NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

June 24, 2012

AIRWORTHINESS

Group Chairman's Factual Report

WPR11MA454

A. ACCIDENT: WPR11MA454

Operator:	James K. Leeward
Location:	Reno, Nevada
Date:	September 16, 2011
Time:	1626 Pacific Daylight Time
Aircraft:	North American P-51D
Registration Number:	N79111

B. AIRWORTHINESS GROUP

Chairman: Clinton R. Crookshanks
National Transportation Safety Board
Denver, Colorado

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Federal Aviation Administration
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Member: Robert “Hoot” Gibson
Reno Air Race Association
Murfreesboro, Tennessee

Member: Curt Burris
Aerodynamic Consulting, LLC
Marietta, Georgia

Member: Rodger Farley
NASA/Goddard Space Flight Center
Greenbelt, Maryland

C. SUMMARY

On September 16, 2011, about 1626 Pacific daylight time, an experimental single seat North American P-51D, N79111, collided with the airport ramp in the spectator box seat area following a loss of control while maneuvering during an unlimited class gold heat race at the National Championship Air Races (NCAR) at Reno Stead Airport (RTS), Reno, Nevada. The airplane was registered to Aero-Trans Corp, Ocala, Florida, and operated by the pilot as Race 177, the Galloping Ghost, under the provisions of 14 *Code of Federal Regulations* (CFR) Part 91. The commercial pilot and 10 people on the ground sustained fatal injuries; more than 60 people were treated for minor to serious injuries. The airplane fragmented upon impact with the ramp. Visual meteorological conditions prevailed, and no flight plan had been filed for the local air race flight, which departed RTS about 10 minutes before the accident.

D. DETAILS OF THE INVESTIGATION

1.0 Airplane

The North American P-51D Mustang is an all metal (with the exception of some control surface skins), low wing, single seat, single engine, propeller driven airplane originally designed and built as a long range fighter and used during World War II and the Korean War. The airplane was designed in 1940 by North American Aviation in response to a specification issued by the British Purchasing Commission. The first prototype flew on October 26, 1940, and entered production in 1941. The P-51D variant began production in April 1944 and more than 8,000 airplanes were produced. The stock airplane is 32 feet 3-5/16 inches long, has a level tail height of 12 feet, 2-1/16 inches, a wing span of 37 feet, 5/16 inch, and a conventional landing gear arrangement (Figure 1)[1]. The stock airplane empty weight is 7,635 pounds and the maximum gross weight is 12,100 pounds. The stock airplane has power off stall speeds of 94 mph and 87 mph in the clean and landing configurations, respectively, at a gross weight of 8,000 pounds. The accident airplane, Serial Number (S/N) 44-15651, was delivered to the Army Air Forces on December 23, 1944, and subsequently declared surplus and sold in July 1946.

The airplane was purchased by Cliff Cummings in February 1960 and started racing at the NCAR in Reno in 1969 as Race 69, Miss Candace. For the first year at Reno the airplane was essentially a stock P-51D airplane. In 1970 the airplane again raced at Reno but had several modifications specifically for racing[2]. Engine troubles during the 1970 race required a forced wheels-up landing in the desert that caused extensive damage. After almost two years of repair work, the airplane showed up again in Reno in 1972 and participated (or attempted to participate) in the NCAR from 1972 through 1978. The airplane was then sold to Dennis Schoenfelder and Dave Zeuschel in 1979 and participated in the NCAR as Race 69, Jeannie. Following the 1979 races the airplane was sold to Sanders Lead Company, Inc. in January 1980. About 1 week prior to the 1980 NCAR, the airplane was involved in a crash during takeoff from the Van Nuys airport. The engine quit and the airplane performed a wheels-up landing in a corn field that tore off the propeller, air scoop, and caused extensive airframe damage. The airplane was repaired in less than a week and participated in the races from 1980 through 1982 before being acquired by

[1] All figures are presented in Appendix A to this report.
[2] See Section 9.0 for a discussion of the modifications and associated FAA documents.

James Leeward in July 1983. Mr. Leeward raced the airplane at Reno under three different names through 1989 until it was placed in storage; Race X, Spectre, Race 44, Leeward Air Ranch Special, and Race 9, Leeward Air Ranch Special. During one race as Race 44 (the year could not be verified), the canopy and turtle deck departed the airplane during flight damaging the vertical stabilizer. In 2007, the airplane was reportedly removed from storage and began its transformation to Race 177, the Galloping Ghost.

1.1 Galloping Ghost Modifications

The group interviewed two mechanics[3] from the Galloping Ghost race team, examined numerous photographs, and examined the wreckage from the airplane to determine the modifications that had been made to the airplane. The three most noticeable modifications to the airplane were the shortening of the wings, the installation of a racing canopy, and the removal of the air scoop from beneath the wing. The group determined that the following modifications were performed on the airplane and are discussed in detail below.

- Wings were shortened;
- Ailerons were shortened and the outboard hinge was eliminated;
- New wing tips and end plates were added;
- Electric trim actuators were installed for aileron and elevator trim;
- Right aileron trim tab was eliminated;
- Horizontal stabilizers and elevators were shortened;
- Weight of elevator and rudder counterweights was increased;
- Horizontal stabilizer incidence was changed;
- Vertical stabilizer incidence was changed;
- Right elevator trim tab was fixed in place and disconnected;
- Rudder trim tab was eliminated;
- Elevator inertia weight was reduced;
- Under wing air scoop was removed;
- Boil off cooling system was installed in the fuselage;
- Racing canopy and turtle deck was installed; and
- Solid engine mounts were installed;

The Galloping Ghost is shown in Figure 2. The Ghost began its transformation in Arizona at GossHawk Unlimited and later was trucked to McKinney, Texas, and finally to Minden, Nevada, where it was completed in fall 2009. The airplane remained in Minden when not participating in the NCAR.

The wings were shortened by removing the removable outboard section of wing from wing station 190 to the tip and further cutting the front and rear spars outboard of the center aileron hinge located at wing station 166. A new wing tip with end plate incorporated was installed and the ailerons were shortened from a stock length of about 7 feet to about 3 feet. The outboard aileron hinges were eliminated so the shortened ailerons only had two hinges and the trim tab on the right aileron was removed. The shortening of the wings occurred before Mr. Leeward purchased the airplane in 1983. Utilizing a scaled photograph of the lower surface of the wing

[3] The interview summaries can be found in Attachment 1 to this report.

(Figure 3) the Ghost half wingspan was measured to be about 173 inches which works out to a wingspan of 28 feet, 10 inches. An S-TEC electric trim actuator was installed at the wing root to run the aileron trim as opposed to the stock manual trim wheel. The aileron travel is ground adjustable to 10°, 12°, or 15° by attaching the rod end into one of three holes on the aileron bell crank. The Ghost aileron travel was set to 15° (Figure 4). By all accounts the wing incidence was not changed from the stock value of 1°.

The horizontal stabilizer and elevator tip caps were removed and replaced by a flat end cap that reduced the horizontal stabilizer span from 13 feet, 2-1/8 inches, to about 12 feet, 1 inch. The horizontal stabilizer, elevators, and trim tabs were of all-metal construction but had up to 1/8 inch of filler material on the upper and lower skins. The elevator counterweights were recovered in the wreckage and weighed 26 pounds for the left and 27.5 pounds for the right (Figure 5 and 6). The right elevator counterweight had some of the elevator structure, including the outboard hinge assembly, still attached while the left did not. The P-51D Structural Repair Instructions[4] (SRI), Section III, Paragraph 4(a)(2) and Drawing[5] 73-22034 both list the elevator counterweight maximum total weight of the casting and lead as 13.75 pounds. A photo was obtained from the build-up of the Ghost in 2009 that shows the left elevator and attached trim tab being balanced on the center and outboard hinges (Figure 7). The elevator is in a leading edge down position with the tab in its limiting trailing edge up position. The upper rudder counterweight was also recovered in the wreckage and weighed 25 pounds (Figure 8). The SRI, Section III, Paragraph 4(a)(1) and Drawing 73-24008 both list the rudder counterweight maximum total weight of the casting and lead as 16.60 pounds. The horizontal stabilizer forward attach fitting part number (P/N) could not be determined by examination of the wreckage. The P-51D should have a P/N 122-21031 forward fitting per Technical Order 01-60-100[6] discussed below. See Figure 9 for an annotated scaled photograph of one of the horizontal stabilizer forward attach fittings from the Ghost. The aft horizontal stabilizer attach fittings were buried in the structure and were not examined. There was a 0.135 inch shim installed between each of the horizontal stabilizer forward attach fittings and the empennage structure. There was a tapered shim installed between the vertical stabilizer rear spar and the empennage structure (Figure 10) such that the leading edge of the vertical stabilizer would be moved to the right of the longitudinal axis of the airplane. The stock P-51D airplane had a vertical stabilizer offset of 1° left of the longitudinal axis of the airplane. The vertical stabilizer front spar attach fitting was also identified in the wreckage (Figure 11). There was an area on the left side of each of the elevator cable pass-throughs that was modified to remove material to give additional cable clearance as identified by the red arrows in Figure 11. The left and right legs of the fitting were about the same length. The effects of the right elevator trim tab were removed from the pitch trim control system by disconnecting the trim cable and removing the trim actuator from the right horizontal stabilizer. The right trim tab was fixed in place and faired with the right elevator by installing a steel rod between the trim guide installed on the horizontal stabilizer rear spar and the trim tab push rod (Figure 12). The left elevator trim tab remained installed as designed. The rudder trim tab was removed from the airplane along with the associated control cables. The trim tab cutout in the rudder was covered with fabric.

[4] Document AN 01-60-3 Structural Repair Instructions for Airplanes, Army Models A-36A, P-51 A, B, C, D, K, and M, F-6B, C, D, and K, and TF-51D, 15 March 1952 Revision.
[5] All pertinent drawings discussed can be found in Attachment 2 to this report.
[6] Technical Orders are not required for airplanes registered in the Experimental category.

The pitch control system of the airplane was changed by reducing the elevator inertia weight (bob weight) and removing the manual pitch trim actuation cables from the cockpit aft to the horizontal stabilizer forward spar. There was an S-TEC electric trim actuator installed on the forward side of the horizontal stabilizer forward spar to actuate only the left elevator trim tab. The elevator trim cables were wrapped around the actuator drum on the front spar and ran aft through a cutout in the spar to a pulley where they changed direction and ran to the left elevator trim actuator in the left horizontal stabilizer. There was a switch installed on the left side of the cockpit to actuate the pitch trim (Figure 13, green arrow) either nose up or nose down. There was also an indicator light to provide a neutral or zero trim indication to the pilot (Figure 13, red arrow). According to the manufacturer, the servos for the pitch and roll trim on the airplane are actuated through the input of power but freewheel when they are unpowered. Interviews of the crew on-scene indicated that the left elevator trim tab would travel from full up to full down in about 20 seconds. The elevator inertia weight was not identified in the wreckage. Assembly photos of the airplane show the elevator inertia weight on the floor prior to installation (Figure 14, red arrow). None of the photos provided specifically show the inertia weight installed but the sequence of photos suggests it was. One of the crew members interviewed specifically remembered seeing the bob weight installed in the airplane during the build-up. The P/N 109-52217 Elevator Inertia Weight drawing and Technical Order 01-60-90 indicate that the assembly should weigh 20.75 ±0.50 pounds and 20.15 ±0.50 pounds, respectively. Based on the photo of the Ghost bob weight (Figure 15), it appears that the ends of the weight outboard of the attach brackets were removed.

The lower air scoop that normally housed the radiator for the engine coolant, engine oil and aftercooler was removed from the airplane. Engine cooling was performed using a boil-off system that submerged the engine coolant and engine oil radiators in their own water/methanol bath. As the water/methanol mixture absorbed heat it would boil off and be vented overboard as steam. The vents for the boil off system were situated in the lower fuselage just behind the wing trailing edge with two on the left side and one on the right side. The two boilers were installed aft of the pilot seat and the area was sealed off from the cockpit. Structure was added between the fuselage longerons to secure the boilers. The boilers and supporting structure were reportedly manufactured by GossHawk Aviation. The left wing tank was converted to hold the water/methanol mixture and had a capacity of 150 gallons. The water/methanol mixture was also used in the engine and injected in the fuel/air charge upstream of the supercharger to cool the mixture and prevent auto detonation, normally called ADI (anti-detonation injection). A custom built piece of fuselage structure (Figure 14, green arrow) was installed in place of the scoop to provide an aerodynamic shape aft of the wing. This structure reportedly came from a previous racer, Race 84, Stiletto (See Section 2.1). No information on the skin gauge or other details was available for this structure.

The existing racing canopy was removed and replaced with a different racing canopy. The racing canopy had a smaller frontal area to decrease drag and hinged upward instead of sliding aft. The upper fuselage or turtle deck structure above the upper longeron was also modified to accept the smaller racing canopy. According to the crew, portions of the canopy and turtle deck were taken from a previous racer, Sumthin' Else, Race 6.

The accident airplane had a Rolls Royce V1650-9A engine installed that had been modified for racing and a Hamilton Standard 24D50 propeller that had not been modified. The stock elastic engine mounts were replaced with solid aluminum mounts to prevent the engine from moving at the high race power settings (Figure 16). The stock aluminum inlet duct was replaced with a carbon fiber duct from the inlet "smile" aft to the carburetor.

The reasons for many of the modifications could not be established. Mr. Leeward's family and the airplane crew were not aware of any detailed drawings, engineering calculations, or substantiation data for any of the modifications. Some of the crew indicated that Mr. Leeward wanted the Ghost to be like Stiletto. According to the crew members, Mr. Leeward was the only person to fly the airplane from its build-up in 2009 until the accident.

1.2 Oxygen System and Pilot Seat

The National Air-Racing Group (NAG) Unlimited Division rules require that there is a safety harness and oxygen system installed in each aircraft and they must be used when practicing, qualifying, and racing. According to the crew the seat installed on the airplane was a stock P-51D seat that attached to the longerons (Figure 17). There was a five-point safety harness installed that attached directly to the seat. The shoulder harnesses had an inertia reel that was installed on the seat back and was able to be manually locked in any position.

According to the crew there was a small portable oxygen bottle installed in the cockpit of the airplane. A view of the oxygen bottle prior to installation can be seen in Figure 18. It was reported that the oxygen would last several races before having to be refilled.

2.0 Accident Aircraft Examination

The airplane was extremely fragmented due to impact forces. A preliminary examination was performed on scene and several pieces of the control systems were set aside. The group met December 6-9, 2011, at the Plain Parts facility in Sacramento, California, to perform a detailed examination of the wreckage. Several pieces of wreckage were removed and shipped to the NTSB Materials Laboratory for examination[7].

A large chunk of wreckage with extensive impact damage was recovered that included most of the empennage. The wreckage included the vertical stabilizer, the inboard portion of the right horizontal stabilizer, the elevator control horn, the rudder control horn, the inboard portion of the left elevator, the inboard portion of the left horizontal stabilizer, the aft fuselage, and portions of the tail wheel retract mechanism. The right and left elevator torque tubes were attached to the elevator control horn with three bolts. The nut on the forward left torque tube attach bolt was not installed and the bolt threads exhibited damage. There was an impact impression on the elevator control horn fitting aligned with the end of the bolt. The right elevator torque tube was fractured circumferentially along the inboard rivet line where the torque tube attached to the elevator nose rib on the right side. The rivets in the corresponding location on the left side were all sheared and the inboard portion of the left elevator remained attached to the torque tube but was displaced

[7] The details of the lab examination are presented in the NTSB Materials Laboratory Factual Report 12-029 in the public docket.

outboard. The four horizontal stabilizer mounting points were examined. The two forward bolts and the two aft bolts were intact. The forward right attach point was separated from the structure. The aft left fuselage fitting was fractured through the attach bolt hole and separated from the structure. There was an electric servo motor installed on the forward side of the front spar for the pitch trim system. The elevator trim cable was wound around the servo capstan and the cables were run through the spar and out to the remains of the left horizontal stabilizer. The cable was fractured in one spot and there was one cable strand fractured in another location. The turnbuckle on the elevator trim cable was installed and safety wired. The elevator control horn with attached portions of the torque tube was retained for further examination[8].

Most of the left elevator was separated from the horizontal stabilizer. The outboard hinge was intact and the stabilizer hinge half was pulled from the stabilizer structure. The center hinge was intact and the stabilizer hinge half was pulled from the stabilizer structure. A portion of the trim tab from the center hinge to the outboard edge was still attached to the elevator. The remaining portion of the left elevator trim tab from the inboard edge to the center hinge separated from the elevator prior to impact and was recovered on the north side of runway 8-26 near the home pylon (N 39° 39’ 50”, W 119° 52’ 36”). The recovered portion of tab was clean and relatively undamaged. The inboard trim tab hinge was separated and the tail of the screw remained installed in the spline nut on the elevator side of the hinge. The remainder of the screw was not identified in the wreckage. The tab side of the hinge had some localized scuffing and scratching of the paint but no major damage. There was some scuffing evidence on both the upper and lower surface of the tab consistent with over travel. The center and outboard trim tab attach screws exhibited some looseness. No evidence of repeated over travel was observed at the elevator or tab hinge points. The left elevator counterweight was separated from the elevator and recovered in the wreckage. The left elevator[9], separated inboard portion of the left elevator trim tab[10], and the inboard trim tab hinge were retained for further examination[11].

The left horizontal stabilizer rear spar was found separated from the stabilizer and adjacent to the initial impact point. The trim tab push rod guide was fractured and the upper half remained attached to the rear spar. The lower half of the guide was not identified in the wreckage. There was an additional piece of structure attached to the rear spar that appeared to be a support for the trim tab push rod (Figure 19, green arrow). The aft end of the left elevator trim tab push link assembly was attached to the left trim tab at the rod end and was fractured about 3 inches forward of the rod end. The push link was also fractured at the forward clevis in the threaded area and recovered separated in the wreckage. The aft end of the trim tab actuator push rod was separated and the push link clevis was attached to the end of the trim tab actuator push rod. The clevis bolt was installed in the cutout in the trim tab actuator push rod and bent forward. The rivets were sheared at the forward end of the push rod and the collar was displaced aft. A spring from the trim tab actuator was recovered but the remainder of trim tab actuator was not identified in the wreckage. The trim tab actuator push rod and the separated portion of the push link assembly were retained for further examination[12].

[8] See Evidence Control Form WPR11MA454-AIR-002.
[9] See Evidence Control Form WPR11MA454-AIR-003.
[10] See Evidence Control Form WPR11MA454-AIR-001.
[11] See Evidence Control Form WPR11MA454-AIR-004.
[12] See Evidence Control Form WPR11MA454-AIR-010.

The right elevator was separated and recovered in two pieces. The elevator was fractured at the outboard end of the trim tab. The right elevator trim tab remained attached to the right elevator. No evidence of repeated over travel was observed at the elevator or tab hinge points. The right elevator trim tab hinges exhibited some looseness. The torque tube was fractured along the inboard rivet circumference and a portion of the torque tube remained inside the elevator. The inboard section of the right elevator was retained for further examination[13].

The right trim tab push link was attached to the tab and broken at the forward clevis end in the threaded area. The push rod and clevis link remained attached together and were held in place in the rear spar push rod guide. A bolt was installed horizontally through the guide to fix the trim tab in place. The elevator trim actuator hangar brackets in the right horizontal stabilizer were not installed between the front and rear spars. The right trim tab push rod guide and fixed push rod were retained for further examination[14].

The left nose-down elevator cable was attached to the elevator control horn and fractured about 31 inches forward of the control horn. The right nose-down elevator cable was attached to the elevator control horn but the cable was fractured at the end of the swaged terminal. The left and right nose-up elevator cables were intact and continuous from the elevator control horn to the forward elevator bellcrank. The left nose-up elevator cable attach clevis was fractured from the elevator bellcrank but the attach bolt remained installed through the clevis lugs and swaged cable end. The right nose-up elevator cable was attached to the elevator bellcrank. The elevator bellcrank was fractured at the flap torque tube circumference. The upper arm of the elevator bellcrank was recovered separated and the cables were not attached. The nose-down elevator bellcrank cable attach holes were deformed and ovalized (Figure 20). The remainder of the nose-down elevator cables were not conclusively identified in the wreckage.

The fabric covered rudder was intact and separated from the vertical stabilizer. The upper end was smashed downward. The right rudder cable was intact from the rudder control horn to the adjustment bracket normally installed at the base of the rudder pedals. The rudder balance cable was fractured about 4 inches forward of the adjustment bracket. The left side of the rudder control horn was fractured and separated.

The tail gear actuator was still attached to the empennage, the tail gear assembly remained attached to the empennage by only the steering cables, and the tail wheel was separated from the gear assembly. The tail wheel uplock hook assembly was separated from the empennage. The rod was bent, the hook was intact, the cable horn was fractured, and the rod was pulled from the bearing blocks at both ends. The right bearing block was fractured. The left block was not identified. The uplock hook assembly was retained for further examination[15]. The tail wheel downlock pin was in the retracted position.

The left aileron and trim tab were recovered separated from each other. The trim tab hinges were all intact but the outboard hinge was pulled from the tab and aileron. The trim tab hinges all

[13] See Evidence Control Form WPR11MA454-AIR-005.
[14] See Evidence Control Form WPR11MA454-AIR-009
[15] See Evidence Control Form WPR11MA454-AIR-011.

exhibited some looseness. The right aileron was also recovered separated from the wing. The left aileron trim tab[16] and the outboard hinge[17] were retained for further examination.

The portable oxygen bottle valve was found in the airplane wreckage and sent for x-ray examination to determine the position of the valve[18]. The bottle was not identified in the wreckage. See the x-ray image in Figure 21.

All of the control cable fractures examined exhibited a broomstrawed appearance consistent with tension overload.

Portions of the fuselage skins were identified in the wreckage and the skin thickness was measured using a micrometer. The following skin thickness measurements were taken during the examination.

Right fuselage forward skin - 0.082 inch
Right fuselage center skin - 0.065 inch
Right fuselage aft skin - 0.047 inch
Right fuselage upper aft skin - 0.040 inch
Left fuselage forward skin was not conclusively identified
Left fuselage center skin was not conclusively identified
Left fuselage aft skin - 0.042 inch
Left fuselage upper aft skin - 0.040 inch
Lower fuselage skin was not conclusively identified
Turtle back skin - 0.042 inch
Empennage skin - 0.043 inch
Boiler Floor thickness - 0.104 inch

2.1 Other Aircraft

The owner of Race 5, Voodoo, a modified P-51D airplane, allowed the group to examine the airplane on March 13, 2012, to document the modifications to the airplane and the differences between it and the Ghost. A racing canopy and modified turtle deck were installed to decrease drag. The Voodoo canopy opened rearward similar to the stock canopy. The wings were shortened by removing the removable outboard section of wing from wing station 190 to the tip. A new wing tip was added to close out the wing and the ailerons were shortened from about 7 feet to about 5 feet. The wingspan was measured at 32 feet, 10 inches. The horizontal stabilizer and elevator tip caps were removed and replaced by a flat end cap that reduced the horizontal stabilizer span from 13 feet, 2-1/8 inches, to about 12 feet, 1 inch. The horizontal stabilizer was set to ½° incidence and the vertical stabilizer was set to 0° incidence by installing a flat 0.100 inch thick shim. The elevators were checked for trueness and it was measured that the right elevator was about 0.5° less than the left elevator. Both elevator tabs had about 0.060 inches of play at the trailing edge as installed which is about 0.75°. The elevator and rudder counterweights were examined and all appeared to match the drawings with no obvious

[16] See Evidence Control Form WPR11MA454-AIR-006.
[17] See Evidence Control Form WPR11MA454-AIR-007.
[18] See Evidence Control Form WPR11MA454-AIR-008.

additional weight added. An additional elevator trim push rod guide was added between the upper and lower flanges at the aft end of the horizontal stabilizer on both the right and left sides. The ailerons were set to the 12° travel location on the bellcrank. The elevator inertia weight was measured to be about 8.5 inches wide, 2 inches long and 3 inches high.

The elevator trim tabs from Voodoo were removed and examined. The tabs were of all metal construction and utilized flush head rivets on the skins. The elevator trim tab horn was attached to the skin of the tab by screws. The upper and lower skins had aerodynamic filler applied to smooth them and were painted. The weight of the right elevator trim tab was measured to be 894 grams and the left was measured to be 887 grams. The CG was measured by balancing the tab on a knife edge on the lower skin such that the chord of the tab was horizontal. The CG was measured along the lower skin to be 2.56 inches forward of the trailing edge for both tabs.

Race 38, Precious Metal, has standard metal elevator trim tabs that have not been painted or had aerodynamic filler applied to them. The tabs utilized button head rivets on the skins and had cast elevator trim tab horns. The trim tabs were weighed and the center of gravity was measured by the owner. The tabs were weighed without any hardware installed and measured 666.7 grams and 685.6 grams. The CG of both was 2.725 inches forward of trailing edge.

The group examined an essentially stock North American P-51D (N151MW, S/N 45-11633), Lady Alice, on May 7-8, 2012, in Chino, California. The horizontal stabilizer was set to ½° incidence and the vertical stabilizer was set to 1° left incidence. The elevators were measured to be within 0.1° of each other. The elevators and trim tabs were installed tight and had very little movement or slop. The elevator trim tab travel was checked at the upper and lower limits. The limits are set through the installation of cable stops on the upper and lower cables that contact the stabilizer front spar. At full nose down trim the deflection of the tabs were measured at 10.9° for the right and 9.7° for the left. At full nose up trim the deflection of the tabs were measured at 28.0° for the right and 24.0° for the left. The trim cable was measured to travel 21 ¾ inches from stop to stop at the horizontal stabilizer front spar. The distance between the left elevator trim actuator and the trim pulley in the center of the horizontal stabilizer was measured to be about 22 inches. The ailerons were set to the 15° travel position on the bellcrank. The elevator bob weight spanwise width was shortened from the original dimensions and was measured to be 4.5 inches wide. The bob weight was measured to be 2 inches long and 3 inches high. The elevator counterweights appeared to be stock with no obvious additional weight added. The left and right trim tab push links were both measured to be 9 3/8 inches between the centers of each rod end. The trim tab actuators in each stabilizer were examined for movement and binding and none was noted. The right actuator would provide about 1 inch of linear movement through about 5 ¼ turns and the left actuator would provide about 1 inch of linear movement through about 4 ¾ turns. The trim actuators were disconnected to allow the tabs to travel to their extreme trailing edge up and down positions. No binding was noted anywhere in the system when moving the elevators through their extremes. The trim tab guide and attached fixed trim tab push link from the accident airplane was installed in the right horizontal stabilizer of Lady Alice to examine the movement of the aft end with it only attached at the guide on the stabilizer rear spar. Almost no movement was noted when applying significant forces to the tab push link aft end both vertically and laterally. The right elevator and trim tab were then installed on the stabilizer to examine the movement of the trim tab. Less than 1/16 inch of trailing edge tab movement was noted. An

experiment was performed on both the left and right trim tab actuators with the trim cables disconnected. The tabs were set in the zero deflection or faired position and the tab trailing edge was jiggled to simulate vibration in the tab. The right trim tab actuator would rotate and the tab trailing edge would move down. Similarly the left trim tab actuator would rotate and the tab trailing edge would move up. The tabs would not move with the trim cables attached to the actuator since the motions opposed each other.

Race 84, Stiletto, was a modified P-51D airplane that raced at the NCAR from 1984 to 1992 (Figure 22). The airplane had shortened wings, horizontal stabilizers, and elevators cut to the same dimensions as the Ghost. The lower air scoop was removed and radiators were installed in the wings. The airplane had only the left elevator trim tab for pitch trim control and only the left aileron trim tab for roll trim control. Both were actuated electrically from the cockpit. There was a racing canopy and modified turtle deck installed. The cockpit was moved aft about 20 inches and the empty weight was reduced to about 5,800 pounds. Skip Holm, an accomplished Lockheed Skunk Works test pilot, was involved in the Stiletto project and published an article in the January 1985 issue of Air Progress magazine on flying Stiletto[19]. The article details a fairly rigorous flight test program that was flown to determine the flying qualities of the airplane. The power off stall speeds for the modified airplane were reported to be about 127 mph clean and about 124 mph dirty. "A dynamics evaluation was accomplished at each flutter point, with the aircraft being essentially deadbeat in the yaw and roll axis [sic] but exhibiting high sensitivity in the pitch axis." Further, the article documented a divergent longitudinal oscillation that occurred during a race when the pitch trim was accidently actuated. The airplane had an F-86 trim actuator installed in place of the stock actuator. The airplane was said to have a "destructive mode with any large upset."

3.0 Maintenance[20]

The airframe logbooks were examined with particular attention to the entries since 1983 when the airplane was purchased by Mr. Leeward. On August 17, 1983, there was an entry for the issuance of the experimental certificate made by an Aviation Safety Inspector from the FAA Long Beach Manufacturing Inspection District Office (MIDO). There was no aircraft total time associated with this entry, and the last entered total time was 1257.0 hours on August 12, 1980. A condition inspection was performed and signed off on August 16, 1984, at an aircraft total time of 1327.2 hours. A condition inspection was performed and signed off on August 20, 1985, at an aircraft total time of 1379.3 hours. A condition inspection was performed and signed off on September 6, 1986, at an aircraft total time of 1407.3 hours. A condition inspection was performed and signed off on September 7, 1988, at an aircraft total time of 1422.5 hours. A condition inspection was performed and signed off on August 30, 1989, at an aircraft total time of 1428.9 hours. The aircraft was then reportedly parked and there were no further entries until 2007.

An extensive logbook entry was made for the work accomplished between April 27, 2007 and October 21, 2008 at the GossHawk Unlimited facility. The logbook entry details the overhaul and assembly of the entire airplane into its current racing configuration. The airplane was then

[19] See Attachment 3 to this report for a copy of the article.
[20] See Attachment 4 to this factual report for the pertinent airframe, engine, and propeller logbook pages.

disassembled and transported to McKinney, Texas and then to Minden, Nevada for final assembly. On August 18, 2009, a logbook entry was made to document the certification of the transponder. The reassembly of the airplane was accomplished in fall 2009 and documented in a logbook entry dated September 16, 2009. In this entry the airframe total time was recorded as 1422.5 hours and the tach time was recorded as 0.0 hours. The entry also stated that the airplane was assembled in accordance with the P-51D&K Erection and Maintenance Manual (AN 01-60JE-2), a boil off cooling system was installed for oil and coolant cooling, and a condition inspection was accomplished in accordance with "Appendix D of part 43". On September 22, 2009 a logbook entry was made and signed off by Mr. Leeward that certified that "the prescribed flight test hours have been completed and the aircraft is controllable throughout its normal range of speeds and throughout all manevers [sic] to be executed, has no hazardous operating characteristics or design features, and is safe for operation." On September 10, 2010, a new generator was installed at an airframe total time of 1436.7 hours. The most recent logbook entry was for a condition inspection signed off on July 29, 2011, at an aircraft total time of 1447.2 hours.

The engine logbook was examined and had 8 entries since August 1983. On September 8, 2009, two almost identical entries were made to document that the engine was repaired and assembled in accordance with the US Army Manual AN 02-55AC-3 (Revision 07-15-1945) to the manufacturer tolerances listed in sections X-XI at an airframe total time of 1428.9 hours. The aircraft total time in both entries was 1428.9 hours. On July 29, 2011, there was an entry for a condition inspection of the engine at an airframe total time of 1453.6 hours. From August 16, 1984 to August 30, 1989 there were a total of 5 entries all for condition inspections (in 1984, 1985, 1986, 1988 and 1989) The engine was listed as a Rolls Royce V-1650-9A, S/N V381980, on the first page of the engine logbook.

The propeller logbook was examined and had four entries in total. The propeller was listed as a Hamilton Standard Model 24D50-6523A-24 with blade serial numbers 449707, 449708, 449709, and 449710. The propeller was overhauled on June 1, 2006, by San Antonio Propeller and installed on the Ghost on September 16, 2009. On July 29, 2011, a condition inspection of the propeller was performed at a propeller time of 24.7 hours. On September 4, 2011, the propeller had a dynamic balance performed.

As part of the 2011 Reno Air Races the accident airplane underwent an Unlimited Division Safety Inspection[21]. All items on the inspection sheet were checked off with the exception of the Wings-Fabric Condition and Landing Gear-Nose Tire items that were lined out. The parachute date of 8/31/11 and the oxygen date of 8/11 were handwritten adjacent to the items in addition to being checked off. The Remarks section of the form had an entry "elev trim tab screws too short, area washer in L/H wheel well". According to interviews with the technical inspectors and the crew, the trim tab squawk was due to one or more screws on the right elevator trim tab not having enough threads protruding from the nut and there was an area washer missing in the wheel well. The squawks were reportedly both addressed by the crew and the airplane was approved to race on the course. There was no written procedure or sign off to ensure the squawks were addressed. The date 7/29/11 was written on the form above the Aircraft Inspection Complete block that was checked 'Y'. According to the inspectors this is the date of the most

[21] See Attachment 5 to this factual report for the safety inspection sheets.

recent condition inspection for the airframe. The inspection was signed off and dated September 12, 2011.

The 2010 Safety Inspection was provided to the investigation by the Unlimited Division. All items on the inspection sheet were checked off with the exception of the Wings-Fabric Condition and Landing Gear-Nose Tire items that were lined out like on the 2011 inspection. The parachute date of 7/10 and the oxygen date of 6/06 were handwritten adjacent to the item in addition to being checked off. There was a handwritten note adjacent to the Powerplant-Installation item that stated "R/H nut short", one adjacent to the Empennage-Rudder/Trim Tab item that stated "loose bearing" and one adjacent to the Propeller-Hub item that stated "09". The Remarks section had a lengthy entry that stated "RH FWD engine nut needs replaced, clamp breather lines w/aftercooler, safety upper engine mount to firewall bolts, safety p-leads, safety temp probes on oil tank. Safty [sic] cuno plug, top rudder bearing loose". There was also a note to see the reverse side of the form for notes. The notes referred to the inspection of the boil off system in the airplane that was performed on September 13, 2010, and indicated that the technical inspectors had limited access to the boil-off system due to a lack of cooperation from the crew and owner. Based on the notes the FAA verified the approval of the boil-off system and the technical inspectors indicated that the areas they were able to inspect looked OK. The form was the same as the 2011 form and had no indication that the squawks were rectified. The Aircraft Inspection Complete was checked 'Y' and the date 9-16-09 was written above the block. The inspection was signed off and dated September 12, 2010.

4.0 Weight and Balance

The last weight and balance was performed on September 14, 2009[22]. The airplane empty weight was listed as 6,474 pounds empty with a center of gravity (CG) of 135.38 inches. This condition included the "Operational Boiler Fluid Weight" of 147 pounds at an arm of 215 inches. The pilot was listed as 200 pounds at an arm of 172 inches. The full flight weight was listed as 2,021 pounds with a CG of 142.64 inches. Interviews with the crew established that 2021 pounds was not the full flight weight of the airplane but only the total weight of the maximum fuel and ADI in the wing tanks. The weight and balance report indicated that the CG limits for the airplane were 135.77 to 143.8 inches.

A document with information about the Ghost fluid servicing was obtained from the crew. According to the document the Ghost had a capacity of 150 gallons of ADI mix in the left wing and 150 gallons of fuel in the right wing. The documented densities were 7.45 pounds/gallon for ADI and 6 pounds/gallon for fuel. Per the document a typical flight profile would include 125 gallons of fuel and 100 gallons of ADI for a total of about 750 pounds in each wing tank. On a typical flight "significantly more water will be consumed than fuel and the aircraft will return with the right wing heavy." The boiler aft of the cockpit could hold 20-30 gallons of ADI mixture. The document noted that an additional 20 gallons of ADI mixture was to be added if the boiler was empty and it would then be filled from the wing tank on taxi out.

[22] See Attachment 6 to this factual report for the weight and balance information.

The FAA approved Weight & Balance for the Type Certificate was obtained from the Type Certificate Holder. The CG limits are given as 135.8 inches aft of the datum for the forward and 143.8 inches aft of the datum for the aft. The wing fuel tanks arm was listed as 163 inches.

The group was able to obtain the documented fuel and ADI burn rates for the accident airplane. According to the crew, the boiler was filled before each race and emptied after each race so that a known quantity of ADI fluid was used. The airplane would reportedly use 15-20 gallons of ADI fluid for start, warm-up, and taxi, some of which would be blown over board and not boiled off. The airplane would use about 5 gallons of fuel for start, warm-up, taxi, and takeoff. According to the crew chief, the amount of ADI required for a race would be calculated based on the anticipated power settings and the duration of the race. Once this was obtained, 40 gallons would be added to cover the takeoff, join-up, cool down, and recovery of the airplane after the race. The fuel burn rate, engine ADI burn rate, and boiler ADI boil-off rate are based on manifold pressure and engine RPM[23]. The crew stated that there was essentially no engine ADI use below 60 in Hg[24] of manifold air pressure (MAP). The data in Table 1 was excerpted from the supplied engine data.

Engine (RPM)	MAP (in Hg)	Fuel Burn (GPM[25])	Engine ADI (GPM)	Boiler ADI (GPM)
2400	30	0.99	0	0.99
2400	35	1.15	0	1.15
2800	40	1.54	0	1.54
2800	50	2.03	0	2.03
2800	60	2.58	0.85	3.43
3000	40	1.65	0	1.65
3000	50	2.23	0	2.23
3000	60	2.81	0.90	3.71
3200	90	4.52	1.44	5.96
3200	100	5.05	1.60	6.65
3200	105	5.31	1.69	7.00
3400	100	5.26	1.67	6.93
3400	105	5.53	1.76	7.29
3400	110	5.81	1.85	7.66
3400	115	6.03	1.94	7.97
3500	100	5.37	1.71	7.08
3500	105	5.64	1.80	7.44
3500	110	5.92	1.88	7.80
3500	115	6.20	1.97	8.17

Table 1 – Fuel/ADI burn rate data

[23] Revolutions Per Minute
[24] Inches of Mercury
[25] Gallons Per Minute

5.0 National Air-Racing Group (NAG) [26]

The NAG Unlimited Division is the governing body for the pilots and airplanes that race in the unlimited class at the NCAR. The Unlimited Division developed the official competition rules and bylaws that include Aircraft Specifications, Pilot Qualification Specifications, and Technical Inspection Regulations. The most recent version of the rules was adopted in January 2006. Failure to comply with the rules will result in disqualification of the pilot and/or aircraft from the race competition.

Each aircraft must qualify to establish eligibility and starting position for the races. A qualification run consists of two laps on the Reno race course with the best one lap speed used for qualifying. There is a provision in Section V, Rule 11, for RARA to have the option of adding aircraft to the end of the qualified list even if they have not successfully completed a qualification attempt in order to complete the field if "the pilot and aircraft have demonstrated their ability to perform at race speed." There is a minimum qualification speed of 300 mph for any unlimited aircraft. Once qualified, any airplane that starts a race will be paid prize money on a schedule established by the class and approved by RARA. During the race, the rules state that the maximum race altitude is 1500 feet AGL. Any aircraft above this altitude is considered to have left the race. Established emergency procedures are outlined in Section VIII F for maydays and obvious emergency situations. The maximum race altitude for certain sections of the course can be set lower by the FAA and any airplane violating these provisions will be disqualified under Section IX Penalties. There will be several showlines set for the course by RARA and the FAA. Crossing any of these showlines will result in disqualification. In operation, aircraft that are experiencing a problem of some kind will pull up from the course above the 1500 feet maximum altitude to orbit the airport and establish the nature of the emergency or problem. If necessary they can be allowed to land immediately on the nearest available runway while the race continues.

Appendix B lists the Special Rules for the Unlimited Division and contains two special rules for the Reno race course. A special rule is established under the Section IX Penalties to allow for an escape route for aircraft that cannot fly down runway 8-26 past the home pylon. An airplane is allowed to exit the race course west of the runway 8 threshold and climb to 1500 feet AGL. It may then pass behind the spectator area above 1500 feet AGL and re-enter the course passing east of the runway 26 threshold. The other special rule applies to Section VIII Racing and establishes the starting procedures for Reno.

Appendix C is the NAG Unlimited Division Aircraft Specifications. Any aircraft that is to participate in the unlimited division must be propeller driven, reciprocating engine powered, have all necessary current FAA licenses and certificates, and must pass an inspection by the Technical Committee of the NAG Unlimited Division prior to qualification. There are no restrictions on engine or airframe modifications. All aircraft must be capable of limit load factors from -3.0 g to +6.0 g and must be designed to accepted structural design criteria. The following two specifications are quoted directly from the Section III. AIRFRAME.

[26] See Attachment 7 to this report for the documents discussed in this section.

C. Aircraft must demonstrate adequate maneuverability (controllability) at racing speed. This can be determined during aircraft qualification.
D. Aircraft that are not modified versions of previously designed and built fighter aircraft will be designated as "Custom Built" aircraft and will be required to meet certain design and test criteria to ensure their safe operation, above and beyond those criteria specified in the preceding sections. The design of any flight-worthy aircraft should, for the safety of the pilot and those on the ground, be substantiated by the proper computational analysis. The following criteria are considered essential to ensure that an aircraft is properly designed and adequately tested.

1. Structural load analysis for the +6.0 g and -3.0 g load factors, including consideration of design loads, limit loads, and ultimate loads, will be submitted. The ground rules and basic calculations for the structural load limits must be presented in a format that indicates the aircraft designer is familiar with and has used accepted aircraft design procedures and safety factors.
2. A flight flutter test analysis, test plan, and test results will be submitted to verify that the aircraft will safely operate within the structural limits and not be in the flutter region at speeds and load factors within the anticipated flight envelope.
3. Weight and balance data for an empty and full vehicle shall be submitted.
4. The flight test plan and flight test results will be submitted to verify safe operation of the vehicle within its flight envelope.
5. The items specified in 1 through 4 above will be made available for review by qualified technical personnel to ascertain the validity and credibility of the submitted data. The Unlimited Division Board of Directors will hire, for pay, impartial qualified personnel such as Registered Professional Engineers or people known to be experts in their fields, to review and comment on the data. The review will be made far enough in advance that appropriate modifications, recommended by the qualified experts can be implemented, tested and re-evaluated.

Any types of fuel or fuel additives are allowed. The specifications require that each aircraft have an oxygen mask system, a seat belt and shoulder harness, and a functioning two-way communication radio, all of which must be used during practicing, qualifying, and racing.

Appendix E contains the technical inspection requirements for the Unlimited Division. The requirements require that each aircraft will be inspected at the race site by the technical inspection committee prior to race competition along with all of the associated logs and paperwork. There is a stipulation to allow aircraft to practice prior to technical inspection if they receive a provisional approval after a walk-around inspection is performed. The committee will examine the aircraft registration certificate, airworthiness certificate, airframe log, engine log, parachute pack date substantiation and hydrostatic test substantiation for currency. The committee is to keep a set of records on each aircraft substantiating the records review and the physical inspection of the aircraft. Any aircraft may be re-inspected at any time during the race if it is deemed necessary by the committee and will typically happen as a result of an unusual maneuver, after a mayday, or after an engine, propeller, control surface, or structural member

repair or change for any reason. The re-inspection must be approved before the aircraft is allowed to continue in the event. Section II. AIRCRAFT INSPECTION is quoted below.

> A. The aircraft structure, and all functional components attached to the aircraft structure, will be inspected for structural and functional integrity, for proper attachment and containment, (i.e., safetywire, cotter pins and retention washers) and for cleanliness for fire prevention, (i.e., excessive oil and/or hydraulic fluid and/or fuel and/or other combustible fluid leakage or accumulation).
> B. The specific major areas to be inspected are:
> a. Main fuselage and cockpit area
> b. Wings and control surfaces
> c. Vertical and horizontal surfaces and control surfaces
> d. Engine and Nacelle components
> e. Propeller and actuating controls
> C. The following major systems are to be inspected:
> a. Hydraulic and landing gear systems
> b. Fuel tanks and fuel distribution systems
> c. Oxygen tanks and oxygen distribution systems
> d. Oil and oil cooling system
> e. Coolant and coolant cooling system
> f. Control surface actuating system
> g. Engine controls and actuation systems
> h. Electrical and communication systems
> i. Canopy actuation system and seat belt and shoulder harness system
> j. Crash helmet system (hard shelled full coverage helmet; visor recommended)
> k. Emergency systems; gear retraction, fire extinguishing system, parachute system and egress system
> l. Proximity of combustible systems to each other, (i.e., fuel and oxygen systems)
> D. After the aircraft has been inspected or reinspected the appointed chief of the Technical Inspection Committee must give an approval to the pilot and/or owner of the aircraft and to the Chief Judge verifying that the vehicle is ready to commence competition. This approval will be in the form of a signature on the standard inspection form for that aircraft for the date inspected or reinspected.
> E. The approval of the Technical Inspection Committee does not constitute a representation or warranty of any kind or character whatsoever concerning the mechanical condition of the aircraft or whether or not it is airworthy.

Prior to the NCAR in 2009 the Unlimited Division was concerned about those airplanes that would show up with major changes or alterations and queried RARA by email. In an email dated August 31, 2009, the Unlimited Division was informed that there were two airplanes that reported having a major change or major alteration on their entry forms; Race 77, Rare Bear, and Race 177, Galloping Ghost.

6.0 Reno Air Racing Association (RARA)

RARA is the organization that conducts the National Championship Air Races each year in Reno, Nevada. The Official Rules of Competition 2011 provided the rules and guidance for holding the event and were effective on September 1, 2011[27]. The first pages of the document list the definitions used throughout. In this section, the definition of Conditional Entries provides for three types of entries received after the closing date and time. A Conditional Entry to Fill the Field will be allowed when the field of racers is not filled in the class[28] in question and will be allowed the opportunity to qualify. A Conditional Entry to Fill the Field upon the Failure of Sufficient Aircraft to Qualify will be allowed to qualify if all of the on time and conditional entries to fill the field are unable to qualify. A Conditional Entry to Fill the Field if the Field is not Full by the First Heat Race in its Class is a conditional entry that has not qualified but will be allowed to start as the last place aircraft in the lowest heat in the class. In order to be "on time" the complete entry package must be received by RARA at the designated date and time specified on the entry form. Section II designates the officials and their authority for the air races. In addition to the RARA official positions the class technical inspection and pilot qualification committees are designated officials. None of the officials can be involved with any of the racers or race sponsors. Section III provided the aircraft eligibility criteria. All aircraft must meet the eligibility requirements of their respective class, can only be entered in one class, and no aircraft weighing less than 4,500 pounds will be allowed in the unlimited division. Similar to the Unlimited Division rules, the RARA rules require that the registration certificate, airworthiness certificate, special flight permit, operating limitations, airframe and engine logs be made available to the FAA and RARA for inspection. Additionally, documentation of any modifications performed on the aircraft or engine shall be made available to the technical inspection committee of the class. RARA specifically references Federal Air Regulation (FAR) 21.93, FAR 1.1 major alteration and FAR 91.9 for any modifications. Any new aircraft that has not been previously inspected by the technical inspection committee or any aircraft that has had a major change or major alteration per the referenced FARs since the last registration "must register and have their aircraft ready for inspection no later than 1200 hours the first Sunday of race week. All FAA approved documentation must be presented to the Class Tech/Safety Inspection Committee during the inspection of the aircraft." Additionally, if a major change or alteration has been performed since the time the aircraft last raced at Reno or within the 12 months prior to the current race, "all provisions established by the FAA for a major change or alteration, through the FAA Approved Aircraft Operating Limitations, must be accomplished and documented in the aircraft records prior to arrival at Reno/Stead (RTS) and such documentation and related correspondence shall be made available to the FAA and RARA at Pilot Registration." The class technical inspection committee is given final authority over the eligibility of any aircraft for the races. RARA further stipulates that the race class is responsible for insuring that all aircraft have been inspected by their technical inspection committee prior to flying on the course. In Section VII Qualification of Aircraft, the rules stipulate that "all pilots must be registered, have their aircraft inspected, and in place and ready to qualify no later than 1200 hours on Tuesday of race week." Pilots and aircraft that do not meet this become conditional entries. Section VIII defines the race course. Since 2003, RARA has used an optimum race path based on the speed and load factor information provided by each class. The Unlimited race course is 8.4333 miles long based upon a speed of 500 mph and a load factor of 3.5 G's. The participating aircraft are timed using high speed cameras and their average calculated

[27] See Attachment 8 to this report for the full text of the document.
[28] RARA utilizes 'class' interchangeably with 'division' throughout the document.

ground speed is used to determine official race speeds. The race course minimum altitude is situated at the top of the pylons (or the bottom of the "R" in RENO on the home pylon) and the pilot's eye level (or cockpit) must remain above this at all times. The maximum altitude on the race course is 350 feet AGL[29] except during the start or when passing a slower aircraft. For those aircraft capable of speeds in excess of 500 mph (Gold racers in the Unlimited and Jet classes) have a further altitude restriction at pylon Outer 8. At this point the maximum altitude is limited to 250 feet AGL while passing pylon Outer 8. The RARA rules also define the escape route behind the crowd identical to the NAG rules. Section XII defines the Emergency Procedures for the races. The pilots have the option of calling "mayday" if they are having an emergency and the standard procedure is to climb to a safe altitude to assess the situation. Race control can also notify the other racers if they notice an aircraft obviously having an emergency situation. There is no defined safe mayday altitude and all other aircraft will continue to race after a "mayday" has been declared. The aircraft having the emergency, however, has the right of way and all other aircraft must give way. The Unlimited Class field is limited to the 24 fastest qualifiers. Each heat race will have a minimum of 5 aircraft and a maximum of 9 aircraft while the Silver or Gold race will have a minimum of 7 aircraft and a maximum of 10 aircraft.

The official speeds recorded by RARA for the Galloping Ghost in 2010 and 2011 are listed below. The supplied speeds are average ground speeds calculated based on the elapsed time to complete the specified number of laps on the optimum race path length of 8.4333 miles.

Type	Date	Speed (mph)
Medallion Race 1C (6 laps)	9/16/2010	339.424
Bronze Heat Race 2C (6 laps)	9/17/2010	364.505
Silver Heat Race 3B (6 laps)	9/18/2010	373.284
Qualification Lap 1 (1 lap)	9/13/2011	436.418
Qualification Lap 2 (1 lap)	9/13/2011	465.807

Historical records for the accident airplane under its previous name, Leeward Air Ranch Special, indicate it participated in the NCAR and posted official recorded race speeds in 1984, 1985, 1986, 1988, and 1989.

Section IX Racing indicates that maximum cross wind component for takeoff and maximum wind allowed during a race shall be included in the class rule. There are no established maximum wind speeds in the NAG rules.

6.1 Reno Air Races Entry Forms and Correspondence[30]

In 2009 Mr. Leeward entered the Galloping Ghost for the 2009 races. The entry deadline was June 30 and the form was dated July 30, 2009. The fax header on the form was dated July 1, 2009 and there was a hand written note that stated the entry is "Not Late" and was received at 11:59 on June 30. The entry originally was for race #9 and a hand written note indicates that this number cannot be used since it was assigned to the airplane called Cloud Dancer. A second entry form was contained in the package that was also dated July 30, 2009 with no fax header that lists the race #177. The package indicated that the Aircraft Data and Safety Data Information form for

[29] Above ground level
[30] See Attachment 9 to this report for the entry forms and correspondence.

the Ghost was received by RARA on July 31, 2009. The entries on this form indicated that the aircraft was previously approved for racing, had an oxygen system, and had a wingspan of 28 feet. The 'yes' was also circled for the major change or major alteration since the airplane last raced at Reno. Included as part of this package was the airworthiness certificate issued by the NM-MIDO FAA office and the airworthiness limitations dated 1983. The 2009 registration was eventually withdrawn with no refund given when the airplane did not show up for the 2009 races. On the 2009 Pilot Data form, Mr. Leeward listed his age as 59, 13,700 total pilot hours, 40 hours in the last 90 days, 2500+ hours in the Entered Race Aircraft, and 2500+ hours in the make & model. He also listed the 2007 races as his last time at Reno. The form was dated June 22, 2009.

Mr. Leeward also registered as an alternate for the 2009 races on the airplane N240CA a Chance-Vought F4U-4 Corsair.

In 2010 Mr. Leeward again entered the Galloping Ghost for the NCAR. The initial entry forms were dated July 17, 2010 and the paperwork indicated that most of the required forms were received by RARA on July 22, 2010. On the Aircraft Data form the 'no' was circled for the major repair or major alteration since the last time the airplane raced at Reno and the engine displacement was listed at 1550 cubic inches on the aircraft data form as opposed to the 1650 listed for the previous year. On the pilot data form he listed his total time at 13,000±, age as 59, 35± hours in the last 90 days, 2010 as the last year competed at Reno, 34 total years at Reno, 2500± hours in race aircraft, 2500± hours in make & model, and 2000 last completed pylon racing seminar.

The 2011 entry package was reviewed for the Ghost. There was no 2011 Entry Form supplied as part of this package. In this package his age was typed as 59 with it crossed out and a hand written 74 entered, 13,200± total pilot hours, 38 hours in the last 90 days, 35 years at Reno, 2700± hours in the registered airplane, 2700± hours in make & model, 43 years as a pilot. The form was dated June 30, 2011. There was a biennial flight review listed on 4/10/10. The engine displacement was again listed as 1550 on the aircraft data form and the 'no' was circled under major repair or major alteration. A Dealer's Registration Certificate, Airworthiness Certificate and Operating Limitations were included. A flight review certificate was included with a copy of his pilot certificate and medical certificate.

The investigation obtained an email communication from RARA to Mr. Leeward dated September 4, 2009. In response to some concerns and uncertainty about the required aircraft arrival times, RARA sent an email to Mr. Leeward that cited the RARA rules for Qualification of Aircraft and Aircraft Eligibility and added an interpretation of the rules. The RARA Rule Committee took the position that:

"1. The GHOST has been previously inspected by the Tech. Committee;
2. The installation of a RACE ENGINE in an aircraft that has previously had a race engine DOES NOT require the Sunday arrival date;
3. The DANCER has been previously inspected by the Tech. Committee;
4. If there have been no "major changes" or "major alterations" pursuant to the above FAR sections, the aircraft must comply with the "1200 hours Tuesday of race week" time frame or be considered "a conditional entry"."

7.0 Telemetry Data[31]

The accident airplane was equipped with a data gathering and telemetry system that allowed the race crew to monitor flights in real time. The data telemetered to the ground during the accident flight was obtained from the crew after the accident. Additional telemetry data from many other flights was obtained from the pilot's family along with selected data from two different race aircraft. According to the crew, the system allows them to monitor the engine instruments during the race and alleviate some of the pilot's workload. The crew reported that they had a lot of trouble with the telemetry system as a whole when the airplane first flew in 2009 due to a connection problem somewhere in the system. The connection problem was reportedly solved before the 2010 NCAR. They still had some problems with individual parameters not recording accurate values but were working out the issues. The oil pressure signal typically was about 10 psi lower than what was actually produced in the engine and they relied on the cockpit gages for the most accurate parameter values. During the accident flight the system recorded magnetic and true course, vertical acceleration, GPS position, velocity and altitude, boiler pressure, ADI pressure, coolant temperature, induction temperature, fuel pressure, oil temperature, oil pressure, manifold air pressure, and engine RPM.

Figure 11 in the referenced report shows the engine parameters during the accident race. The oil temperature is about 78° C as the airplane is coming down the chute to begin the race. The oil temperature slowly and steadily climbs throughout the duration of the race to about 86°C at the time of the upset. The oil pressure is about 105 psi as the airplane is coming down the chute and remains in this vicinity for about 30 seconds. At about the time the airplane levels out on the course the oil pressure drops to about 70 psi in the course of about 2 seconds. The oil pressure then remains essentially constant at about 70 psi for the reminder of the flight until the upset. The manifold pressure is about 65 in Hg[32] and climbing as the airplane is coming down the chute. The manifold air pressure (MAP) climbs steadily for about 30 seconds until it reaches about 100-105 in Hg. It remains essentially constant at this level for about 40 seconds and then climbs about 10 in Hg to about 110 in Hg. The manifold air pressure varies between 105 in Hg and 115 in Hg for most of the remainder of the race. The manifold air pressure drops to about 105 in Hg about 10 seconds prior to the upset. The engine RPM is about 3050 RPM as the airplane is coming down the chute then climbs to about 3150 RPM in 2 seconds, stays at this level for about 10 seconds, spikes up to about 3400 RPM and back down to about 3250 RPM in about 6 seconds, and remains at about 3250 RPM for about 40 seconds. The RPM then climbs to about 3400 RPM in about 3 seconds and varies between 3350 RPM and 3450 RPM for about the next 15 seconds. The RPM varies between about 3400 RPM and 3500 RPM for most of the remainder of the flight. About 10 seconds prior to the upset the RPM drops to about 3350 RPM. After the upset at about 1624:30 the MAP drops to about 90 in Hg and the RPM drops as low as about 600 RPM then rises to about 2650 before the recorded data ends. The airplane enters the chute at a GPS Altitude of about 9300 feet MSL and levels off on the course at about 5400 feet MSL. Variations in the terrain and variations in the course flown result in the altitude varying between about 5100 feet MSL and 5650 feet MSL during the accident race. The altitude is steady at about 5300 feet MSL for the 10 seconds preceding the upset. The GPS velocity peaks at about 450

[31] See the Data Recorders Specialist's Factual Report in the public docket for this accident for the details.
[32] Inches of Mercury

knots as the airplane levels off on the course and varies between this and about 420 knots for the first 40 seconds. The velocity data was not recorded for a large portion of the race but was again about 450 knots prior to the upset.

All of the other flights where data was recorded were examined and ten of these flights were plotted in the referenced report. These additional plotted flights included 6 flights on the Reno race course and 4 other flights. According to the crew they performed a couple of flights on September 21 and 22, 2009, after the airplane was completed. They stayed in Minden for the next several days and may have flown the airplane a few more times. The crew returned to Minden in late 2009 to perform some additional test flights. All of these initial test flights were reported to be about 15-20 minutes in length. They gradually increased the flight lengths to 30 minutes and then to 45 minutes as they accumulated more hours on the airplane. Due to the telemetry problems discussed earlier, many of these flights were not captured.

Recorded data was obtained for two other unlimited class airplanes to compare with the data from the Galloping Ghost. The data obtained was limited to course, vertical acceleration, velocity, and altitude. Three race flights including the accident race were obtained for the modified North American P-51D, Voodoo (Race 5), and two flights were obtained for the modified Hawker Sea Fury, September Fury (Race 232). One of the Sea Fury flights was for the airplane with stock wings and the other was for a race after the wingspan had been shortened by about 5 feet.

8.0 North American Aviation (NAA)/Army Air Forces (AAF) Service Information

Structural Repair Instructions (SRI) for Airplane P-51D (AN 01-60-3)
The SRI was examined in order to establish the baseline structural information for the P-51D airplane. Figure 23 shows the P-51D station diagram. The fuselage structure is based around two main longerons that run the length of the fuselage. The wing and air scoop attach to the lower longeron and the canopy attaches to the upper longeron (Figure 24). The empennage attached to the aft end of the fuselage at station 248 (Figure 25). On the stock airplane the forward fuselage skin is 0.081 inch thick 24ST[33] Alclad, the center fuselage skin is 0.064 inch thick 24ST Alclad, the aft and upper fuselage skins and empennage skins are 0.040 inch thick 24ST Alclad. The engine mount attached to the forward end of the fuselage at station 75 on the lower longeron and station 80 on the upper longeron (Figure 26).

P-51D & K Reference Manual (Report No. NA-8419)
Operating Instructions, Flight Operating Cautions, page 13 – "As stick forces are comparatively light during high-speed dives, make pull-outs gradually to prevent structural failure. If airplane porpoises in dives, reduce power before compressibility effect becomes more violent."

P-51 Pilot Training Manual (AAF Manual 51-127-5) dated 15 August 1945
In the Flying Characteristics section there is a CAUTION that states "In designing the later models of the P-51and adding new equipment such as radio units and an additional gas tank, the center of gravity of the airplane has been moved back. The effect is the amount of back pressure necessary to move the stick has been reduced. Instead of a force of 6 pounds per G of

[33] 24ST is the previous name for 2024 aluminum.

acceleration, you exert a force of only 1 ½ pounds, the stick forces reversing as acceleration exceeds 4 G's." It further advises the pilot to be careful in steep turns or sharp pull outs as there is a tendency for the pilot to black out or exceed the capability of the structure. In a following section of the manual entitled Reversibility, the manual describes a situation where the pilot would have to push forward on the stick to prevent the airplane from tightening a turn or a pull out. The manual indicates that the condition will happen when the airplane has fuel in the fuselage fuel tank located behind the pilot seat that corresponds to an aft CG condition. The manual goes on to state "The P-51D's reversibility characteristics have been improved by the addition of a 20-pound bobweight to the elevator control system bell-crank. This weight reduces the amount of forward pressure you'll have to exert to overcome the reversibility tendency." The manual also devotes a section to Compressibility. In this section, the manual does not give many details on what the causes are but advises the pilot that the airplane is susceptible to compressibility effects beginning at about 75% of the speed of sound. Compressibility manifests itself in the P-51 by one or more of the following effects; tail buffeting, stiffening of the controls, uncontrollable pitching or porpoising, or uncontrollable rolling or yawing. It further warns the pilot that structural failure may occur if the speed of the airplane is not reduced.

USAF F-51D Flight Handbook (T.O. No. 1F-51D-1) dated 20 January 1954
Section V of the handbook deals with the operating limitations of the airplane. There is a small section on compressibility that indicates the same effects as those detailed in the Pilot Training Manual. In the subsection entitled Acceleration Limitations, the limit load factor is given as positive 8 G and negative 4 G but only applies to a clean airplane gross weight that does not exceed 8,000 pounds. The airspeed is limited to 505 mph IAS (Vne). See Figure 27 for the V-n diagram. The Center-of-Gravity subsection states that the CG limitations cannot be exceeded with any external load that the airplane is designed to carry but does warn that "unsatisfactory flight characteristics" can be possible at adverse aft CG conditions. The fuselage fuel tank is limited to 65 gallons maximum due to these CG issues. Section VI of the Flight Handbook deals with the flight characteristics of the airplane. The manual states that the stock airplane is stable at all normal loadings and the trim tab controls are sensitive and susceptible to over trimming. It specifically states that there is an elevator bobweight installed to artificially load the controls and prevent over acceleration in turns or pull outs because of light stick forces. In the Maneuverability subsection there is a CAUTION that states "Avoid rapid movement of the elevators in dives and maneuvers at speeds above 350 mph IAS or .7 Mach, particularly at aft CG positions, to prevent rapid uncontrolled increase in G-loads."

8.1 Technical Orders[34]

While the P-51 airplane was in military service, the Army Air Forces used Technical Orders to communicate service information, operating instructions, and maintenance requirements for the airplanes.

On November 20, 1944, the headquarters of the Army Air Forces issued technical order 01-60-90 to install an elevator inertia weight on the P-51D. The listed purpose of the modification was "to prevent reversal of the elevator control stick forces during maneuvers". The technical order did not specifically apply to the accident airplane since the serial number was outside of the

[34] See Attachment 10 to this report for the referenced Technical Orders.

range listed. However, the TO did specify that those P-51D airplanes outside the serial number range would be modified by the contractor prior to delivery to the Army Air Forces. The elevator inertia weight is P/N 109-52217 and per the drawing the assembly should weigh 20.75 +/- 0.50 pounds.

On unknown date, the headquarters of the Army Air Forces issued technical order 01-60-100 to install metal covered elevators on the P-51D airplane. The technical order was applicable to the accident airplane and replaced the fabric covered elevators because "during dives in which the pilots' indicated airspeed, corresponding to 75 percent of the speed of sound is approached or exceeded, and during dives to very high indicated airspeeds, the airplane may be subjected to severe longitudinal oscillations". In addition, the horizontal stabilizer incidence was reduced from 2 degrees leading edge up to ½ degree leading edge up. The incidence was changed by replacing the forward and aft horizontal stabilizer attachment brackets. The ½ degree brackets are P/N 122-21031 for the forward and P/N 122-21033 for the rear.

On July 10, 1944, the headquarters of the Army Air Forces issued technical order 01-60J-25 to publish dive limitations for the P-51D airplane. The technical order stated in part that "All modern high speed, high altitude airplanes are affected by compressibility to a varying degree. Compressibility phenomena are caused by the formation of compression waves or shock waves in the air flowing over the wings and other parts of the airplane when the true airspeed of the airplane approaches the speed of sound. These phenomena may be evidenced by occurrence of instability, uncontrollable rolling or pitching, or stiffness of controls, or combinations of these effects. The exact speed at which compressibility effects are noticed varies with different airplane models and with the condition of the airplane… The first compressibility effects occur on the P-51 airplane at a speed approximately 75 percent of the speed of sound and are evidenced by a tendency of the airplane to porpoise." Further the order issues the warning "CARE MUST BE EXCERCISED IN PULL-OUTS, SINCE THE STICK FORCES ARE RELATIVELY LIGHT AND ABRUPT PULL-OUT MAY CAUSE STRUCTURAL FAILURE. THE ELEVATOR TRIM TAB WILL NORMALLY NOT BE REQUIRED TO AID RECOVERY, HOWEVER, IF FOUND NECESSARY IT SHOULD BE USED WITH CARE AND IN SMALL INCREMENTS."

On November 23, 1945, the headquarters of the Army Air Forces issued technical order 01-60-126 to define and describe the flight characteristics and restrictions of the P-51D airplane. The information in this technical order was issued to reduce the possibility of structural failure of the wings on the P-51D. Based on the increasing weights of the airplanes over time as more equipment was added, and the variation in the center of gravity position based on loading, the following restrictions were issued.

CG Aft of	Restriction
27.5% MAC	a. Aerobatics and pull-ups are prohibited above 15,000 feet pressure altitude b. Instrument flying and issuance of flight clearances for flights under instrument conditions at pressure altitudes above 15,000 feet are prohibited.
28.5%MAC	a. Aerobatics, dive bombing, and pull-ups are prohibited AT ALL ALTITUDES. b. Instrument flying and issuance of flight clearances for flights under

instrument conditions are prohibited AT ALL ALTITUDES.
c. Flight in rough or turbulent air is to be avoided.

31%MAC a. Release of the airplane for flight is prohibited.

9.0 FAA documents[35]

The official FAA airworthiness and registration files were obtained for the accident airplane. The airplane was purchased by Bahia Oaks, Inc. (James K. Leeward-President) on July 18, 1983 from Sanders Lead Company, Inc. and registered with the FAA on the same day. Subsequently the airplane was transferred between Bahia Oaks, Inc. and Aero-Trans Corporation (both d/b/a Leeward Aeronautical Sales) several times. The most current registered owner of the accident airplane in the FAA files was Aero-Trans Corporation with a Bill of Sale dated December 12, 2007. The airplane began its racing career in 1969 under the ownership of Cliff Cummings who purchased the airplane on February 8, 1960. Mr. Cummings sold the airplane to Dennis Schoenfelder and Dave Zeuschel on March 19, 1979 who then sold it to Sanders Lead Company, Inc. on January 24, 1980.

On August 17, 1983, Mr. Leeward applied for and received a Special Airworthiness Certificate from the Long Beach, California, Manufacturing Inspection District Office (MIDO) of the FAA. The certificate was for the category/designation Experimental-Exhibition/Racing and the purpose Operating Exhibition Racing Aircraft. There was no expiration date for the airworthiness certificate and operating limitations with the same date were issued. On July 16, 2010, Mr. Leeward requested a replacement airworthiness certificate with the stated reason that the old certificate had been lost. A replacement certificate was issued with the original date of issuance of August 17, 1983, with the category Experimental and the purpose Exhibition/Air Racing. The replacement certificate was issued by the Reno, Nevada, Flight Standards District Office. The original 1983 operating limitations remained in place and there was no expiration date. Historically, the airplane was operated under a Limited Airworthiness Certificate until July 1970 when Mr. Cummings first applied for and received an Experimental Airworthiness Certificate for the purpose of Exhibition. Operating Limitations were issued as part of the certificate and both the Airworthiness Certificate and Operating Limitations were valid for only one year. The airplane was issued Experimental Airworthiness Certificates for the purpose(s) of Exhibition and/or Air Racing along with Operating Limitations each year from 1970 through 1980 with the exception of 1971. Each of these certificates and limitations were valid for one year until the last set issued in 1980 which were valid for an unlimited period of time unless established otherwise by the FAA.

In July 1970, a FAA Form 337 Major Repair and Alteration was filed for racing modifications that included clipping the wings at the stock production break (station 190), installing fiberglass wing tips with fences, shortening the ailerons, converting the aileron tabs to servo boost tabs, modifying the canopy for racing, and installing a nitrous oxide system. In April 1967, a Form 337 was filed to remove the Cessna seats (2) previously installed on a Form 337 dated August 30, 1962. The Cessna seats were removed and replaced with a single stock Mustang seat. The lower wing skins on both the left and right wings from station 75 to 145, and from the front spar to the trailing edge, were removed and replaced to eliminate the gun ejection ports and all

[35] See Attachment 11 to this report for the documents.

unnecessary holes and patches per a Form 337 in October 1965. The Empennage skins were all replaced in October and November of 1965 on several Form 337's.

According to the FAA website "a special airworthiness certificate in the experimental category is issued to operate an aircraft that does not have a type certificate or does not conform to its type certificate and is in a condition for safe operation."

The operating limitations for S/N 44-15651 were issued at the same time as the original special airworthiness certificate. The limitations were generally in agreement with the items in FAR 91-319 with the following exceptions. The airplane was to be based and maintained at Leeward Air Ranch Airport in Ocala, Florida, all proficiency flights were to be conducted within a 100 mile radius. There was a special allowance for proficiency flights to be conducted enroute to air shows or air races. Regarding maintenance, the limitations stated "The cognizant FAA flight Standards Office must be notified and their response received in writing, prior to flying this aircraft after incorporating a major change as defined by FAR 21.93." The limitations also required a condition inspection at least every 12 months in accordance with Part 43 Appendix D and that inspection shall be documented in the airplane logbook.

FAA Order 8130.2G, Airworthiness Certification of Aircraft and Related Products, chapter 4, section 10, provides guidance for FAA inspectors when dealing with the certification and operation of aircraft under the experimental purposes of exhibition and air racing. On December 21, 2011, FAA headquarters issued a deviation to this section in order to clarify the operating limitations placed on experimental airplanes operating for the purposes of exhibition and air racing. Under this guidance a P-51D airplane such as the Galloping Ghost will be a Group 3 aircraft since it is propeller driven, has a takeoff rating of more than 800 HP, a V_{ne} greater than 250 knots, and a maximum takeoff gross weight not more than 12,500 pounds. Utilizing the table in the order the limitations presented in Appendix B should be issued for a Group 3 aircraft if it were registered presently.

9.1 FAA correspondence

The FAA RNO FSDO supplied the investigation with some email and mail correspondence that they had with Mr. Leeward prior to the races in 2009. On September 9, 2009 Mr. Leeward sent two emails to the FAA to inform them that the boil-off cooling system installed in the Ghost was from an ex-Reno racer, Stiletto. The system had been run at Reno and based on the email the same mechanic that installed it on Stiletto installed the system on the Ghost. The correspondence indicated that the airplane was currently in Texas and that they would be transporting the airplane to Stead (Minden as an alternate) for the phase I flight test of 3 hours with 3 takeoffs and landings. The tests were scheduled to begin on September 12, 2009. An email dated September 10, 2009 referenced a phone call and that the tests were going to be performed in Minden instead of Stead. An email dated September 11, 2009 served as an official notification and asked for the concurrence of the Reno FSDO to perform the flight testing in Minden. The testing was supposed to comply with operating limitation 9 as stated in the email. On September 11, 2009, the FAA issued a letter to Mr. Leeward detailing the concurrence requested in the email. The letter indicated that the airplane had undergone a major change, incorporation of a boil-off cooling system. The limitations were that the flight testing should be conducted within

50 miles of Minden, a minimum of 3 hours of flight time, at least 3 take-offs and landings to a full stop, and operation into Stead was prohibited during this testing. The FAA also suggested the logbook entry that was to be made after the testing was completed.

The investigation obtained a letter written by the FAA Reno FSDO to another racer that discusses the interpretation of the P-51 Limited Type Certificate, LTC-11, in August 2008. The accident airplane was not certificated in the limited category but many other P-51 airplanes are. The letter specifies that the FAA has no objection to the interpretation that the addition of ADI, a radiator spray bar, and the extension of the radiator exit door could be classified as minor alterations on the basis that they do not present an obvious hazard to safety under the type certificate language.

9.2 Pertinent FAA Regulations

FAR 1.1 - Major alteration means an alteration not listed in the aircraft, aircraft engine, or propeller specifications - (1) That might appreciably affect weight, balance, structural strength, performance, powerplant operation, flight characteristics, or other qualities affecting airworthiness; or (2) That is not done according to accepted practices or cannot be done by elementary operations.

FAR 21.93 Classification of changes in type design. (Excerpted)
(a) In addition to changes in type design specified in paragraph (b) of this section, changes in type design are classified as minor and major. A "minor change" is one that has no appreciable effect on the weight, balance, structural strength, reliability, operational characteristics, or other characteristics affecting the airworthiness of the product. All other changes are "major changes" (except as provided in paragraph (b) of this section).

FAR 91.9 Civil aircraft flight manual, marking, and placard requirements. (Excerpted)
(a) Except as provided in paragraph (d) of this section, no person may operate a civil aircraft without complying with the operating limitations specified in the approved Airplane or Rotorcraft Flight Manual, markings, and placards, or as otherwise prescribed by the certificating authority of the country of registry.

FAR 91.319 Aircraft having experimental certificates: Operating limitations. (Excerpted)
(a) No person may operate an aircraft that has an experimental certificate—
(1) For other than the purpose for which the certificate was issued; or
(2) Carrying persons or property for compensation or hire.
(b) No person may operate an aircraft that has an experimental certificate outside of an area assigned by the Administrator until it is shown that—
(1) The aircraft is controllable throughout its normal range of speeds and throughout all the maneuvers to be executed; and
(2) The aircraft has no hazardous operating characteristics or design features.
(c) Unless otherwise authorized by the Administrator in special operating limitations, no person may operate an aircraft that has an experimental certificate over a densely populated area or in a congested airway. The Administrator may issue special operating limitations for particular aircraft to permit takeoffs and landings to be conducted over a densely populated area or in a

congested airway, in accordance with terms and conditions specified in the authorization in the interest of safety in air commerce.

(d) Each person operating an aircraft that has an experimental certificate shall—

(1) Advise each person carried of the experimental nature of the aircraft;

(2) Operate under VFR, day only, unless otherwise specifically authorized by the Administrator; and

(3) Notify the control tower of the experimental nature of the aircraft when operating the aircraft into or out of airports with operating control towers.

10.0 Tests & Research

The P-51D wing was drawn in AutoCAD based on the dimensions published in the NAA Wing Analysis Report (Report No. NA-5891). The dimensions of the shortened Galloping Ghost wing were added to the drawing as seen in Figure 28. Also included on the drawing were the wing 25% and 50% chord line. A graphical method was utilized to determine the location and dimensions of the wing mean aerodynamic chord (MAC) for both the stock and modified wing (Figure 29). A construction line equal in length to the root chord of 104 inches was added forward of the leading edge at both the stock tip chord and the modified tip chord. Construction lines equal in length to the tip chord of the stock wing of 50 inches and equal to the tip chord of the modified wing of 60.983 inches were added aft of the trailing edge at the root chord. The ends of the construction lines for both the stock and modifies wings were joined. The location where the diagonal line intersects the 50% chord line defines the location of the MAC according to the method. The MAC line was drawn and the dimension measured. The stock wing has a MAC of 80.146 inches located 94.997 inches outboard of the airplane centerline. The modified Ghost wing has a MAC of 84.081 inches located 79.326 inches outboard of the airplane centerline.

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