



AVIATION



HIGHWAY



MARINE



RAILROAD



PIPELINE

Aviation Investigation Final Report

Location:	Olive Branch, Mississippi	Accident Number:	CEN22LA153
Date & Time:	March 23, 2022 10:38 Local	Registration:	N627PR
Aircraft:	Piper Aircraft Inc Pa-46-600Tp	Aircraft Damage:	Substantial
Defining Event	Loss of control on ground	Injuries:	2 None
Flight Conducted Under:	Part 91: General aviation - Personal		

Analysis

****This report was modified on July 22, 2026. Please see the public docket for this accident to view the original report.****

The pilot was landing the airplane with a right quartering headwind, resulting in a right crosswind component of about 10 to 14 kts, which was less than but near the airplane's maximum demonstrated crosswind component of 17_kts. The airplane touched down left of runway centerline. After touchdown, the pilot attempted to correct to the right toward the centerline with rudder inputs. As the airplane decelerated through about 68 kts and approached the runway centerline, the airplane entered a 45° hard right turn about a 45° angle, and the pilot reported that he was unable to control the turn with left rudder input. The airplane departed the right side of the runway, about 1,330 ft from the threshold and about 570 ft after touchdown, and the nose landing gear (NLG) collapsed. The airplane sustained substantial damage to the engine mount.

Postaccident examination of the runway surface revealed rubber transfer markings consistent with the NLG, right main landing gear (RMLG), and left main landing gear (LMLG). The NLG transfer mark began about 900 ft from the threshold and about 10 ft left of the centerline, with light intensity and its tread pattern evident, consistent with a rolling, non-skidding tire. The rolling tire marking continued until the right veering began, at which point it was of moderate intensity with tread pattern evident and transitioned to heavy intensity and no tread pattern, consistent with a skidding tire.

A review of the airplane's avionics data revealed that the RMLG touched down first, followed by the LMLG about 1 second later, consistent with a right crosswind landing. The NLG touched down about 1 to 2 seconds after the RMLG. Starting about 2 seconds after LMLG touchdown, the heading and track diverged, with the nose to the right of the track, until near the runway departure location, indicating that the airplane was in a skid. The maximum divergence occurred about 1 second before the runway excursion, when the heading was about 223° and the track was about 195°. At the same time, the lateral acceleration increased, also consistent with the airplane being in a left skid. The airplane departed the runway with the heading and track mostly aligned.

Postaccident examination of the NLG assembly did not reveal anomalies that would have affected its operation or steering. However, damage precluded examination of the rake angle, NLG steering adjustments, and main landing gear (MLG) alignment. The rake angle of the NLG was designed to be 90° from the airplane longitudinal axis with a very tight tolerance of +0.5°/-0.0°, allowing which equated to a 0.0° to 0.5° forward rake caster angle. and zero aft rake. The zero-rake angle is good for static stability and taxiing at slower speeds but can be problematic for dynamic stability at higher speeds.

For NLG to be directionally stable when rolling, they must have positive dynamic trail. However, because the M600 NLG was designed with zero caster angle and zero offset (and thus zero mechanical trail), positive dynamic trail was dependent on positive pneumatic trail. Pneumatic trail varies according to tire inflation pressure, tire speed, runway friction, and tire slip angle.

A zero or aft rake can tend to cause the NLG tire to turn more sharply if deflected in some conditions. In a 2008 customer information letter, the manufacturer cautioned operators that low tire pressure, excessive clearance between the steering arm and steering horn rollers, and low rudder cable tension could each result in the NLG pointing in a different direction than commanded by rudder pedal inputs, even if a pilot uses proper crosswind landing technique. In a 2020 service letter, the manufacturer directed operators to perform inspection and adjustment, as necessary, of NLG steering components at 100-hour intervals.

The NTSB's investigation compared the PA-46 series (including the M600) to airplane types with similar weight and power and found it to be unique in having NLG with zero caster angle and in requiring stringent NLG maintenance. When normalized for the number of airplanes produced, the PA-46 had the highest rate of veer events investigated by the NTSB among the compared airplane types. On NLG touchdown, the NLG strut will deflect aft due to spin-up loads, increasing the negative rake that could cause instability, and will undergo a damped oscillation.

For this event, runway markings and simulation results indicated that the NLG was initially aligned with the runway upon touchdown, in accordance with proper crosswind landing technique for an airplane with steerable NLG, and then became fully deflected to the right within a few seconds. The investigation was unable to determine with certainty the source of the NLG steering inputs (that is, whether they were commanded by the pilot via the rudder pedals, the result of ground reaction forces on the tire, or a combination). However, the pilot's description of the event, the design of the NLG that depended on variable pneumatic trail for directional stability, and the known behavior of the NLG when operated outside of tight maintenance tolerances all support an adverse airplane-pilot coupling event, in which a change in control forces or directional stability of the NLG steering system likely led to an unexpected response to control inputs and a loss of directional control.

~~The design of the NLG with zero rake and no trail requires that the NLG tire be aligned with the runway upon touchdown, which it was during the accident landing as evidence by the runway markings. Any misalignment or steering input may result in a steering hardover due to the dynamic instability inherent in the NLG design. The circumstances of this accident indicated that the NLG turned hard right soon after touchdown, when the NLG dynamic instability manifested itself as the pilot was correcting back to the centerline of the runway with rudder input.~~ The manufacturer redesigned the lower NLG fork ~~area~~ to move the axle 0.5 inches aft of the steering axis. This is equivalent to raking the NLG forward 5°, ~~making it increasing inherently dynamically directional stability.~~ The new NLG should be dynamically stable even during aft deflection since the steering axis will remain forward of the vertical axis (center of the tire contact patch) and provide a restoring force to the NLG tire if deflected. The new NLG improves the dynamic stability of the NLG allowing the nose wheel to self-center. To the NTSB's knowledge, no veer events have been reported with the new NLG design.

Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this accident to be:

The airplane's ~~uncommanded~~ hard right turn during landing in crosswind conditions and a subsequent loss of directional control due to adverse airplane-pilot coupling during landing in crosswind conditions. Contributing to the accident were the dynamic ~~instability attributable to the design~~ of the nose landing gear, whose directional stability was sensitive to operational conditions and compliance with precise maintenance tolerances, and the crosswind conditions.

Findings

Aircraft (A1)	Nose/tail landing gear - Design
Aircraft (A1)	Directional control - Attain/maintain not possible

Factual Information

History of Flight

~~Landing-landing roll~~ — ~~Loss of control on ground (Defining event)~~

~~Landing-landing roll~~ — ~~Landing gear collapse~~

~~Landing-landing roll~~ — ~~Loss of control on ground (Defining event)~~

~~Landing-landing roll~~ — ~~Runway excursion~~

~~Landing-landing roll~~ — ~~Landing gear collapse~~

On March 23, 2022, at 1038 central daylight time, a Piper PA-46-600TP (M600) airplane, N627PR, was substantially damaged when it was involved in an accident near Olive Branch, Mississippi. The pilot and passenger were not injured. The airplane was operated as a Title 14 *Code of Federal Regulations* Part 91 personal flight.

The pilot reported that he conducted the instrument landing system approach in visual meteorological conditions to runway 18 with the wind reported as 220° at 16 knots (kts) gusting to 22 kts. As the airplane approached the final approach fix, the pilot reduced engine power and extended the landing gear. About 550 ft above ground level, he disconnected the autopilot. The airplane landed “softly,” about 85 kts, to the left of the runway centerline. The airplane rolled about 1,200 ft as the speed decreased, and the pilot reported that he was in control moving toward the centerline.

About 68 kts as the airplane approached the runway centerline, ~~he-the pilot~~ had both hands on the yoke, holding it back slightly, and was making light rudder inputs to get to the airplane to the runway centerline. At that time, the airplane entered a hard right turn about a 45° angle. The pilot stated the left directional input was not working and that he applied more pressure with the left rudder. He reported, “It felt as if the nose quit rolling for a nano second, and the tail of the plane was skidding to the left.” The pilot applied neutral rudder pedals and the skid reduced.

The airplane exited the right side of the runway and continued across wet and muddy grass when the nose gear collapsed, and the airplane came to rest nose down. (See figure 1.) The airplane departed the runway about 1,330 ft from the threshold and about 570 ft after touchdown. The engine mount sustained substantial damage.



Figure 1. Accident airplane (Source: OLV airport operations).

Pilot Information

Certificate:	Private	Age:	59, Male
Airplane Rating(s):	Single-engine land, Single-engine sea	Seat Occupied:	Left
Other Aircraft Rating(s):	None	Restraint Used:	3-point
Instrument Rating(s):	Airplane	Second Pilot Present:	[SAFTISecndPilotPresent]
Instructor Rating(s):	None	Toxicology Performed:	[SAFTIToxicologyPerformed]
Medical Certification:	Class 3 With waivers/limitations	Last FAA Medical Exam:	November 22, 2021
Occupational Pilot:	UNK	Last Flight Review or Equivalent:	December 3, 2021
Flight Time:	935 hours (Total, all aircraft), 69 hours (Total, this make and model), 880 hours (Pilot In Command, all aircraft), 20 hours (Last 90 days, all aircraft), 13 hours (Last 30 days, all aircraft), 0 hours (Last 24 hours, all aircraft)		

The pilot obtained his private pilot certificate in September 2015. Between 2015 and 2021, his flight experience included about 185 total hours in a Cessna 182 airplane, and 737 total hours in Cessna T240 airplanes.

In November and December 2021, after purchasing the accident airplane, the pilot received 20 hours of M600 training from a Piper Aircraft dealer pilot, and 10 hours from Legacy Flight Training, Vero Beach, Florida, an authorized Piper Aircraft training provider. The 10 hours provided by Legacy Flight Training included 4 hours in a simulator and 6 hours in the accident airplane.

According to the pilot, during his initial flights with the accident airplane, he commented to the sales staff that the nose wheel steering and responsiveness was quite different from other airplanes he had experience operating (the T240 airplane's nose wheel is free-castering; the Cessna 182 airplane's nose wheel is steerable). The sales staff responded that his experience was normal for this airplane, and he should get used to it.

Aircraft and Owner/Operator Information

Aircraft Make:	PIPER AIRCRAFT INC	Registration:	N627PR
Model/Series:	PA-46-600TP	Aircraft Category:	Airplane
Year of Manufacture:	2021	Amateur Built:	[SAFTIAmateurBuilt]
Airworthiness Certificate:	Normal	Serial Number:	4698190
Landing Gear Type:	Retractable - Tricycle;	Seats:	6
Date/Type of Last Inspection:	January 12, 2022 100 hour	Certified Max Gross Wt.:	6050 lbs
Time Since Last Inspection:	28 Hrs	Engines:	1 Turbo prop
Airframe Total Time:	74.8 Hrs at time of accident	Engine Manufacturer:	Pratt and Whitney
ELT:	C126 Installed, activated, did not aid in locating accident	Engine Model/Series:	PT6A-42A
Registered Owner:	ROWES IGA MANAGEMENT LLC	Rated Power:	600 Lbs thrust
Operator:	On file	Operating Certificate(s) Held:	None
Operator Does Business As:	[SAFTIOperatorDoesBusinessAs]	Operator Designator Code:	[SAFTIOperatorDesignatorCode]

According to the Piper M600 Pilot's Operating Handbook (POH), the maximum demonstrated crosswind component for the airplane is 17 kts. Based on the reported wind conditions at the time of the landing, the crosswind component was about 10 to 14 kts.

According to the POH, the width between the left main landing gear (LMLG) and right main landing gear (RMLG) is 163.44 inches, and the width between the nose landing gear (NLG) and each ~~main landing gear (MLG)~~ is 81.72 inches. The longitudinal distance between the NLG and main landing gear is 99 inches.

The NLG rake angle on the M600 is the angle between the lower fuselage skin and the centerline of the NLG strut. The rake angle is set at the factory to be 90°, with a tolerance of +0.5°/-0.0°. This corresponds to a caster angle (measured from vertical) of 0.0° to 0.5° forward. Piper Service Letter 1286D (Nose Landing Gear Steering Components Inspection and Adjustment), originally issued as Piper Service Letter 1286 on August 18, 2020, provides instructions for inspection and adjustment of the NLG

steering components at 100-hour intervals, including NLG alignment, rudder cable tension, rake angle, and clearance between the steering arm and steering horn rollers. The service letter has been revised four times since original issuance, but the rake angle has not changed. The service letter specifies that the clearance between the steering arm and the steering horn rollers must be between 0.010 and 0.030 inches.

At a rake angle of 90° for the M600, the steering axis passes through the NLG axle and intersects the ground coincident with the center of the tire contact patch with the airplane stationary (zero mechanical trail). At a rake angle of 90.5° for the M600, the steering axis still passes through the NLG axle, but intersects the ground slightly forward of the center of the tire contact patch with the airplane stationary (positive mechanical trail). Examination of the structural response of a landing gear at wheel touchdown showed that the gear will deflect aft initially due to wheel spin-up loads and then undergo a fore-aft damped oscillation about its equilibrium point.

In 2008, Piper issued a customer information letter that addressed customer concerns with PA-46 NLG steering. It summarized several actions Piper had taken to improve PA-46 steering characteristics since the introduction of the first turboprop-powered PA-46 in 2000, including using a stiffer bungee and a different tire inflated to a higher pressure. The letter also highlighted the effects of improper maintenance on PA-46 steering performance, cautioning that low tire pressure “can increase the forces associated with steering the aircraft on the ground,” that a rake angle outside of the 90.0° to 90.5° range “may result in dynamic instability, creating steering forces that exceed the pilot’s ability to control,” that excessive clearance between the steering arm and the steering horn rollers “will result in loose steering and allow the nose wheel to point in a different direction than is commanded by rudder pedal inputs,” and that low rudder cable tension could result in the NLG “pointing in a direction that differs from the aircraft line of travel at the instant of touchdown” even if a pilot uses proper crosswind landing technique.

Landing Procedures

The POH contains the airplane normal procedures in section 4.5p. (See figure 2.) The procedures caution the pilot about centering the rudder prior to nosewheel touchdown.

4.5p LANDING

CAUTION

In crosswind conditions, the nosewheel may not be aligned with the runway as the wheel touches down because of opposite rudder input. To prevent swerving in the direction the nosewheel is offset, the rudder must be promptly centered just as the nosewheel touches down.

CAUTION

Abrupt or aggressive application of reverse thrust during landing rollout, especially during crosswind landings, may reduce directional control.

NORMAL TECHNIQUE

POWER Lever.....IDLE
Brakes.....MODERATE (or as required)
POWER Lever..... BETA (or REVERSE as required)

Figure 2. POH normal landing procedures.

Maintenance History

A review of the maintenance records revealed that the accident airplane underwent its manufacturer's warrantable first 50-hour inspection at a Piper authorized service center on January 12, 2022, at a total airplane time of 46.6 hours. During the maintenance visit, both MLG and the NLG were removed, painted black, and reinstalled. The maintenance was completed in accordance with the airplane's maintenance manual. Piper Service Letter 1286D, NLG Steering Components Inspection and Adjustment, was also complied with during the maintenance.

The most recent maintenance on the airplane was performed on March 11, 2022, at a total time of 64.5 hours, when a new auto-throttle and autopilot controller were installed. At the time of the accident, the airplane had accrued 74.8 hours total time.

Meteorological Information and Flight Plan

Conditions at Accident Site:	Visual (VMC)	Condition of Light:	Day
Observation Facility, Elevation:	KOLV, 402 ft msl	Distance from Accident Site:	0 Nautical Miles
Observation Time:	10:33:00 Local	Direction from Accident Site:	327°
Lowest Cloud Condition:	Clear	Visibility	10 miles
Lowest Ceiling:	Overcast / 2500 ft AGL	Visibility (RVR):	[SAFTIVisualRangeFT]
Wind Speed/Gusts:	16 knots,22 knots	Turbulence Type Forecast/Actual:	None / None
Wind Direction:	220°	Turbulence Severity Forecast/Actual:	N/A / N/A
Altimeter Setting:	29.73 inches Hg	Temperature/Dew Point:	8°C / 5°C
Precipitation and Obscuration:	No Obscuration; No Precipitation		
Departure Point:	Jacksonville, FL (CRG)	Type of Flight Plan Filed:	IFR
Destination:	Olive Branch, MS (CRG)	Type of Clearance:	IFR
Departure Time:	08:57 Local	Type of Airspace:	Class D

Airport Information

Airport:	Olive Branch Airport OLV	Runway Surface Type:	Asphalt
Airport Elevation:	402 ft msl	Runway Surface Condition:	Dry
Runway Used:	18	IFR Approach:	ILS
Runway Length/Width:	6000 ft / 100 ft	VFR Approach/Landing:	None

Wreckage and Impact Information

Crew Injuries:	1 None	Aircraft Damage:	Substantial
Passenger Injuries:	1 None	Aircraft Fire:	None
Ground Injuries:	[SAFTIInjuryGroundTotal]	Aircraft Explosion:	None
Total Injuries:	2 None	Latitude, Longitude:	34.97875°, -89.7868° estimated

Runway and Ground Scars Examination

Examination of the runway surface revealed a light rubber transfer mark consistent with the LMLG that began about 760 ft from the runway 18 threshold and about 17 ft left of the centerline. The transfer mark was continuous until it departed the right side of the runway and varied in intensity. A light rubber transfer mark with the tread pattern evident, consistent with the NLG, began about 900 ft from the threshold and about 10 ft left of the centerline. The mark was mostly continuous until it departed the right side of the runway and varied in intensity. The LMLG and NLG rubber transfer marks were aligned, separated by about 80 inches, and drifted to the left until about 1,140 ft from the threshold when they veered sharply to the right. (See figures 3 and 4.)



Figure 3. Initial touchdown runway markings (Source: Piper Aircraft, ~~Inc.~~, annotated by NTSB).



Figure 4. Runway markings (Source: Piper Aircraft, ~~Inc.~~, annotated by NTSB).

A rubber transfer mark from the RMLG was not discernable until about 1,170 ft from the runway threshold and was not continuous to the departure point. At the point where the RMLG mark became evident, the perpendicular distance between the RMLG and NLG

marks measured 51 inches and between the LMLG and NLG measured 106 inches. Throughout the right veer, the LMLG rubber transfer mark varied from moderate to heavy intensity with the tread pattern evident consistent with moderate to heavy braking. The NLG rubber transfer mark during the veer was initially of moderate intensity with the tread pattern evident but transitioned to heavy intensity with no tread pattern evident, consistent with a skidding tire.

Between the centerline and the departure point, the NLG skipped once and transitioned to light intensity with a tread pattern just before the departure. The RMLG rubber transfer mark was sporadic from its beginning to departure with moderate intensity. At the runway centerline, the perpendicular distance from the RMLG to NLG measured 33 inches and from the LMLG to the NLG measured 107 inches. At the departure point, the perpendicular distance between each MLG and the NLG measured 82 inches. The airplane departed the right side of the runway, about 1,330 ft from the threshold. There was no disturbance of the grass for about 10 ft beyond the runway edge, after which there were three deep ruts in the grass; each rut displayed a tire tread pattern in the mud. The NLG rut stopped about 68 ft from the initial point, and the airplane came to rest about 80 ft further along the path.

Airplane Examination

Postaccident examination of the airplane revealed that the NLG, retract actuator, engine mount, and emergency extension spring sustained damage. The NLG wheel and tire were installed and rotated freely. The NLG tire pressure measured 84 lbs per square inch (psi). There was some crosswise scuffing on the NLG tire tread, but no evidence of scuffing on the sidewalls. The damage precluded examination of the rake angle, NLG steering adjustments, and MLG alignment. There was no damage to the LMLG or RMLG. The tire pressure on each MLG measured 90 psi. There was some crosswise scuffing on both MLG tires, but no sidewall scuffing or flat spots were noted. The NLG assembly was removed for further examination.

The NLG assembly was further examined at Piper Aircraft ~~Inc.~~, Vero Beach, Florida, under the supervision of the National Transportation Safety Board. The NLG tire spun freely and there was minimal perceptible play between the wheel and axle. The axle nut was installed finger-tight. The wheel, torque links, and wire harness were removed, and the NLG was disassembled. No anomalies were noted during the dimensional check of the components that would have precluded normal operation.

Recorded Flight Data

The Garmin G3000 Integrated Avionics System on the airplane records certain flight parameters at a rate of 1 hertz for each flight. A maintenance-oriented data set (CMC data) is recorded and stored internally on the unit, and flight-oriented data (log data) is recorded directly to an SD card. Both the CMC and log data for the accident flight were downloaded from the airplane. According to the data (see figure 5), the right main landing gear (RMLG) touched down first at a recorded indicated airspeed about 76 kts,

followed by the LMLG about 1 second later at a recorded indicated airspeed about 74 kts. The NLG touched down about 1 to 2 seconds after the RMLG. Starting about 2 seconds after LMLG touchdown, the heading and track diverged, with the nose to the right of the track that continued until near the runway departure location, indicating that the airplane was in a skid. The maximum divergence occurred about 1 second before runway departure when the heading was about 223° and the track was about 195°. At the same time, the lateral acceleration increased to a maximum of about 0.88 g about 2 seconds before runway departure, also consistent with the airplane in a left skid. The airplane departed the runway about 6 seconds after the RMLG touchdown at a ground speed about 47 kts with the heading and track mostly aligned. The pitch parameter showed a sharp decrease about 2 seconds after runway departure, consistent with a collapse of the NLG.

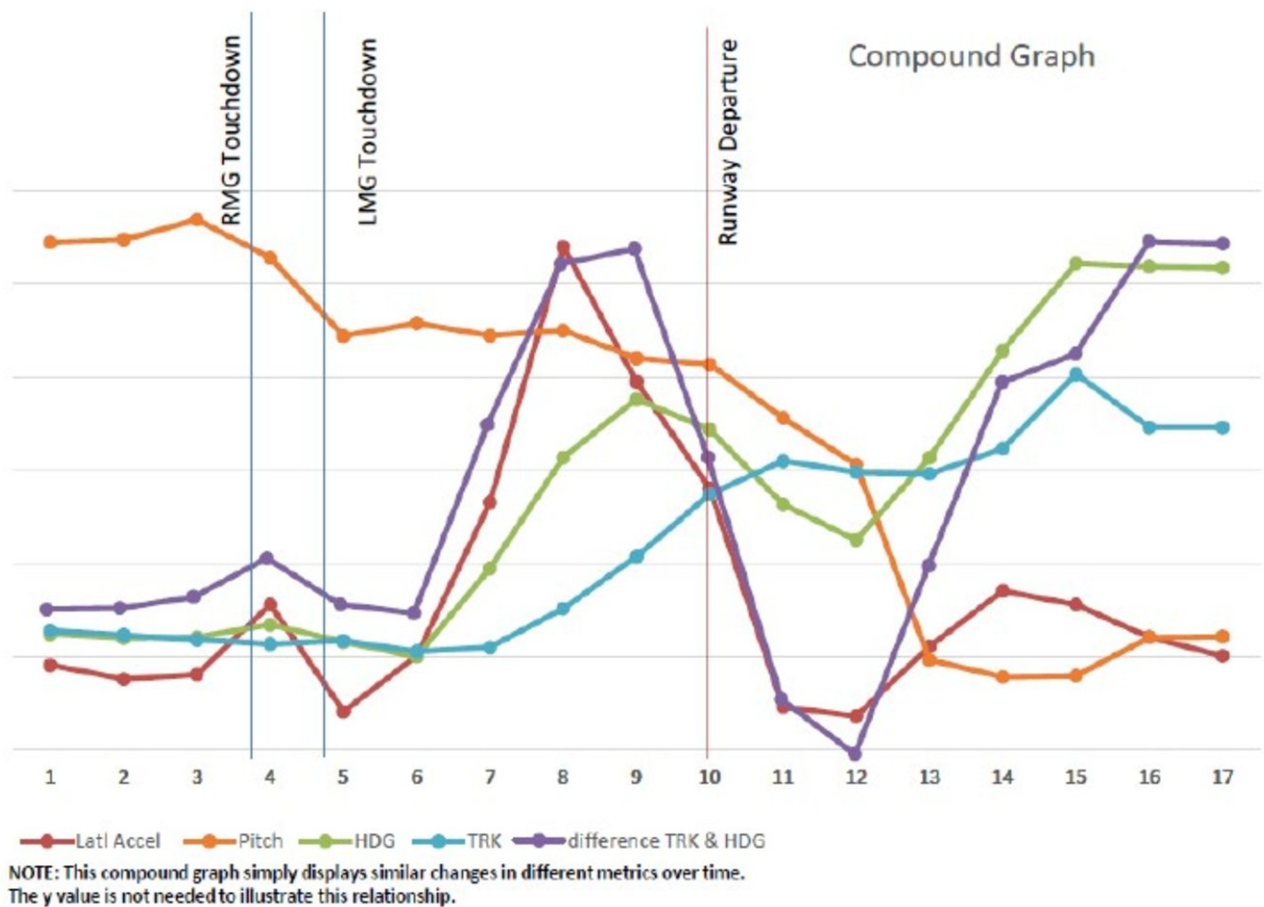


Figure 5. Plot of Garmin data from accident landing (Source: Piper Aircraft Inc.).

Additional Information

The Federal Aviation Administration Airplane Flying Handbook (FAA-H-8083-3C), Chapter 9, page 18, states in part, "In those airplanes having nose-wheel steering interconnected with the rudder, the nose-wheel is not aligned with the runway as the main wheels touch down because opposite rudder is being held for crosswind correction. To prevent swerving in the direction the nose-wheel is offset, the corrective rudder pressure needs to be relaxed as the nose-wheel touches down."

In preparation for an unpaved field operational environment, Piper began installing a new NLG on the PA-46-600TP airplanes starting at S/N 4698198 (accident airplane was S/N 4698190). The new NLG incorporates an updated lower NLG strut assembly with a different fork and redesigned torque links. The new fork is a machined aluminum structure, sized by analysis and testing to accommodate the loads generated by the increase in ~~geometric~~~~mechanical~~ trail. The new fork offsets the NLG axle aft 0.5 inch from its previous position, which results in a trail value of 0.5 inch, in which the steering axis is 0.5 inch forward of the center of the tire contact patch. The new NLG with offset is equivalent to 5° of forward ~~rake~~~~caster~~ angle, resulting in positive ~~mechanical~~ trail and increased ~~positive dynamic~~~~directional~~ stability, which Piper desired for unpaved field operations. A kit for the new NLG is offered on airplanes S/N 4698001 – 4698197.

Tests and Research

NLG Design Considerations

The sum of the ground reaction forces on a tire acts at the contact point of the tire. When the tire is static (not rolling), the contact point is directly under the center of the tire. The distance between the tire static contact point and the intersection of the NLG strut rotation axis with the ground line is called "static trail" or "mechanical trail" and is positive when the tire contact point is aft of the strut rotation axis. One way to vary NLG mechanical trail is to adjust the longitudinal "caster angle" of the NLG strut. A caster angle equal to zero results in zero mechanical trail (see figure 6, item A). A positive caster angle results in positive mechanical trail (see figure 6, item B), and a negative caster angle results in negative mechanical trail. Mechanical trail can also be changed through the use of offset, in which the tire axle is moved aft of the steering axis through the design of the lower end of the landing gear, similar to the front wheels on a shopping cart (see figure 6, item C). Figure 6 illustrates caster angle, offset, and the resulting mechanical trail for several NLG configurations.

~~NLG trail refers to the location of the steering axis in relation to the vertical axis through the axle and can be positive, neutral, or negative. Neutral trail (see figure 6. Item A)~~

occurs when the steering axis is vertical and coincident with the vertical axis and axle location resulting in minimum steering forces required and no appreciable torque about the steering axis when the wheel is rolling (neutral dynamic stability). This configuration has neutral static stability. Positive trail (see figure 6. Item B) occurs when the steering axis intersects the ground forward of the vertical axis and results in a self-aligning torque about the steering axis when the wheel is rolling (positive dynamic stability). This configuration requires increased steering forces and is statically unstable if not restrained. Negative trail (see figure 6. Item B except angle is aft) occurs when the steering axis intersects the ground aft of the vertical axis and results in a torque about the steering axis that acts to increase the turn angle (negative dynamic stability) and is typically not used for NLG. This configuration requires increased steering forces and is considered statically unstable if not restrained. One way of obtaining trail on a NLG is to angle the NLG strut to some value known as the rake angle. A positive rake angle results in positive trail, a neutral rake angle results in neutral trail, and a negative rake angle results in negative trail.

Another way to achieve positive trail on the NLG is through the use of offset. In this scenario the axle is moved aft of the steering axis through the design of the lower end of the landing gear (see figure 6. Item C) and is similar to the front wheels on a shopping cart. This configuration has neutral static stability and positive dynamic stability but is more susceptible to shimmy than neutral trail landing gear. For a landing gear with offset and zero rake the trail is the horizontal distance between the location of the axle and the vertical centerline (steering axis) of the landing gear.

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With the tire rolling straight on the runway, the frictional force generated by the NLG wheel is aligned with the longitudinal axis of the tire. Once the NLG is rotated left or right for steering, the frictional force has a component aligned along the longitudinal axis of the tire and a component aligned 90° to the longitudinal axis of the tire. It is this side force that can affect the stability based on the trail. Positive trail results in positive dynamic stability and negative trail results in negative dynamic stability.

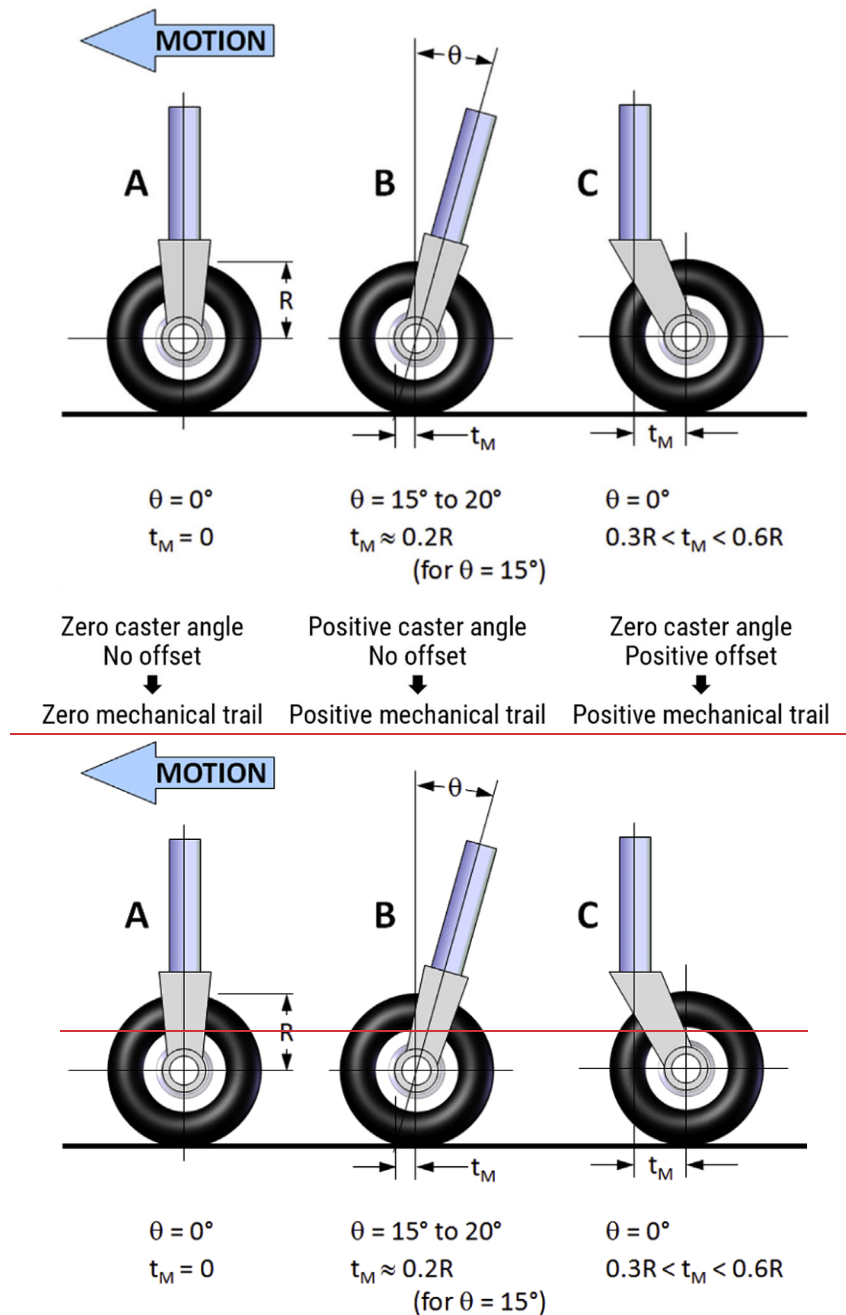


Figure 6. Nose landing gear Caster angle (θ) and mechanical trail (t_M) for several nose landing gear configurations (Source: reproduced in part from Snorri Gudmundsson, General Aviation Aircraft Design: Applied Methods and Procedures, First Edition, Elsevier, Inc., 2014).

When the tire is rolling, the contact point moves aft, and the resulting distance between the rolling contact point and the strut rotation axis is called "dynamic trail." The difference between dynamic trail and mechanical trail is the "pneumatic trail." Research into the behavior of pneumatic trail in pneumatic tires indicates that it is not a constant, but depends on variables such as the tire inflation pressure, tire speed, runway friction,

and the slip angle of the tire (that is, the difference between the tire steering angle and the tire drift angle).

The dynamic trail has a strong effect on the directional stability and steering forces of the NLG. Positive dynamic trail results in directionally stable NLG, and negative dynamic trail results in directionally unstable NLG. That is, when the NLG is rolling and dynamic trail is positive, the torque acting on the NLG will tend to return the NLG into alignment with the direction of travel of the airplane when disturbed from that alignment; when dynamic trail is negative, the NLG will deviate further from alignment when disturbed. Also, the magnitude of the dynamic trail will affect the ratio of pedal force to NLG steering angle and the consequent control feel of the system.

Landing Veer Events Involving Piper PA46 Series Airplanes

The NTSB has records of 19 post-landing lateral runway excursion events since 2001 (including the accident landing) involving Piper PA46 series aircraft in which the pilots involved complained of or recorded data indicated an airplane “veer” following NLG touchdown (where “veer” is defined as an abrupt, surprising, and undesired deviation of the airplane’s heading away from the runway heading that risked or resulted in the airplane crossing over a runway edge.) This corresponds to a rate of 7.02 events per 1,000 airplanes produced. In addition, the NTSB has been made aware of an additional 8 PA46 veer events involving 3 different airplanes (including one event involving a Piper engineering flight test pilot).

NLG Design and Veer Events for Comparable Airplanes

The NTSB reviewed the NLG design and landing veer event history of airplane types of similar power and weight to the PA46 series, including the Cessna 208 and 210, Beechcraft Bonanza, Pilatus PC-12, Socata/Daher TBM series, and the Daher/Quest Kodiak series. These airplane types all have effective NLG caster angles between 12° and 17°. A review of NTSB accident data and airplane production numbers revealed that the rate of NTSB-investigated veer events for these airplane types ranged from about 0.5 (Cessna 210, Pilatus PC-12), to 0.3 (Beechcraft Bonanza), to zero (Cessna 208, Socata/Daher TBM, Daher/Quest Kodiak) per 1,000 airplanes produced.

Of these aircraft types, the NTSB researched the NLG assembly maintenance requirements for the Cessna P210R, Beechcraft BE36TC, and the Socata/Daher TBM700, which most closely match the size and occupancy of the Piper PA46 series. This review of inspection requirements, service bulletins, special airworthiness information bulletins, and airworthiness directives revealed that these airplane types do not require recurrent dimensional inspections to maintain reliable steering and directional control; the inspection requirements for these airplanes are limited to visual inspections only.

Landing Roll Simulations

The NTSB created a simple six-degree of freedom simulation of an airplane generally representative of an M600, based on aerodynamic and mass properties models from an M600 Advanced Aviation Training Device. The simulation included the weather conditions at the time of the accident and was used to estimate the NLG steering angle (driven by rudder pedal inputs) that would be required to approximately match the airplane trajectory recorded in the G3000 data.

The simulations indicated that although full nose-right deflection of the NLG is required for the model to approximately match the dynamics recorded in the G3000 data, the model matches the data better if the NLG rotates from centered to full-right over about 3 seconds, as opposed to snapping to full-right almost instantly after NLG touchdown.

Airplane-Pilot Coupling

The National Research Council (NRC), in *Aviation Safety and Pilot Control: Understanding and Preventing Unfavorable Pilot-Vehicle Interactions*, defines adverse airplane-pilot coupling (APC) events as “rare, unexpected, and unintended excursions in aircraft attitude and flight path caused by anomalous interactions between the aircraft and the pilot.”

The NRC further states:

Although it is often difficult to pinpoint the cause of specific APC events, a majority of severe APC events result from deficiencies in the design of the aircraft (especially with regard to the [flight control system]) that result in adverse coupling of the pilot with the aircraft. In certain circumstances, this adverse coupling produces unintended oscillations or divergences when the pilot attempts to precisely maneuver the aircraft. If the [pilot-vehicle system] instability takes the form of an oscillation, the APC event is called a “pilot-involved oscillation” (PIO).

Administrative Information

Investigator In Charge (IIC):	Link, Samantha		
Additional Participating Persons:	Brooks Vaughan; Federal Aviation Administration Damian Galbraith; Piper Aircraft Inc.; Vero Beach, FL		
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Note:	The NTSB did not travel to the scene of this accident.		
Investigation Docket:	https://data.nts.gov/Docket?ProjectID=104834		

The National Transportation Safety Board (NTSB), established in 1967, is an independent federal agency mandated by Congress through the Independent Safety Board Act of 1974 to investigate transportation accidents, determine the probable causes of the accidents, issue safety recommendations, study transportation safety issues, and evaluate the safety effectiveness of government agencies involved in transportation. The NTSB makes public its actions and decisions through accident reports, safety studies, special investigation reports, safety recommendations, and statistical reviews.

The Independent Safety Board Act, as codified at 49 U.S.C. Section 1154(b), precludes the admission into evidence or use of any part of an NTSB report related to an incident or accident in a civil action for damages resulting from a matter mentioned in the report. A factual report that may be admissible under 49 U.S.C. § 1154(b) is available.