the "relieved" controller remains at the position to provide OJT to another controller not yet qualified on the position. Standard operating procedures for the transfer of position responsibilities are contained in appendix D of the Handbook. The standard operating procedure (SOP) was established to allow the continued expeditious movement of traffic without compromising safety during the position relief process. The Handbook acknowledges that a proper position relief briefing causes additional workload for the relieved and the relieving controller at the time of position relief. The SOP is to allow the complete transfer of position relief information with a minimum of additional workload. Both controllers share the responsibility for the completeness and accuracy of the position briefing. The briefing should include abnormal and special interest items, information regarding any applicable traffic, and response to questions on the operational situation at hand. A position relief briefing normally requires 1 to 3 minutes; the briefing of a controller, new to the position, could take longer. When the briefing is completed, the relieving controller signs a log indicating acceptance of the responsibilities of the position, and the relieved controller signs off.

The position log at the East Radar position indicated that the developmental controller signed on at 1228. (The accident also occurred at 1228.) The area supervisor signed on at 1221. The applicable communications tape showed that the developmental controller made at least one radio transmission (not to Army 18061) before the collision; thus, it was determined that she actually assumed the duties of the position (under supervision) in the minute before the accident. The position relief briefing preceded her signing on at the position and was believed to have required about 1 minute based on the relative lack of complexity of the operational situation. Interviews revealed that she was briefed regarding the five aircraft under the control of the sector, and the FDB targets of those aircraft were individually pointed out to her. The developmental controller reported that no LDB targets were pointed out to her during the position relief briefing. (LDB targets should be pointed out during the position relief briefing when they are considered "traffic" for any of the FDB, tracked targets under the operational control of the sector.) After the briefing, she checked and adjusted her radarscope, a process which can be performed rapidly without distorting the radar presentation. Both controllers remained on the position for a few minutes after the accident and logged off at 1234. During the time that the area supervisor was assigned the East Radar position, he was also logged on as the area supervisor. He had arranged for another controller to handle his supervisory duties while he was working at the East Radar position; however, the other controller did not log on as the supervisor.

The Safety Board is concerned that the position relief briefing occurred at the critical time when the radar targets of N60SE and Army 18061 were converging on the radarscope, yet the convergence of the targets was not noticed by either controller. One possible explanation is that the briefing may have been elevated momentarily to a higher priority than all other ATC responsibilities because it was operationally required by the Handbook. Even though these controllers were not overloaded by their operational environment, the combination of controller complacency (associated with light workload) and the operational requirement of a relief briefing may have caused the controllers to narrow their perception and attention to that single task, in lieu of their other ATC duties.

The Safety Board noted with interest that the workload at the East Radar position was considered light by the involved controllers at the time of the accident. Although the position relief briefing provided an untimely increase in controller workload and a possible distraction immediately before the accident, the traffic was so light that it may have lulled both controllers into a reduced state of vigilance. A reduced state of vigilance would explain why they failed to detect the presence and conflict presented on their radarscope by the LDB representing the PA-31 airplane.

Within the last 12 months the Safety Board has investigated five midair collisions in which the air traffic controller workload was judged light or moderate yet the controllers did not perceive a collision threat and did not issue traffic advisories or safety alerts before any of the collisions. The apparent pattern suggests that periods of low air traffic controller workload may result in periods of reduced vigilance on the part of the controllers and produce a greater hazard to traffic separation than had been previously recognized. In the Safety Board's runway incursion special investigation, 14/ it was found that heavy traffic and reduced visibility were infrequently involved. On the contrary, traffic was reported as light or moderate at the time of most of the incursions where controller actions were involved. In some of the controller-induced runway incursions, the controllers were working as few as two airplanes. The FAA Civil Aeromedical Institute, in a study of ATC operational error incidents occurring from 1965 to 1980, noted that 40 to 50 percent of the errors occurred under moderate controller workloads. Over the period evaluated, there was a reported trend toward increased numbers of incidents occurring during light traffic. 15/

The Safety Board believes that it is more likely that the Kansas City TRACON East Radar controllers were distracted from monitoring traffic in the moments before the collision because of their position relief briefing and associated duties than that they were inattentive and not vigilant as a consequence of their otherwise light workload. Nonetheless, the Safety Board is concerned with the apparent increase of ATC operational errors, runway incursions, and midair collisions which have occurred during periods of low air traffic controller workload. The Safety Board believes that controllers have a tendency to relax their vigilance in the low workload environment making them susceptible to operational errors and omissions. Further, the Safety Board believes that FAA action is needed to preclude reduced controller vigilance during periods of low controller workload.

The Safety Board is aware that both of the Kansas City TRACON East Radar controllers and all other controllers employed by the FAA, since the advent of ARTS tracking systems in the 1970s, were trained to identify and track targets using the ARTS. Recently, the Safety Board has learned that some FAA facilities no longer permit radar controllers to control traffic except by use of the ARTS equipment. The Safety Board is concerned that as a result of their training and possibly operational experience, some radar air traffic controllers may be focusing an inordinate amount of attention to targets identified by FDB targets (tracked targets) to the exclusion of untracked targets identified by LDB or by primary or secondary radar returns.

14/ Special Investigation Report--"Runway Incursions at Controlled Airports in the United States" (NTSB/SIR-86/01).

15/ Schroeder, D. J., "The loss of prescribed separation between aircraft: How does it occur?" Transcripts, 1985 Conference of the Society of Automotive Engineers, 4426-4434.

In conjunction with this investigation and the Safety Board's investigation of the January 15, 1987, Kearns, Utah, midair collision accident, the Radar Training Facility at the FAA Academy in Oklahoma City, was examined. The Safety Board attempted to determine whether there were deficiencies in the training of air traffic controllers that would explain their not detecting collision threats represented on radarscopes by primary, secondary, or LDB radar targets, as opposed to FDB radar targets. A review of the radar controller curriculum and laboratory exercises at the FAA Academy revealed that they were sufficient in terms of exposing controllers to the radar situations described in their Handbooks. The laboratory workshops allow controllers to gain practical knowledge and experience in the application of radar procedures, including the provision of traffic advisories. Controllers were graded on their demonstrated ability to perceive and react to VFR traffic and in making appropriate traffic advisories. However, it was noted in this program that emphasis was placed on the appropriate separation of FDB IFR traffic, and when VFR traffic was introduced, it was always represented by LDB radar targets with altitude information displayed. Thus, it was not possible for developmental radar controllers at the FAA Academy to detect conflicts involving VFR targets represented by primary or secondary radar targets only.

ARTS tracking systems superimpose computer-generated alphanumeric symbology over the primary and secondary radar target information on controller radarscopes. Tracking of radar targets and distinguishing IFR from VFR targets is much easier using the ARTS information than the primary and secondary radar information that is also displayed. Because FDBs provide more alphanumeric symbology (and information) than LDBs, and because radar controllers control traffic that is almost always identified by FDBs, there is reason to believe that LDBs might sometimes be overlooked by controllers, particularly when controller workload is high or when controller vigilance is reduced. Controller dependence on ARTS III FDB target symbology could cause controllers to attach diminished importance to primary, secondary radar, and LDB target information even when mode-C transponder information is provided. The Safety Board believes that the LDB symbology associated with the radar target of N60SE was sufficiently prominent on the controllers' radarscopes that the controllers should have seen it. However, reliance on ARTS FDB radar symbology may have been responsible for their failure to see the target symbology associated with N60SE.

If this type of oversight is occurring elsewhere in the ATC system, controllers are denying themselves radar target information that would potentially reduce the continuing threat of midair collisions between IFR and VFR aircraft. The Safety Board believes that the FAA should examine the underlying ATC factors in midair collisions and near-midair collisions to determine the extent to which controllers have become dependent on ARTS FDB symbology and the training or remedial measures needed to alleviate the problem.

The failure of the East Radar controllers to provide timely traffic advisories and a safety alert to the crew of the U-21 placed that IFR flight at the same midair collision risk as VFR aircraft which were not using FAA flight-following services. The Army pilots, perhaps unknowingly, became completely dependent on their own ability to "see and avoid" other airplanes, with all the inherent limitations of the "see and avoid" method of avoiding inflight collisions. At the same time, they had reason to expect that the radar controllers were not particularly busy (not much radio communication and excellent weather conditions) and would alert them if there was conflicting traffic. Such reasoning would have been reinforced by the traffic advisory provided to them about 3 minutes before the collision. Under the circumstances, the pilots may have been particularly vulnerable to such an accident because of their confidence in the ATC system. Unfortunately, ATC systems in the United States are not equipped with an automated system that would alert the radar controllers to the presence of a conflict between an IFR flight and a mode-C transponder-equipped VFR flight. The East Radar controllers were unable to provide the needed traffic advisory information because they did not detect the threat, even though the information they needed was displayed before them, and because their ARTS computer was not equipped with the programming that would have alerted them to the threat.

Although the Safety Board cannot state with certainty that the pilots would have taken timely and appropriate action to avert the accident if they had received traffic advisory information, the Safety Board believes that the Army pilots' chances of averting the collision would have been improved substantially if such information had been provided. Any information the controllers could have provided to the U-21 pilots would have improved the crew's probability of acquisition of the PA-31 over that of an unalerted flightcrew. The Safety Board believes that the failure of the controllers to perceive the collision threat and to provide traffic advisory information was so important to avoidance of the collision that it is cited as a cause of this accident along with limitations in the ATC system that made it difficult for the controllers to distinguish collision threats between IFR and VFR aircraft.

2.6 Prevention of the Accident

The retrack of the Kansas City TRACON ARTS III data demonstrated graphically how this accident might have been prevented. By manually tagging up the LDB of the PA-31 (during the retrack), an FDB was generated and computer tracking of the PA-31 was initiated automatically. This activated the conflict alert subprogram of the ARTS III equipment. The conflict alert subprogram compared the progress of the flight track and altitude information of the PA-31 with that of all other tracked targets. Then about 40 seconds before the collision, an aural alarm was activated; the data block information of the conflicting targets began to flash on the controller's radarscope; and a conflict alert message identifying the airplanes in conflict was displayed in the preview area of the radarscope. The Safety Board believes that if this type of distinct and unambiguous information had been presented to alert the controllers before the accident, the controller's attention would have been immediately focused on the conflicting airplanes, and the controller would have had ample opportunity to issue a traffic advisory or a safety alert to the U-21 pilots.

The Kansas City TRACON East Radar controllers did not have the benefit of conflict alert before the accident because VFR airplanes are not provided discrete transponder codes, are not tagged up (tracked) unless they request and are provided ATC flight-following services, and because conflict alert programming does not provide a warning to controllers when a conflict between an IFR aircraft and an untracked VFR code 1200 target occurs. Transponder-equipped aircraft on VFR flights normally broadcast code 1200 to inform controllers of their location and VFR status. An LDB is then presented on the controller's radarscope if the transponder has mode C.

The retrack demonstrated that if flight-following services had been provided to the PA-31 pilot, the conflict alert subprogram would have alerted the controllers to the collision threat about 40 seconds before the collision. Obviously, if the application of the conflict alert subprogram could be extended to include VFR mode-C aircraft, air traffic controllers could extend more positive protection against the threat of midair collisions and to a much larger population of aircraft than are protected by the present conflict alert system. Pilots could also avail themselves of the benefits of the conflict alert subprogram if they would use flight-following services on VFR flights when those services are available. Although controllers are not always able to provide flight-following services to VFR aircraft because of workload, there is no reason to believe that such services would not have been provided to N60SE, since traffic was light.

Interviews of the Kansas City TRACON staff and review of their policies indicated that air traffic services typically would have been provided to the PA-31 pilot under the circumstances of the accident flight had those services been requested. During heavy controller workload conditions and at facilities which are normally very busy, VFR pilots may find that their requests for flight-following or other ATC services are frequently not fulfilled. Recognizing that the workload of many facilities is already high at times and would be increased to the extent that some VFR pilots may not always be able to obtain air traffic services, the Safety Board believes that VFR pilots should nonetheless attempt to obtain those services, when they are available, as a means of reducing the potential for involvement in midair collisions. In this case, the Safety Board concludes that the accident probably would have been prevented if the PA-31 pilot had availed himself of flight-following services (or filed an IFR flight plan).

While acknowledging that the excellent record of midair collision prevention, particularly within positive control airspace and in TCAs, is a tribute to controller performance, the Safety Board believes that controllers need additional automated redundancy to assist them in their task. Additionally, pilots need a more positive backup to the "see and avoid" concept of collision avoidance. Conflict alert and improvements in terminal facility computer systems have provided automated assistance, but do not presently allow controllers to identify collision threats which involve untracked VFR aircraft. Many ATC operational errors and serious compromises of separation between IFR aircraft have been prevented because of the conflict alert feature.

The Safety Board has been advised by the FAA that a TRACON ARTS III A computer could be expanded by adding processing capability to include VFR mode-C intruder conflict alert logic. (The FAA plans to upgrade all ARTS III terminal facilities, including the Kansas City TRACON, to the ARTS III A capability.) The Safety Board recognizes that the procurement of additional processors could infringe on other FAA priorities and may be viewed as an interim measure to the future installation of the Advanced Automation System which is due to be implemented in the late 1990s. Nevertheless, the Safety Board believes that the risk of midair collisions in terminal areas will increase with the projected increases in traffic and that such measures must be taken promptly if catastrophic accidents are to be prevented in terminal areas in the next 10 to 12 years.

The National Business Aircraft Association and the Aircraft Owners and Pilots Association provide valuable services to their pilot members by keeping them informed of important and timely safety information. The Safety Board believes that the circumstances of this accident and the importance of pilots availing themselves of air traffic services, when available, should be stressed to pilots in the safety publications of these organizations, along with the importance of good scanning techniques, to further reduce the potential for midair collision accidents.

The Safety Board also believes that the FAA should direct additional effort toward the development of low-cost proximity warning and conflict detection systems for general aviation aircraft to assist pilots in the detection and avoidance of potential collision threats. On June 7, 1972, in conjunction with the publication of a special study of midair collisions, 16/ the Safety Board issued a number of safety recommendations to the FAA including A-72-157 that addressed this issue. On October 2, 1972, the FAA responded to the Safety Board with assurances that efforts were in progress to develop collision avoidance systems and proximity warning instruments that are cost feasible to the general aviation community. Based on these assurances, the Safety Board classified the recommendation "Closed--Acceptable Action." However, it appears that the general aviation community has benefited very little during the past 15 years from the FAA's efforts in the development of collision avoidance systems. Therefore, the Safety Board believes that the FAA should place additional emphasis on the development of these systems for general aviation aircraft.

3. CONCLUSIONS

3.1 Findings

1. The airplanes collided nearly head-on at 7,000 feet msl over the Lake City Army Ammunition Plant, Independence, Missouri, at 1228 central standard time.

2. The collision occurred about 5 miles outside the boundary of the Kansas City TCA in an area where a mix of VFR and IFR flights is authorized and expected.

3. The pilots of both airplanes were qualified and were familiar with the Kansas City area. There were no apparent medical factors influencing their performance.

4. Both airplanes were airworthy. There were no apparent airplane equipment deficiencies or system malfunctions.

5. The accident occurred in visual meteorological conditions where the pilots of both airplanes were required to "see and avoid" the other. There was no indication that either pilot took evasive action to avoid the collision.

6. Both airplanes were equipped with operating mode-C transponders. The U-21 was operating under IFR and the PA-31 was operating under VFR.

7. The U-21 was displayed as an FDB and was a computer-tracked target on the Kansas City International TRACON controllers' radarscope. The PA-31 was displayed as a code 1200 LDB with mode-C altitude information on the same controllers' radarscope.

8. Although the East Radar position was staffed by two controllers, neither observed any target in the vicinity of the data block representing the U-21.

9. The conflict alert subprogram of the ARTS III tracking system was not programmed to alert them of an impending collision involving an IFR aircraft and an untracked VFR aircraft.

16/ Special Investigation Report--"Midair Collisions in U.S. Civil Aviation, 1969-1970" (NTSB/AAS-72/6).

10. Three minutes before the accident, the U-21 was provided a traffic advisory concerning another airplane. Traffic advisories concerning the PA-31 were not provided.

11. The area supervisor had just briefed and was providing instruction to a developmental controller at the East Radar position when the collision occurred. The controller workload at the East Radar position was light.

12. The PA-31 pilot did not use VFR flight-following services that were available to him. Conflict alert would have alerted the East Radar controllers to the collision threat involving the airplanes 40 seconds before the collision if the PA-31 had been a tracked target.

13. The "see and avoid" concept provided marginal opportunity to the pilots of both airplanes to avert the collision.

14. The absence of VFR conflict alert logic in ARTS III equipment at Kansas City diminished the potential for the radar controllers to detect the impending conflict.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of the accident was the failure of the radar controllers to detect the conflict and to issue traffic advisories or a safety alert to the flightcrew of the U-21; deficiencies of the see and avoid concept as a primary means of collision avoidance; and the lack of automated redundancy in the air traffic control system to provide conflict detection between participating and nonparticipating aircraft.

4. RECOMMENDATIONS

As a result of this and three other midair collision accidents, on July 27, 1987, the National Transportation Safety Board recommended that the Federal Aviation Administration:

A-87-98

> Take expedited action to add visual flight rules conflict alert (mode C intruder) logic to Automated Radar Terminal System (ARTS) III A systems as an interim measure to the ultimate implementation of the Advanced Automation System.

As a result of its investigation of this accident, the National Transportation Safety Board recommended:

--to the Federal Aviation Administration:

> Update Advisory Circular 90-48C and emphasize in operational bulletins, the Airman's Information Manual, pilot training programs, and accident prevention programs the advantages of using air traffic control flight-following services on visual flight rules flights as a further means of reducing the midair collision hazard. (Class II, Priority Action) (A-88-24)

Incorporate formal training on the dangers of the low-workload environment at all levels of air traffic controller training. (Class II, Priority Action) (A-88-25)

Establish an ad hoc task force, including controller and human performance expertise, to evaluate the extent to which radar air traffic controllers are dependent on FDB radar symbology to carry out their duties and to make appropriate improvements in initial and recurrent radar training to rectify such deficiencies. (Class II, Priority Action) (A-88-26)

Expedite the development, certification, and production of various low-cost proximity warning and conflict detection systems for use aboard general aviation aircraft. (Class II, Priority Action) (A-88-27)

--to the National Business Aircraft Association and the Aircraft Owners and Pilots Association:

Make the facts and circumstances of this accident known to your membership and encourage the use of the services of the air traffic control system as a means of reducing the potential for midair collisions. (Class II, Priority Action) (A-88-28)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ JIM BURNETT
Chairman

/s/ PATRICIA A. GOLDMAN
Vice Chairman

/s/ JOHN K. LAUBER
Member

/s/ JOSEPH T. NALL
Member

/s/ JAMES L. KOLSTAD
Member

February 3, 1988

5. APPENDIXES

APPENDIX A

INVESTIGATION AND HEARING

1. **Investigation**

The Safety Board's Kansas City Field Office was initially notified of the accident about 1300 central standard time, January 20, 1987 and immediately responded to the accident scene before it was known that two aircraft were involved. About 1700 eastern standard time, the Safety Board was notified by the Federal Aviation Administration that a second aircraft was involved and that there had been a midair collision. Early on January 21, 1987, three additional investigators were dispatched to the scene from Washington, D.C., to participate in the accident investigation.

Parties to the investigation were the Federal Aviation Administration, Sachs Electric Company, the U.S. Army Safety Center, Beech Aircraft Corporation, and Piper Aircraft Corporation.

2. **Public Hearing**

No public hearing or depositions were held.

APPENDIX B

PERSONNEL INFORMATION

Pilot Alan Earl Walls

Pilot Walls, 42, held airline transport pilot certificate No. 1788336, issued June 26, 1979, wi'. airplane multiengine land privileges. He had commercial pilot privileges in single-engine land airplanes. He held a flight instructor certificate, last reissued April 30, 1985, with ratings in single- and multiengine land airplanes and instrument airplane. His most recent airman medical certificate was a first class certificate issued March 27, 1986, without limitations. The pilot had 7,020 hours total flight experience all in civil aircraft, 160 hours in the last 6 months and had been employed by Sachs Electric Company for 10 years when he applied for that medical certificate.

Mr. Walls' pilot records indicated that he had 7,418 hours total pilot experience with 4,751 hours in multiengine airplanes at the time of the accident. Company records indicated that he had in excess of 596 hours in the PA-31 with 586 hours as pilot-in-command. Company records indicated that he had 52 hours pilot experience in the accident airplane in the 90-day period before the accident. Mr. Walls demonstrated his instrument competency in a PA-31 simulator in October, 1985.

Pilot Carroll Leon Baird

Pilot Baird, 40, held airline transport pilot certificate No. 2056660, issued November 30, 1982, with airplane multiengine land privileges. He had commercial pilot privileges in single-engine land airplanes and helicopters, and his instrument qualification included helicopters. He held a flight instructor certificate, last reissued December 16, 1985, with ratings in single- and multiengine land airplanes. He held a second class airman medical certificate issued October 23, 1986, without limitations. Mr. Baird had 5,700 hours pilot experience including 1,000 hours as a military pilot when he applied for that certificate. Mr. Baird had been a warrant officer and pilot in the U.S. Army before obtaining his civilian flying position.

Mr. Baird initially qualified in the U-21 on August 9, 1986. His pilot records indicated that Mr. Baird had 5,983 hours pilot experience at the time of the accident with 4,196 hours in multiengine airplanes. He had logged 217 hours in the U-21 with 130 hours logged as pilot-in-command. In the 90-day period before the accident, he had logged 128 hours pilot time with 95 hours in the U-21. In the last 30 days before the accident, he had flown the U-21 32 hours.

Pilot Michael Glynn Johnston

Pilot Johnston, 35, was an active duty officer in the U.S. Army holding the military rank of Major. He held airline transport pilot certificate No. 2224244 issued September 24, 1980, with airplane multiengine land privileges. He had commercial pilot privileges in single-engine land airplanes and helicopters, and his instrument qualification included helicopters. He held a second class airman medical certificate which was issued May 20, 1985, without limitations. He reported 4,800 hours pilot experience when he applied for that medical certificate.

Major Johnston initially qualified in the U-21 on June 10, 1978. His pilot records indicated that he had 6,266 hours total pilot experience with 1,528 hours in the U-21. In the 90 days before the accident, he had logged 33 pilot hours with 18 hours in the U-21.

Supervisory Air Traffic Control Specialist David W. Hope

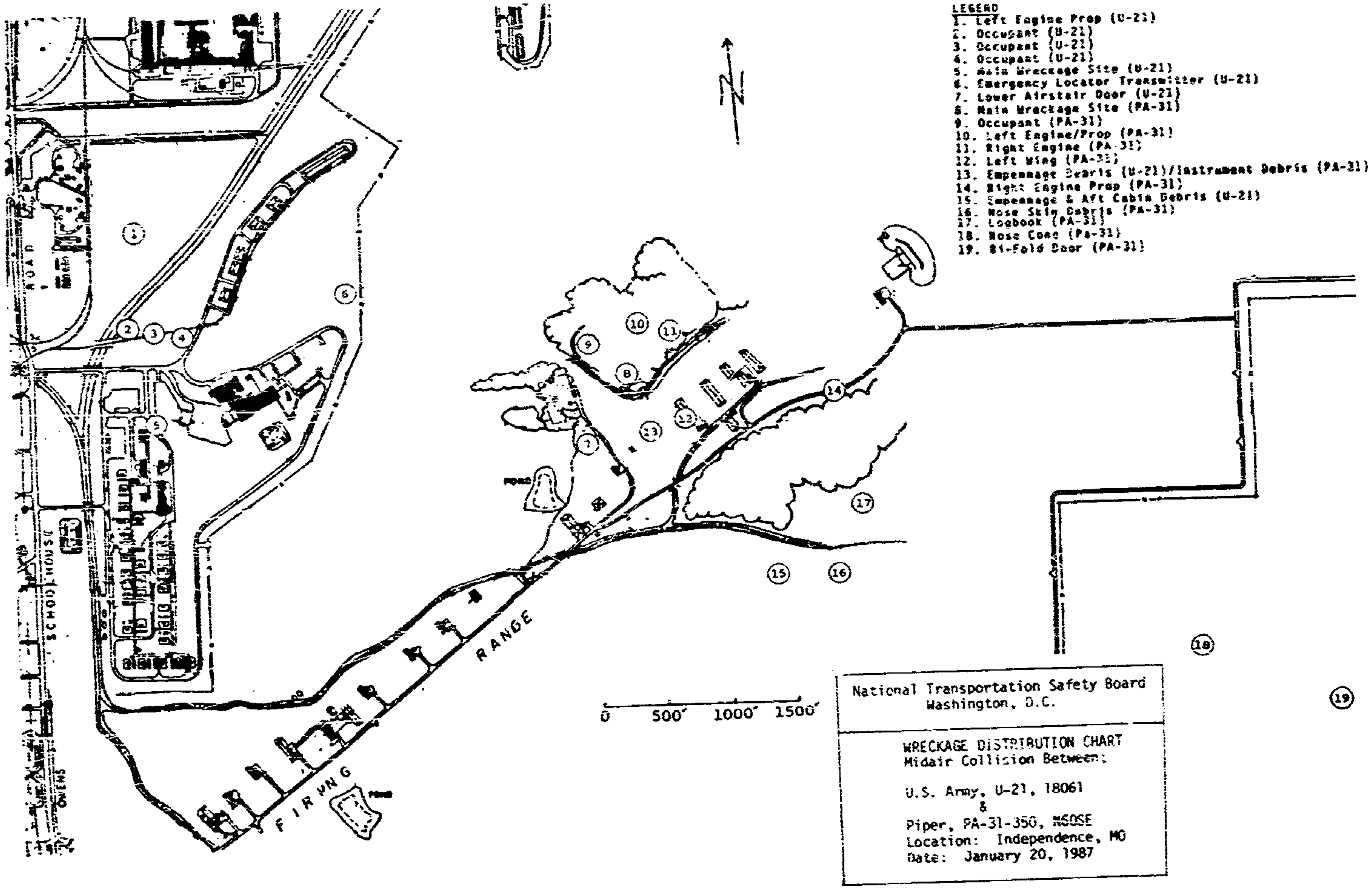
Mr. Hope, 35, entered on duty with the FAA on May 13, 1974. He had been assigned to the Kansas City International Air Traffic Control Tower (ATCT) since October 20, 1985. He held FAA control tower operator certificate No. 485646346 with rating endorsement for the Kansas City International ATCT issued January 30, 1986. He was qualified at all control positions and was qualified as a first line area supervisor in the TRACON. Mr. Hope held a second class airman medical certificate issued August 20, 1986, without limitations.

Developmental Air Traffic Control Specialist Christine L. Hatem

Ms. Hatem, 29, entered on duty with the FAA at Kansas City International ATCT on May 3, 1984. She completed training in the tower and received FAA control tower operator certificate No. 495685067 on April 11, 1985. She began radar training on December 7, 1985. At the time of the accident, she was qualified on two TRACON radar positions but was not qualified on the East Radar position. Her training records reflected above average progress in completing training on the two radar positions on which she was qualified. She had about 50 hours experience at the East Radar position and was reportedly making above average progress toward checkout on the position. She had not yet been recommended for checkout. She held a second class airman medical certificate issued October 16, 1986, without limitations. Ms. Hatem had previous experience as an air traffic controller in the U.S. Navy.

APPENDIX C

WRECKAGE DISTRIBUTION CHART



APPENDIX D

COCKPIT FIELD OF VISION PLOTS

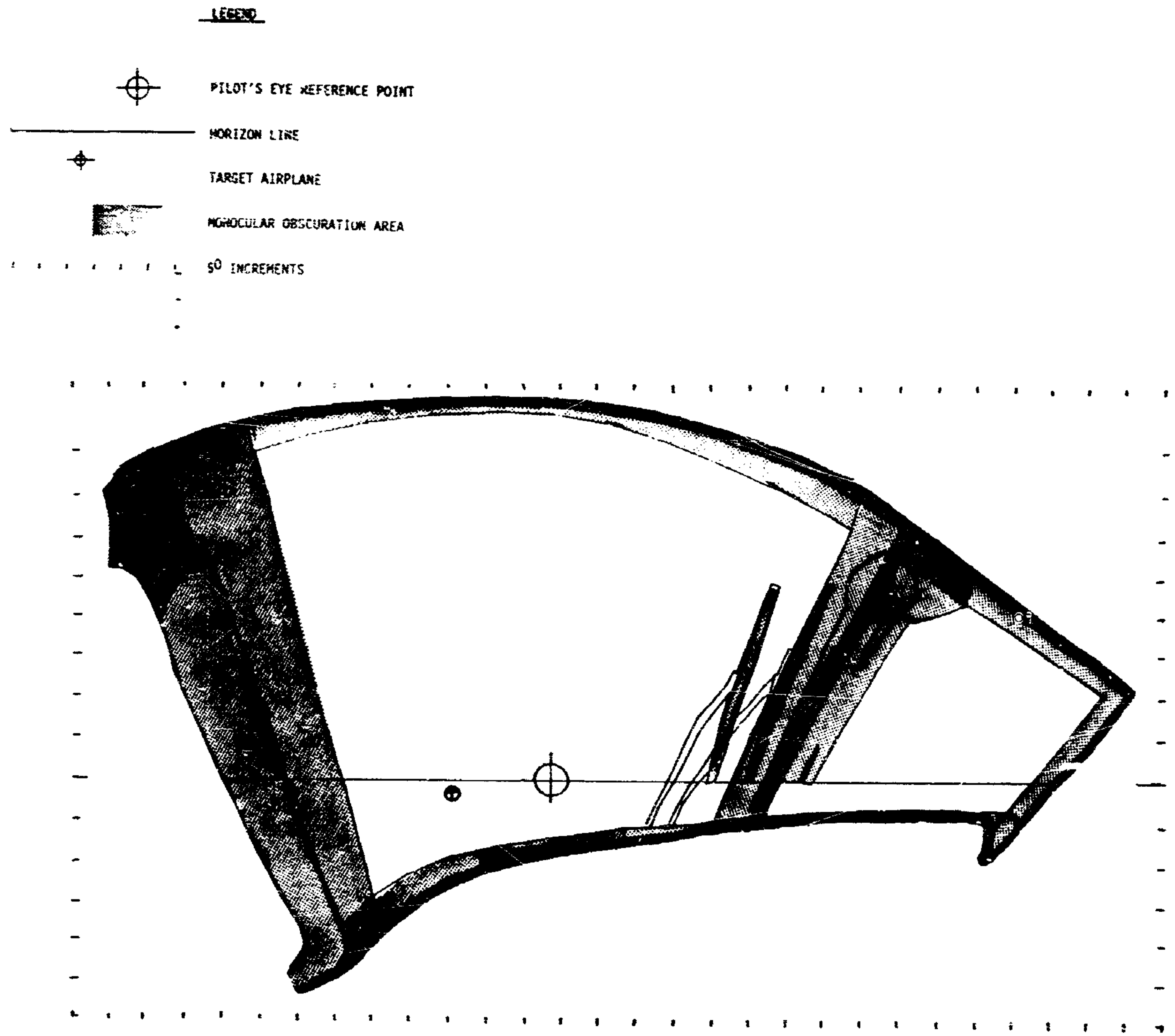


Figure 1. U21A, R18061, Pilot's Design Eye Reference Position at 41.5 in. Above the Floor and 5 in. Aft of the Rear Most Column Movement.

LEGEND

PILOT'S EYE REFERENCE POINT

HORIZON LINE

TARGET AIRPLANE

MONOCULAR OBSCURATION AREA

5° INCREMENTS

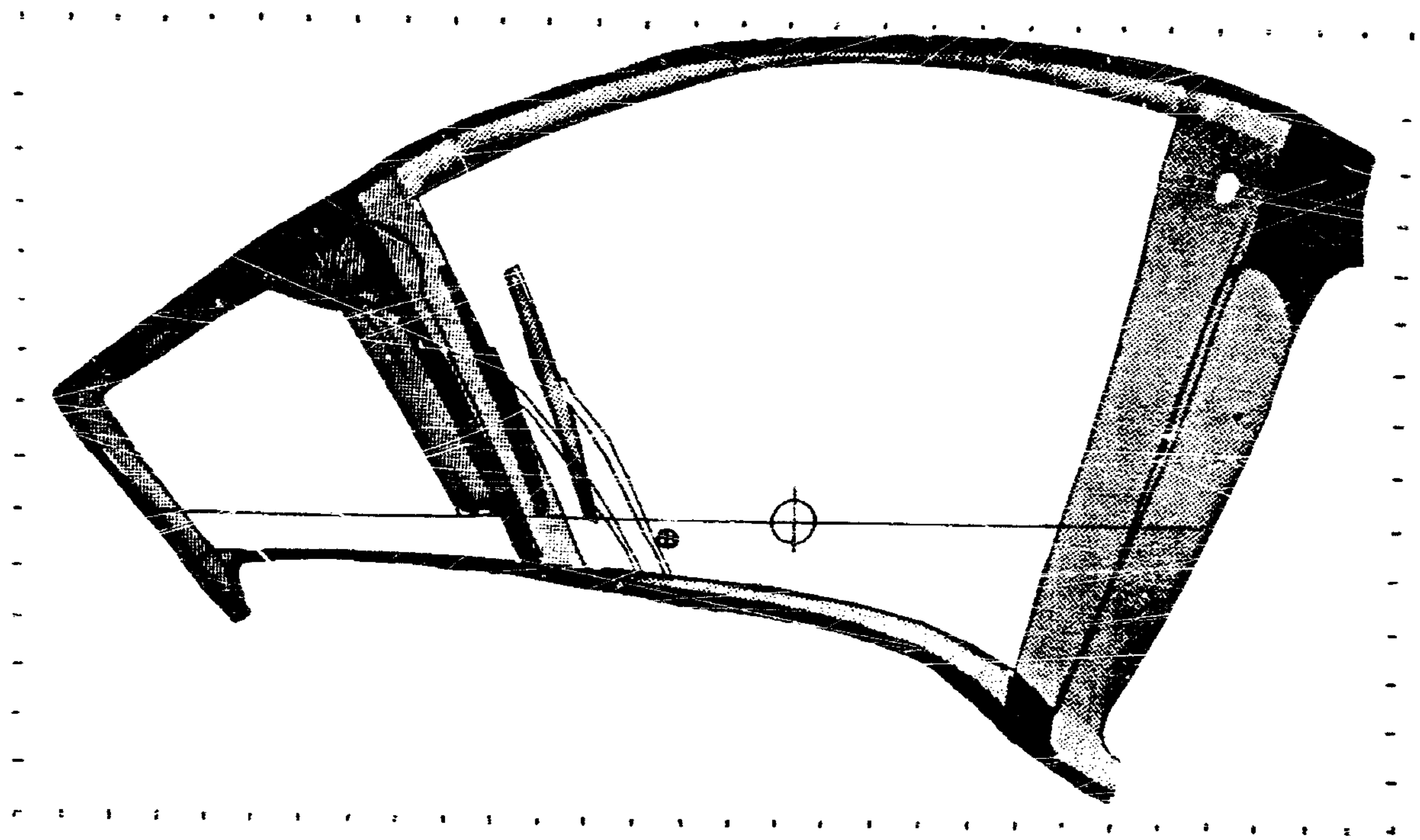


Figure 2. U21A, R18061, Copilot's Design Eye Reference Position at 41.5 in. Above the Floor and 5 in. Aft of the Rear Most Column Movement.

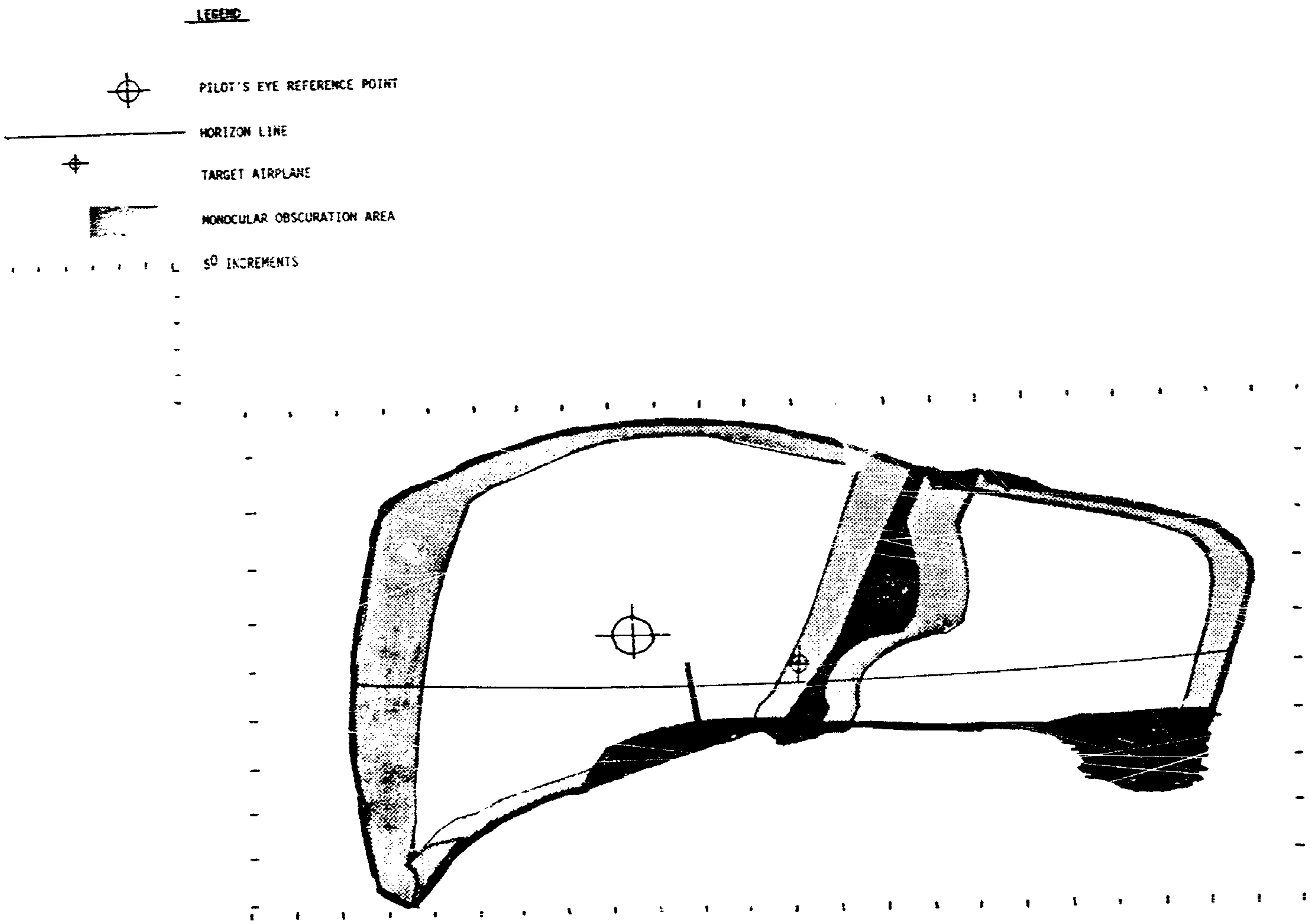


Figure 3. PA31-350, N60SE, Pilot's Design Eye Reference Position at 43.5 in. Above the Floor and 5 in. Aft of the Rear Most Column Movement.

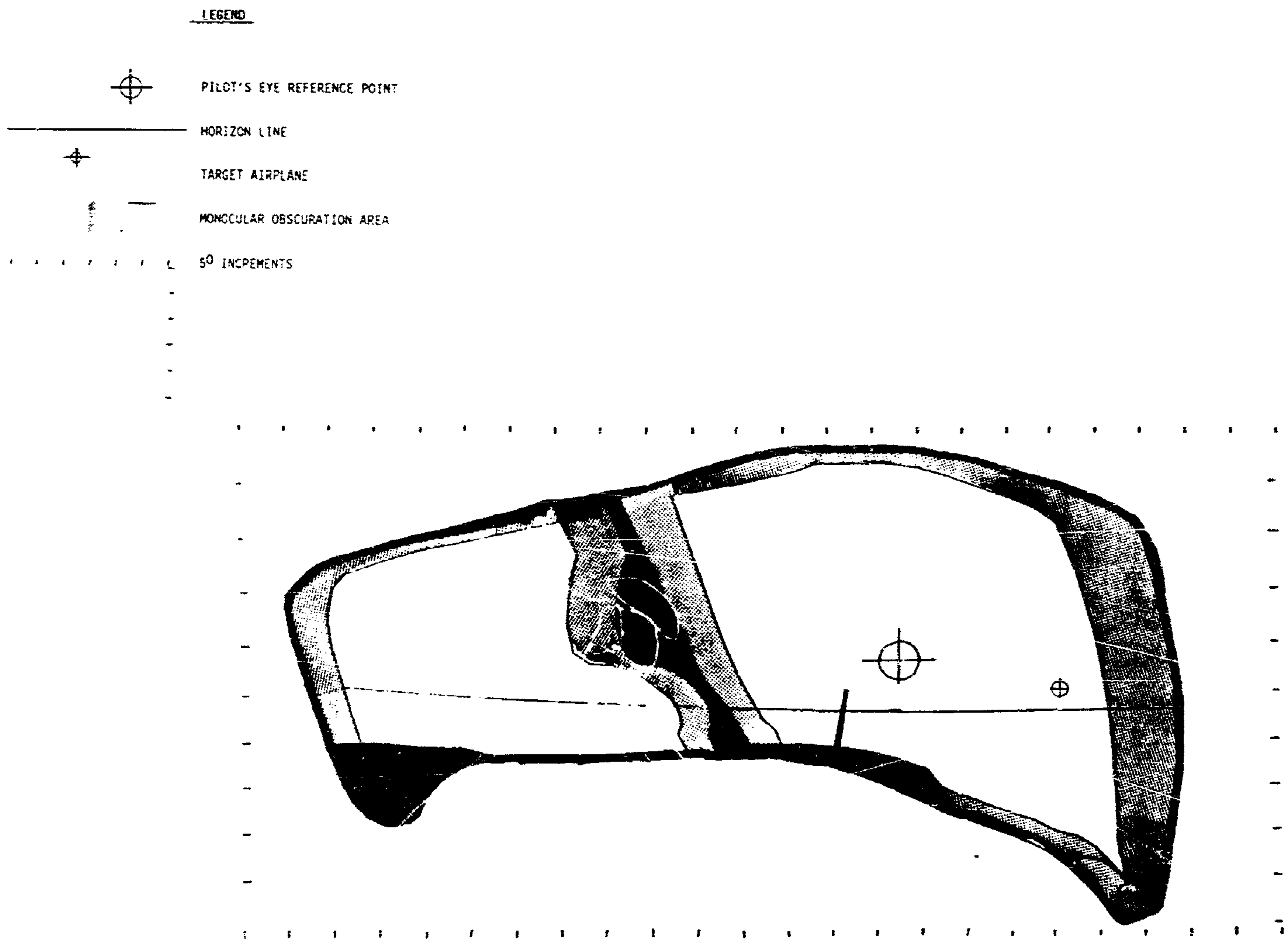


Figure 4. PA31-350, N60SE, Copilot's Design Eye Reference Position at 43.5 in. Above the Floor and 5 in. Aft of the Rear Most Column Movement.

APPENDIX E

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LINCOLN LABORATORY
APPLICATION OF PILOT AIR-TO-AIR VISUAL ACQUISITION RESEARCH TO INDEPENDENCE, MISSOURI, ACCIDENT

LEXINGTON, MASSACHUSETTS 02173-0073

03 September 1987 42C-3408

Area Code 617
863-5500

Mr. Jack Drake
National Transportation Safety Board
800 Independence Avenue, S.W.
Washington, DC 20594

Dear Mr. Drake:

This letter provides an analysis of pilot air-to-air visual acquisition that is applicable to the recent mid-air collision in Independence, Missouri. The analysis is based upon a mathematical model of visual acquisition that was developed at Lincoln Laboratory during FAA-sponsored flight tests (Ref. 1 and 2) of collision avoidance systems. A recently completed series of flight tests at Lincoln Laboratory (Ref. 3) has allowed this model to be applied to unalerted search conditions (i.e., visual search when no traffic advisories are available). This is the same model that has been provided to the National Transportation Safety Board for the investigation of the Cerritos mid-air collision.

The basis of the model is the experimental observation that the probability of visual acquisition in any instant of time is proportional to the product of the angular size of the visual target and its contrast with its background. The cumulative probability of visual acquisition is obtained by integrating the probabilities for each instant as the target aircraft approaches.

Basic characteristics associated with the visual target (such as closing rate, target aircraft size, and meterological visual range) are explicity accounted for in the model. A model parameter β is then adjusted to accurately reproduce the observed performance of pilots in test flights. β can be viewed as a measure of pilot search efficiency. The model contains no explicit description of the physiological or mental processes underlying pilot performance. The effects of such factors are reflected in the value of β observed in flight tests. The model does not apply to any situation in which special phenomena not present in flight tests degraded visual search. Among such special phenomena are empty field myopia, target approaching out of the sun, target hidden by window post, and unusual crew distractions.

In some cases, the probability of visual acquisition can be written as a simple closed-form expression. For instance, if aircraft are on an unaccelerated collision course and the visual range is infinite, then the probability of acquisition for a single-pilot is

$$P[\text{acq by } r_2] = 1 - \exp\left[\frac{-\beta A}{|\dot{r}|}(1/r_2 - 1/r_1)\right]$$

where β is the pilot efficiency parameter, $\dot{r}$ is the closing rate, r_1 is the range at which visual search begins, and A is the visual area (square feet) presented by the approaching target. A more complicated expression that takes finite visual range into account is described in Ref. 2.

In the analysis that follows, the model was used to predict visual acquisition probabilities for the particular circumstances of the Independence, Missouri mid-air collision. That is, the closing rate, aircraft types, and meteorological visual range that were reported were used as input to the model. Appropriate β values for unalerted search were obtained from reference to flight test results. It should be recognized that the model does not say directly what happened during the actual event - it only says what pilot performance statistics can be expected for situations such as the one that arose. Nevertheless, the results can be useful in evaluating the plausibility of different explanations for the actual event and in formulating strategies to prevent accidents in similar circumstances.

Relevant Circumstances of the Missouri Mid-air Collision

The encounter conditions used in the analysis are listed in Table 1.

TABLE 1

Encounter Description Used in the Analysis

	Navajo	U-21
airspeed (true)	150 kt	205 kt
number of pilots engaged in visual search	1	2
pilot search efficiency parameter (β)	17,000/s	17,000/s
head-on area of aircraft	81 sq ft	127 sq ft
side view area of aircraft	171 sq ft	267 sq ft
relative heading (angle between velocity vectors)	165 degrees	
visual range	20 nmi	

Using the data from Table 1, the following additional variables can be calculated:

closing rate - 352 knots

bearing of Navajo (seen from U-21) - 6.3 deg from 12 o'clock

bearing of U-21 (seen from Navajo) - 8.7 deg from 12 o'clock

visual area of Navajo (seen from U-21) - 89 sq ft

visual area of U-21 (seen from Navajo) - 137 sq ft.

Table 2 shows the predicted probabilities of visual acquisition. The "either" curve is obtained by assuming independent search on the part of the two aircraft. Then

P[either acquires] =

1 - (1 - P[Navajo acquires]) x (1 - P[U-21 acquires])

TABLE 2

Probabilities of Visual Acquisition (unalerted)

Time to Collision(sec)	P[ACQ by Navajo]	P[ACQ by U-21]	P[ACQ by either]
6.00 sec	0.5520	0.6454	0.8411
12.00 sec	0.2735	0.3341	0.5162
18.00 sec	0.1585	0.1935	0.3213
24.00 sec	0.1000	0.1197	0.2077
30.00 sec	0.0662	0.0763	0.1374
36.00 sec	0.0449	0.0488	0.0915
42.00 sec	0.0307	0.0304	0.0602
48.00 sec	0.0209	0.0175	0.0380
54.00 sec	0.0138	0.0082	0.0220
60.00 sec	0.0086	0.0014	0.0100

It can be seen that the probabilities of visual acquisition are not high until the last few seconds before collision. The Navajo has a somewhat lower chance of acquiring than the U-21 because only one pilot is searching. This is true despite the fact that the U-21 is larger in area.

Alerted Search Analysis

The possible benefits of a traffic advisory can be examined by using a value of β obtained from tests of the Traffic Alert and Collision Avoidance System (TCAS). Table 3 shows performance in TCAS-alerted search. It is assumed that a traffic advisory is received at a typical TCAS II alarm point (40 sec before the range reaches 0.3 nmi, or 43 sec before collision). After the alert, the single-pilot β value is the same as that in the TCAS II flight tests described earlier (increasing from 17,000/sec before the alert to 140,000/sec after the alert).

It can be seen that the alert results in a marked improvement in visual search effectiveness. The median acquisition time increases by about 20 seconds. There is high probability of visual acquisition in time to execute an avoidance maneuver.

TABLE 3

Probabilities of Visual Acquisition
(aircraft alerted by TCAS)

Time of Collision (sec)	P[ACQ by Navajo]	P[ACQ by U-21]
6.00 sec	0.9983	0.9998
12.00 sec	0.9111	0.9569
18.00 sec	0.7018	0.7914
24.00 sec	0.4814	0.5709
30.00 sec	0.2973	0.3624
36.00 sec	0.1542	0.1881
42.00 sec	0.0452	0.0492
48.00 sec*	0.0209	0.0175
54.00 sec*	0.0138	0.0082
60.00 Sec*	0.0086	0.0014

*No alert has appeared for times prior to 43 sec.

Visual search with traffic advisories provided from ATC may be somewhat less effective than visual search based on TCAS. This is because the TCAS bearing indication tends to be more accurate and the TCAS display is updated once per second.

Sincerely,

John W. Andrews

John W. Andrews
Staff Member, Group 42

JWA/dcb

Attachment

REFERENCES

1. Andrews, J.W., "Air-to-Air Visual Acquisition Performance with Pilot Warning Instruments (PWI)", ATC-73, FAA-RD-77-30, MIT Lincoln Laboratory, 25 April 1977.

2. Andrews, J.W., "Air-to-Air Visual Acquisition Performance with TCAS II". ATC-130, DOT/FAA/PM-84-17, MIT Lincoln Laboratory (27 July 1984).

2. Andrews, J.A., "Unalerted Air-to-Air Visual Acquisition", ATC-151, FAA-RD-PM-87/84, MIT Lincoln Laboratory (in preparation).

APPENDIX F

FAA ADVISORY CIRCULAR 90-48C
PILOTS' ROLE IN COLLISION AVOIDANCE

U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

Subject: PILOTS' ROLE IN COLLISION AVOIDANCE

Date: 3/18/83
Initiated by: AFO-820

AC No: 90-48C
Change:

1. PURPOSE. This advisory circular is issued for the purpose of alerting all pilots to the potential hazards of midair collision and near midair collision, and to emphasize those basic problem areas related to the human causal factors where improvements in pilot education, operating practices, procedures, and improved scanning techniques are needed to reduce midair conflicts.

2. CANCELLATION. AC 90-48B, Pilots' Role in Collision Avoidance, dated 9/5/80 is canceled.

3. BACKGROUND.

a. From 1978 through October 1982 a total of 152 midair collisions (MAC) occurred in the United States resulting in 377 fatalities. Throughout this approximate 5-year time period the yearly statistics remained fairly constant, with a recorded high of 38 accidents in 1978 and a low of 25 in both 1980 and 1981. During this same time period there were 2,241 reported near midair collisions (NMAC). Statistics indicate that the majority of these midair collisions and near midair collisions, occurred in good weather and during the hours of daylight.

b. The FAA has introduced several significant programs designed to reduce the potential for midair and near midair collisions. This advisory circular is but one of those programs and is directed towards all pilots operating in the National Airspace System, with emphasis on the need for recognition of the human factors associated with midair conflicts.

4. ACTION. The following areas warrant special attention and continuing action on the part of all pilots to avoid the possibility of becoming involved in a midair conflict.

a. "See and Avoid" Concept.

(1) The flight rules prescribed in Part 91 of the Federal Aviation Regulations (FAR) set forth the concept of "See and Avoid." This concept requires that vigilance shall be maintained at all times, by each person operating an aircraft, regardless of whether the operation is conducted under Instrument Flight Rules (IFR) or Visual Flight Rules (VFR).

(2) Pilots should also keep in mind their responsibility for continuously maintaining a vigilant lookout regardless of the type of aircraft being flown. Remember that most MAC accidents and reported NMAC incidents occurred during good VFR weather conditions and during the hours of daylight.

b. Visual Scanning.

(1) Pilots should remain constantly alert to all traffic movement within their field of vision, as well as periodically scanning the entire visual field outside of their aircraft to ensure detection of conflicting traffic. Remember that the performance capabilities of many aircraft, in both speed and rates of climb/descent, result in high closure rates limiting the time available for detection, decision, and evasive action. (See the "Distance-Speed-Time" chart in Appendix 1.)

(2) The probability of spotting a potential collision threat increases with the time spent looking outside, but certain techniques may be used to increase the effectiveness of the scan time. The human eyes tend to focus somewhere, even in a featureless sky. In order to be most effective, the pilot should shift glances and refocus at intervals. Most pilots do this in the process of scanning the instrument panel, but it is also important to focus outside to set up the visual system for effective target acquisition.

(3) Pilots should also realize that their eyes may require several seconds to refocus when switching views between items in the cockpit and distant objects. Proper scanning requires the constant sharing of attention with other piloting tasks, thus it is easily degraded by such psychophysiological conditions such as fatigue, boredom, illness, anxiety, or preoccupation.

(4) Effective scanning is accomplished with a series of short, regularly-spaced eye movements that bring successive areas of the sky into the central visual field. Each movement should not exceed 10 degrees, and each area should be observed for at least 1 second to enable detection. Although horizontal back-and-forth eye movements seem preferred by most pilots, each pilot should develop a scanning pattern that is most comfortable and then adhere to it to assure optimum scanning.

(5) Peripheral vision can be most useful in spotting collision threats from other aircraft. Each time a scan is stopped and the eyes are refocused, the peripheral vision takes on more importance because it is through this element that movement is detected. Apparent movement is almost always the first perception of a collision threat and probably the most important, because it is the discovery of a threat that triggers the events leading to proper evasive action. It is essential to remember, however, that if another aircraft appears to have no relative motion, it is likely to be on a collision course with you. If the other aircraft shows no lateral or vertical motion, but is increasing in size, take immediate evasive action.

(6) Visual search at night depends almost entirely on peripheral vision. In order to perceive a very dim lighted object in a certain direction, the pilot should not look directly at the object, but scan the area adjacent to it. Short stops, of a few seconds, in each scan will help to detect the light and its movement.

(7) Lack of brightness and color contrast in daytime and conflicting ground lights at night increase the difficulty of detecting other aircraft.

(8) Pilots are reminded of the requirement to move one's head in order to

search around the physical obstructions, such as door and window posts. The doorpost can cover a considerable amount of sky, but a small head movement may uncover an area which might be concealing a threat.

c. Clearing Procedures.

(1) Pilots should:

(i) Prior to taxiing onto a runway or landing area for takeoff, scan the approach areas for possible landing traffic by maneuvering the aircraft to provide a clear view of such areas. It is important that this be accomplished even though a taxi or takeoff clearance has been received.

(ii) During climbs and descents in flight conditions which permit visual detection of other traffic, execute gentle banks left and right at a frequency which permits continuous visual scanning of the airspace about them.

(iii) Execute appropriate clearing procedures before all turns, abnormal maneuvers, or acrobatics.

d. Airspace, Flight Rules, and Operational Environment.

(1) Pilots should be aware of the type of airspace in which they intend to operate in order to comply with the flight rules applicable to that airspace. Aeronautical information concerning the National Airspace System is disseminated by three methods: aeronautical charts (primary); the Airman's Information Manual (AIM); and the Notices to Airmen (NOTAM) system. The general operating and flight rules governing the operation of aircraft within the United States are contained in Part 91 of the FAR.

(2) Pilots should:

(i) Use currently effective aeronautical charts for the route or area in which they intend to operate.

(ii) Note and understand the aeronautical legend and chart symbols related to airspace information depicted on aeronautical charts.

(iii) Develop a working knowledge of the various airspace segments, including the vertical and horizontal boundaries.

(iv) Develop a working knowledge of the specific flight rules (FAR 91) governing operation of aircraft within the various airspace segments.

(v) Use the AIM. The Basic Flight Information and ATC Procedures describe the airspace segments and the basic pilot responsibilities for operating in such airspace.

(vi) Contact the nearest FAA Flight Service Station for any pertinent NOTAMS pertaining to their area of operation.

(3) **Pilots should also be familiar with, and exercise caution, in those** operational environments where they may expect to find a high volume of traffic or special types of aircraft operation. These areas include Terminal Radar Service Areas (TRSA's), airport traffic patterns, particularly at airports without a control tower; airport traffic areas (below 3,000 feet above the surface within five statute miles of an airport with an operating control tower); terminal control areas; control zones, including any extensions; Federal airways; vicinity of VOR's; restricted areas; warning areas; alert areas; Military Operating Areas (MOA); intensive student jet training areas; military low-level high-speed training routes; instrument approach areas; and areas of high density jet arrival/departure routings, especially in the vicinity of major terminals and military bases.

e. Use of Communications Equipment and Air Traffic Advisory Services.

(1) One of the major factors contributing to the likelihood of NMAC incidents in terminal areas that have an operating air traffic control (ATC) system has been the mix of known arriving and departing aircraft with unknown traffic. The known aircraft are generally in radio contact with the controlling facility (local, approach, or departure control) and the other aircraft are neither in two-way radio contact nor identified by ATC at the time of the NMAC. This precludes ATC from issuing traffic advisory information to either aircraft.

(2) Although pilots should adhere to the necessary communications requirements when operating VFR, they are also urged to take advantage of the air traffic advisory services available to VFR aircraft.

(3) Pilots should:

(i) Use the AIM.

(A) The basic AIM contains a section dealing with services available to pilots, including information on VFR advisory services, radar traffic information services for VFR pilots, and recommended traffic advisory practices at nontower airports.

(B) The airport/facility directory contains a list of all major airports showing the services available to pilots and the applicable communication frequencies.

(ii) Develop a working knowledge of those facilities providing traffic advisory services and the area in which they give these services.

(iii) Initiate radio contact with the appropriate terminal radar or nonradar facility when operating within the perimeters of the advertised service areas or within 15 miles of the facility when no service area is specified.

(iv) When it is not practical to initiate radio contact for traffic information, at least monitor the appropriate facility communication frequency, particularly when operating in or through arrival/departure routes and instrument approach areas.

(v) Remember that controller observation of aircraft in the terminal area is often limited by distance, depth perception, aircraft conspicuity, and other normal visual acuity problems. Limitations of radar (when available), traffic volume, controller workload, unknown traffic, etc., may prevent the controller from providing timely traffic advisory information. Traffic advisories are secondary to the controllers' primary duties (which are separating aircraft under their control and issuing safety advisories when aware of safety conflicts). Therefore, the pilot is responsible for seeing and avoiding other traffic. Traffic advisories should be requested and used when available to assist the pilot to see and avoid other traffic by assisting, but not substituting in any way, the pilot's own visual scanning. It is important to remember that advisories which air traffic control may provide are not intended to lessen in any manner the pilot's obligation to properly scan to see and avoid traffic.

f. Airport Traffic Patterns.

(1) A significant number of midair collisions, as well as near midair collisions, have occurred within the traffic pattern environment.

(2) Pilots should:

(i) When operating at tower-controlled airports, maintain two-way radio contact with the tower while within the airport traffic area. Make every effort to see and properly avoid any aircraft pointed out by the tower, or any other aircraft which may be in the area and unknown to the tower.

(ii) When entering a known traffic pattern at a nontower airport, keep a sharp lookout for other aircraft in the pattern. Enter the pattern in level flight and allow plenty of spacing to avoid overtaking or cutting any aircraft out of the pattern.

(iii) When approaching an unfamiliar airport fly over or circle the airport at least 500 feet above traffic pattern altitude (usually at 2,000 feet or more above the surface) to observe the airport layout, any local traffic in the area, and the wind and traffic direction indicators. Never descend into the traffic pattern from directly above the airport.

(iv) Be particularly alert before turning to the base leg, final approach course, and during the final approach to landing. At nontower airports, avoid entering the traffic pattern on the base leg or from a straight-in approach to the landing runway.

(v) Compensate for blind spots due to aircraft design and flight attitude by moving your head or maneuvering the aircraft.

g. Flying In Formation.

(1) Several midair collisions have occurred which involved aircraft on the same mission, with each pilot aware of the other's presence.

(2) Pilots who are required, by the nature of their operations, to fly in pairs or in formation are cautioned to:

(i) **Recognize the high statistical probability of their involvement** in midair collisions.

(ii) **Make sure that adequate preflight preparations are made and the** procedures to be followed are understood by all pilots intending to participate in the mission.

(iii) Always keep the other aircraft in sight despite possible **distraction and preoccupation** with other mission requirements.

(iv) Avoid attempting formation flight without having obtained instruction and attained the skill necessary for conducting such operations.

h. Flight Instructors, Pilot Examiners, and Persons Acting As Safety Pilots.

(1) The importance of flight instructors training pilot applicants to devote **maximum attention to collision avoidance while conducting flight operations in today's increasing air traffic environment cannot be overemphasized.**

(2) Flight instructors should set an example by carefully observing all regulations and recognized safety practices, since students consciously and unconsciously imitate the flying habits of their instructors.

(3) Flight instructors and persons acting as safety pilots should:

(i) Guard against preoccupation during flight instruction to the exclusion of maintaining a constant vigilance for other traffic.

(ii) Be particularly alert during the conduct of simulated instrument flight where there is a tendency to "look inside."

(iii) Place special training emphasis on those basic problem areas of concern mentioned in this advisory circular where improvements in pilot education, operating practices, procedures, and techniques are needed to reduce midair conflicts.

(iv) Notify the control tower operator, at airports where a tower is manned, regarding student first solo flights.

(v) Explain the availability of and encourage the use of expanded radar services for arriving and departing aircraft at terminal airports where this service is available, as well as, the use of radar traffic advisory services for transiting terminal areas or flying between en-route points.

(vi) Understand and explain the limitations of radar that may frequently limit or prevent the issuance of radar advisories by air traffic controllers (refer to AIM).

(4) Pilot examiners should:

(i) During any flight test, direct attention to the applicant's vigilance of other air traffic and an adequate clearance of the area before performing any flight maneuver.

(ii) **Direct attention to the applicant's knowledge of the airspace,** available FAA air traffic services and facilities, essential rules, good operating practices, procedures, and techniques that are necessary to achieve high standards of air safety.

i. Scan Training. The Aircraft Owners and Pilots Association (AOPA) Air Safety Foundation has developed an excellent educational program designed to inform pilots on effective visual scan techniques. All pilots are encouraged to attend FAA/industry sponsored safety meetings which feature this program. The program, called "Take Two and See," is available on loan through the AOPA Air Safety Foundation, 7315 Wisconsin Avenue, Bethesda, Maryland 20814. For further information on the availability of this or any other Accident Prevention Program dealing with collision avoidance, interested persons may contact the Accident Prevention Specialist at any FAA General Aviation District Office or Flight Standards District Office.

Kenneth S. Hunt

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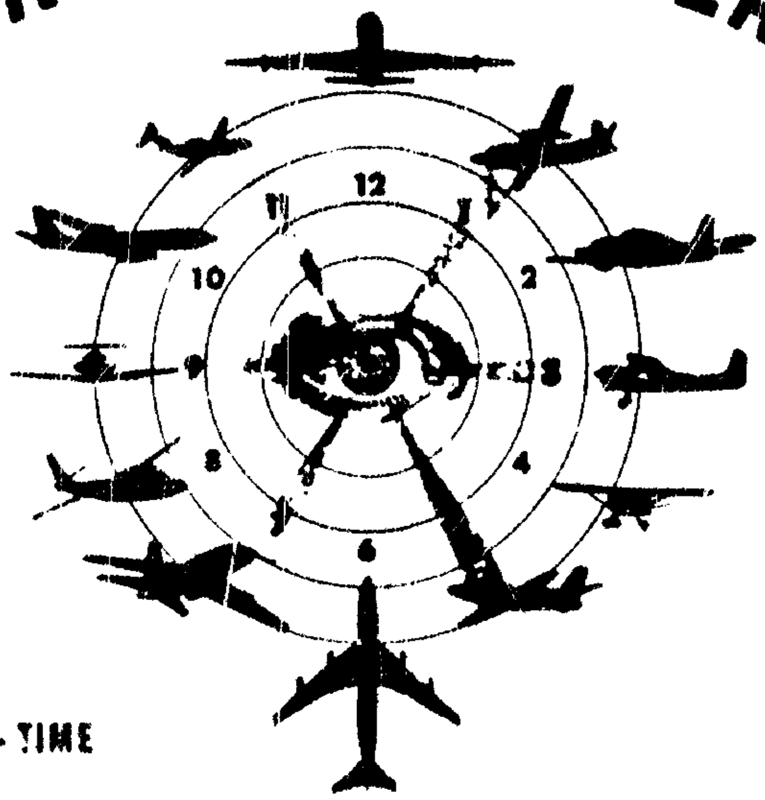
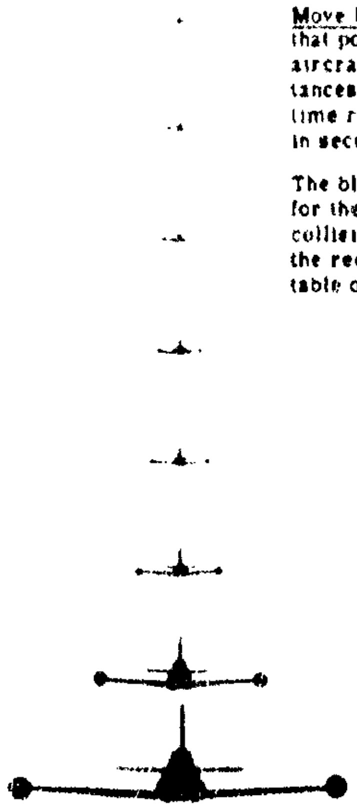
Director of Flight Operations

A RADAR FOR ALL SEASONS



DISTANCE - SPEED - TIME

MPH	600	360
	SECONDS	
10 miles	60	100
6 miles	36	60
5 miles	30	50
4 miles	24	40
3 miles	18	30
2 miles	12	20
1 mile	6	10
½ mile	3	5



CRITICAL SECONDS

Move back 12 feet from this illustration. From that position the silhouettes represent a T 33 aircraft as it would appear to you from the distances indicated in the table on the left. The time required to cover these distances is given in seconds for combined speeds of 360 and 600 mph.

The blocks on the lower left mark the danger area for the speeds quoted, when aircraft are on a collision course. This danger area is based on the recognition and reaction times shown in the table on the lower right.

RECOGNITION and REACTION TIMES

Excerpt

	Seconds
see object	0.1
recognize a/c	1.0
become aware of collision course	5.0
decision to turn left or right	4.0
muscular reaction	0.4
aircraft lag time	2.0
TOTAL	12.5

LOOK ALIVE AND LIVE

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