Aviation Investigation Final Report

Location:	Titusville, Florida	**Accident Number:**	ERA20LA237
Date & Time:	July 3, 2020, 11:57 Local	**Registration:**	N89MA
Aircraft:	Piper PA46	**Aircraft Damage:**	Substantial
Defining Event:	Sys/Comp malf/fail (non-power)	**Injuries:**	3 None
Flight Conducted Under:	Part 91: General aviation - Personal		

Analysis

The pilot was conducting a cross-country flight. He reported that, although the flight had encountered turbulence, it was otherwise uneventful with no anomalies or malfunctions with the airplane noted. During landing, when the two main landing gear (MLG) touched down, the airplane started to veer left, so he relaxed the rudder pressure. As soon as the nose landing gear (NLG) touched down, the airplane immediately veered right. He attempted to correct the veer by applying left rudder and left and right brakes; however, the airplane did not respond. The airplane then exited the right side of the runway and skidded sideways through the grass, which resulted in the left wing and propeller striking the ground and resulted in substantial damage to the left wing and fuselage. The airplane came to rest in the grass about 100 ft from the runway edge.

Examination of the runway revealed distinct tire marks from the NLG and both MLG on the runway extending from the touchdown point to where the airplane exited the right side of the runway, which transitioned to ground scars in the grass. The NLG tire mark was a dark wide line with no evident tread pattern, consistent with the airplane skidding from the touchdown point to the runway departure point. The MLG tire marks had an evident tread pattern, consistent with the tires rolling while braking was being applied. A ground scar near where the airplane came to rest was consistent with a left-wing strike. Examination of the NLG and MLG revealed that dirt and grass were embedded between the NLG's left tire bead, that the tire rim and left sidewall exhibited crosswise scuffing, and that the NLG fork was bent right about 25°. Both MLG tires also exhibited crosswise scuffing on the tread. Further, a review of the airplane's avionics data revealed that, shortly after the left MLG touched down, the airplane's heading and track began to diverge and remained apart throughout the ground roll and that its lateral acceleration increased. All of these factors are consistent with the NLG tire having been turned to the right at touchdown, and with the tire then skidding throughout the rollout.

Examination of the right NLG's strut-to-trunnion mechanical stops revealed that the surface texture of the trunnion stop was embossed on the surface of the strut stop. This finding is also consistent with the

NLG strut being forced to the right mechanical stop at touchdown and remaining there for the entire rollout.

Postaccident examination of the NLG steering system revealed that the aft face of the steering arm's left flange exhibited a witness mark that matched the location and shape of the steering arm mount plate on the engine mount. The steering arm can only contact the mount plate if an external force is applied that turns the NLG left beyond the turn limits indicated on its placard. Therefore, at some point before the accident landing, the NLG had been turned left beyond the placard limits, which resulted in the steering arm contacting the mount plate.

The three bolts that secured the NLG steering horn to the strut were fractured, and the steering horn was found separated from the strut. Examination of the bolt fracture faces, the steering horn bolt holes, and the damage to the top of the strut indicated the left aft bolt fractured predominantly in tension with some shear, the aft right bolt fractured in shear with some bending, the forward bolt fractured in shear with increased bending, and all the bolts fractured in overstress. The direction of the shear failures on the bolts and the strut damage indicated that the strut was rotated left with respect to the steering horn. It was determined that the aft left steering horn bolt fractured first, followed by the aft right bolt and then the forward bolt. The steering horn was reworked at the factory before delivery to better align the steering pad faces with the rollers. The steering horn was deformed during the accident sequence, which precluded taking all the dimensional measurements. The deformation of the left roller could be partially explained due to the exceedance of the left turn limits because the roller should be up to 0.020 inch forward of the steering pad. The remaining measurements did not indicate any gross discrepancies with the steering horn. Therefore, the steering horn was likely fully intact and manufactured in accordance with the drawing.

The NLG must rotate right from its stowed position to extension to align the tire with the airplane's longitudinal axis. The extension mechanism will apply a right turning moment to the steering horn during extension. Given that the NLG was turned right at touchdown, the steering horn must have still been partially attached during gear extension before the accident landing. The NLG tire would only need be turned slightly to the right at touchdown for the frictional forces to result in a right hard-over of the NLG tire. The failure direction of the forward bolt is consistent with right turning moment on the steering horn during NLG extension. It is likely that the forward steering horn bolt fractured during the NLG extension before the accident landing.

If an external force is applied to turn the NLG wheel and strut beyond the left turn limit, the steering arm aft face will contact the steering arm plate on the engine mount. Further, turning left would induce a torsional moment between the strut and steering horn, which would result in the steering horn bolts fracturing in shear/bending in the direction observed. The right turning forces generated during the accident landing could not have produced the damage to the steering arm or the directional fracture of the steering horn bolts further indicating that they failed when the airplane was turned left beyond the limits.

The pilot stated that he was aware of the airplane's towing limitations and witnessed all towing operations except when the airplane was in maintenance before the accident. It could not be determined if the airplane was towed during maintenance or if so, how many times. After the maintenance, four successful flights were conducted in the airplane, and the accident occurred on landing after the fourth flight. Review of the downloaded avionics data for the four flights revealed that the airplane turned left

and right multiple times during taxi operations before and after each flight. At least one of the steering horn bolts must be attached for the airplane to be steerable; therefore, this evidence further supports that the airplane was towed beyond the left turn limits at some point before the accident flight, which fractured one or two of the steering horn attachment bolts.

The failure direction of the forward bolt is consistent with right turning moment on the steering horn during NLG extension. The NLG rotates 90° left through a mechanism during retraction so that the tire is stowed in a horizontal position. If the tire is not horizontal, the NLG doors will not close, and an indication will be given in the cockpit. Given that the pilot reported no such cockpit indication, the steering horn must have still been partially attached during takeoff for the accident flight. As stated previously, the pilot noted that the nosewheel steering did not respond when he applied left rudder after landing. The pilot would have known that the rudder and the NLG were deflected right if the steering horn was in place at the time of landing. Further, the rudder pedals would not have been centered if the tire was deflected right, and the steering horn was in place. Based on all the evidence, all three steering horn bolts must have fractured before the accident landing as a result of being towed over the left turn limits at an undetermined time, which rendered the nosewheel steering ineffective and resulted in the subsequent loss of directional control.

Following the accident, the NLG tire pressure was within acceptable limits, and a review of maintenance records revealed that the NLG tire was properly serviced. Therefore, no issues with the NLG tire pressure contributed to the accident.

The left MLG torque link apex bolt torque links were separated, and the left wheel was not aligned after the accident. Although the apex bolt and cotter pin were not recovered, during examination of the bolt, deformation was found between the cotter pin hole and the bolt's tip, and a remnant of a stripped thread was observed immediately adjacent to the bolt grip, which indicates that the left MLG torque link apex bolt nut and cotter pin were present upon landing.

Probable Cause and Findings

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

The loss of directional control during landing due to the fracture of the steering horn bolts, which rendered the nosewheel steering ineffective and resulted from the airplane being towed over the left turn limits at an undetermined time before the accident.

Findings

Aircraft	Towing - Incorrect use/operation
Personnel issues	Use of equip/system - Unknown/Not determined
Aircraft	Directional control - Attain/maintain not possible

Factual Information

History of Flight

Prior to flight	Ground handling event
Landing	Sys/Comp malf/fail (non-power) (Defining event)
Landing	Loss of control on ground
Landing-landing roll	Runway excursion

On July 3, 2020, about 1157 eastern daylight time, a Piper PA-46-600TP, N89MA, was substantially damaged when it was involved in an accident near Titusville, Florida. The pilot and two passengers were not injured. The airplane was operated as a Title 14 *Code of Federal Regulations* Part 91 personal flight.

The pilot reported that, although the flight from Albert Whitted Airport (SPG), St Petersburg, Florida, to Space Coast Regional Airport (TIX), Titusville, Florida, encountered turbulence, it was otherwise uneventful with no anomalies noted. He added that, just before touchdown at TIX, "the airplane veered left of centerline and he released some of his crosswind correction yet still landed about 3 to 4 ft left of centerline." When the two main landing gear (MLG) touched down, the airplane started to veer left, so he relaxed the rudder pressure.

As soon as the nose landing gear (NLG) touched down, the airplane started to veer right. He attempted to correct the veer by applying left aileron and rudder, as well left and right brakes; however, the airplane did not respond. He continued applying left rudder and brakes as the airplane moved toward the right side of the runway, but the airplane still did not respond. The airplane then exited the right side of the runway and skidded sideways through the grass, which resulted in the left wing and propeller striking the ground and substantial damage to the wing. The airplane came to rest about 100 ft from the runway edge

Data downloaded from the airplane's Garmin G3000 Integrated Avionics System for the accident flight indicated that it was started on the ramp at SPG and that, before takeoff, the airplane turned right 70° on the ramp, left 50° onto taxiway D, right 80° onto runway 18, left 80° onto runway 7, and right 180° to line up on runway 25. Shortly after the MLG touched down during landing at TIX, at an airspeed of about 73 knots, the heading and track began to diverge and the lateral acceleration increased. The heading and track divergence continued for the remainder of the ground roll.

Pilot Information

Certificate:	Airline transport; Commercial	**Age:**	59,Male
Airplane Rating(s):	Single-engine land; Multi-engine land	**Seat Occupied:**	Left
Other Aircraft Rating(s):	None	**Restraint Used:**	3-point
Instrument Rating(s):	Airplane	**Second Pilot Present:**	No
Instructor Rating(s):	None	**Toxicology Performed:**	No
Medical Certification:	Class 2 With waivers/limitations	**Last FAA Medical Exam:**	December 18, 2019
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	June 11, 2020
Flight Time:	4819.5 hours (Total, all aircraft), 21.5 hours (Total, this make and model), 2531.1 hours (Pilot In Command, all aircraft), 39.5 hours (Last 90 days, all aircraft), 28.1 hours (Last 30 days, all aircraft)		

Passenger Information

Certificate:		**Age:**	Male
Airplane Rating(s):		**Seat Occupied:**	Right
Other Aircraft Rating(s):		**Restraint Used:**	3-point
Instrument Rating(s):		**Second Pilot Present:**	No
Instructor Rating(s):		**Toxicology Performed:**	No
Medical Certification:		**Last FAA Medical Exam:**	
Occupational Pilot:	No	**Last Flight Review or Equivalent:**	
Flight Time:			

Passenger Information

Certificate:		**Age:**	Male
Airplane Rating(s):		**Seat Occupied:**	Right
Other Aircraft Rating(s):		**Restraint Used:**	3-point
Instrument Rating(s):		**Second Pilot Present:**	No
Instructor Rating(s):		**Toxicology Performed:**	No
Medical Certification:		**Last FAA Medical Exam:**	
Occupational Pilot:	No	**Last Flight Review or Equivalent:**	
Flight Time:			

Aircraft and Owner/Operator Information

Aircraft Make:	Piper	**Registration:**	N89MA
Model/Series:	PA46 600TP	**Aircraft Category:**	Airplane
Year of Manufacture:	2019	**Amateur Built:**	
Airworthiness Certificate:	Normal	**Serial Number:**	4698109
Landing Gear Type:	Retractable - Tricycle	**Seats:**	6
Date/Type of Last Inspection:	July 1, 2020	**Certified Max Gross Wt.:**	6000 lbs
Time Since Last Inspection:	3.7 Hrs	**Engines:**	1 Turbo prop
Airframe Total Time:	51.8 Hrs at time of accident	**Engine Manufacturer:**	Pratt & Whitney
ELT:	C126 installed, activated, did not aid in locating accident	**Engine Model/Series:**	PT6A-42A
Registered Owner:	D&W Associates FL, Inc.	**Rated Power:**	600 Horsepower
Operator:	D&W Associates FL, Inc.	**Operating Certificate(s) Held:**	None

Nose Landing Gear Steering

The NLG is attached to the engine mount at the upper end of the trunnion assembly by two trunnion bolts. The NLG strut assembly is installed in the trunnion assembly where it rotates for nosewheel steering. The retract actuator is attached to the NLG trunnion assembly and engine mount to allow the NLG to retract aft into the wheel well. During retraction, the NLG strut and tire rotate 90° left through a mechanism that stows the NLG tire in a horizontal position.

The NLG is steerable through a 50° arc, 20° left and 30° right, using the rudder pedals. Primary rudder mechanical stops are installed adjacent to the rudder sector in the empennage to limit the deflection of the rudder and thus the motion of the rudder pedals. Secondary rudder pedal mechanical stops are installed in a machined aluminum fitting aft of the steering bell-crank. The secondary stops allow for a small amount of additional rudder pedal movement as the rudder cables stretch before the stops engage the steering bellcrank. The NLG steering horn is attached to the top of the NLG strut with three bolts. When the landing gear are extended, the right and left forward faces of the steering arm engage the right and left pads and rollers on the steering horn to transmit the linear motion of the rudder pedals to a rotational motion of the NLG strut.

Steering Horn Assembly

During manufacture, a part number 85154-012 steering horn was installed. The steering horn is attached to the NLG strut with three bolts through the base. A rub block is attached to the forward leg of the top plate, a large roller is attached to the top plate's left leg, and a small roller is attached to the top plate's right leg. The two steering pads and two steering rollers interface with the steering arm to provide nosewheel steering with the NLG in the down position. The left roller should be up to 0.020 inch forward of the steering pad. Piper discovered alignment issues with certain steering horn assemblies

installed on airplanes, including the accident airplane, where the location of the steering pads and rollers were not consistent due to variances in the tolerance stack up. The alignment could be adjusted by machining the faces of the steering pads to achieve the necessary dimensional relationship between the pads and rollers.

Accident Airplane Maintenance History

Review of maintenance records revealed that the airplane received its airworthiness certificate on December 7, 2019. On January 17, 2020, the airframe manufacturer reworked the steering horn to align the steering pad faces with the rollers, and it was then reinstalled in the airplane before delivery. The pilot purchased the airplane in June 2020, at which time it had accumulated about 23 hours of total flight time.

After accruing 48.1 hours of flight time, the airplane underwent a 50-hour maintenance interval, which was completed on July 1, 2020. During the maintenance the left MLG strut and tire were replaced, and the MLG alignment and NLG squat switch were adjusted. Review of data from the airplane's avionics unit revealed that, after the maintenance was completed, four flights were conducted in the airplane. The accident occurred upon landing after the fourth flight. The data also revealed that the airplane made multiple left and right turns during taxi operations before and after each flight. The pilot reported that there was no evidence of tow exceedance during his preflight inspection of the airplane on the day of the accident flight.

Airplane Towing History and Guidance

The airplane could be maneuvered on the ground by power equipment using a tow bar attached to the NLG axle. The airplane manufacturer had established turn limits for towing, and a placard installed on the lower end of the NLG trunnion assembly limits turning to about 20° right and left. Corresponding red lines on the NLG strut allow the operator to see the relationship between the turn angle of the NLG strut and the towing limits (see figure 1).

Figure 1 - NLG turn limit placard.

The Pilot's Operating Handbook, Section 8, "Handling, Servicing and Maintenance," contained a caution about towing, which stated, "When towing with power equipment, do not turn the nose gear beyond its steering limit in either directions, as this will result in damage to the nose gear and steering mechanism". Similar cautions were contained in the Aircraft Maintenance Manual and a flight training manual.

If the NLG is externally turned beyond the left or right placard limits, mechanical stops will engage where portions of the NLG and steering mechanism contact. If turned beyond the right limits, a machined stop on the lower portion of the rotating strut assembly will contact a machined stop on the lower end of the stationary trunnion assembly. The right stops will engage when the NLG tire is turned right about 36°. Further, turning right may damage the machined stops and will load the strut-trunnion interface; however, it will not affect the steering arm or steering horn. If turned beyond the left limit, the steering arm left flange aft face will contact the steering arm mount plate on the engine mount. The left stops will engage when the NLG tire is turned about 30.5° left. Further, turning left may damage the steering arm and the three bolts that attach the steering horn assembly to the top of the NLG strut. The rudder primary and secondary mechanical stops do not allow the mechanical turn limit stops to be engaged through pilot rudder inputs.

The pilot stated that he was aware of the towing limitations on the airplane. The airplane was towed six times at his home airport, SPG, and he witnessed all the towing operations except when the airplane was in maintenance. It could not be determined if the airplane was towed during maintenance or, if so, how many times.

Meteorological Information and Flight Plan

Conditions at Accident Site:	Visual (VMC)	**Condition of Light:**	Day
Observation Facility, Elevation:	TIX,33 ft msl	**Distance from Accident Site:**	0 Nautical Miles
Observation Time:	11:50 Local	**Direction from Accident Site:**	
Lowest Cloud Condition:	Scattered / 3300 ft AGL	**Visibility**	7 miles
Lowest Ceiling:	None	**Visibility (RVR):**	
Wind Speed/Gusts:	8 knots /	**Turbulence Type Forecast/Actual:**	Unknown / Unknown
Wind Direction:	260°	**Turbulence Severity Forecast/Actual:**	Unknown / N/A
Altimeter Setting:	29.95 inches Hg	**Temperature/Dew Point:**	33°C / 23°C
Precipitation and Obscuration:	No Obscuration; No Precipitation		
Departure Point:	St Petersburg, FL (SPG)	**Type of Flight Plan Filed:**	IFR
Destination:	Titusville, FL (TIX)	**Type of Clearance:**	IFR
Departure Time:	11:14 Local	**Type of Airspace:**	Class D

Airport Information

Airport:	Space Coast Rgnl TIX	**Runway Surface Type:**	Asphalt
Airport Elevation:	33 ft msl	**Runway Surface Condition:**	Dry
Runway Used:	27	**IFR Approach:**	None
Runway Length/Width:	5000 ft / 100 ft	**VFR Approach/Landing:**	Full stop;Traffic pattern

Wreckage and Impact Information

Crew Injuries:	1 None	**Aircraft Damage:**	Substantial
Passenger Injuries:	2 None	**Aircraft Fire:**	None
Ground Injuries:	N/A	**Aircraft Explosion:**	None
Total Injuries:	3 None	**Latitude, Longitude:**	28.516387,-80.799163(est)

Airplane Examination

Examination of the airplane revealed the outboard 4 to 5 ft of the left wing was deformed upward, the upper wing skin was buckled, and both wing spars were bent. The left aileron was buckled upward about midspan. Four of the five propeller blades were fractured and separated. The fuselage's left side was buckled above the rear spar attachment point. The lower portion of the strut was deformed about 15° right. The left MLG tire beads were separated from the tire, and the tire was deflated. Both MLG tires exhibited crosswise scuffing on the tread.

The NLG tire was aligned with the airplane's longitudinal axis after it came to rest. The NLG strut and lower fork were bent to the right, and the tire was offset about 25° from vertical. Dirt and grass were found embedded between the left tire bead and rim. The NLG tire exhibited crosswise scuffing of the tread that extended part way up the left sidewall. The steering horn was separated from the strut and was resting on top of the NLG assembly, and all three bolts that secured the NLG steering horn to the strut were fractured. The head of one fractured bolt was retained by safety wire, and the other two heads were not recovered. The threaded portions of the fractured bolts remained installed in the strut.

Examination of the three steering horn attachment bolt fracture faces, the steering horn bolt holes, and the damage to the top of the strut revealed that the left aft bolt fractured predominantly in tension with some shear, the aft right bolt fractured in shear with some bending, the forward bolt fractured in shear with increased bending, and all the bolts fractured in overstress. The direction of shear failures on the bolts and the strut damage indicated that the strut was either rotated left with respect to the steering horn or that the steering horn was rotated right with respect to the strut to produce the bolt failures and associated damage (see figure 2).

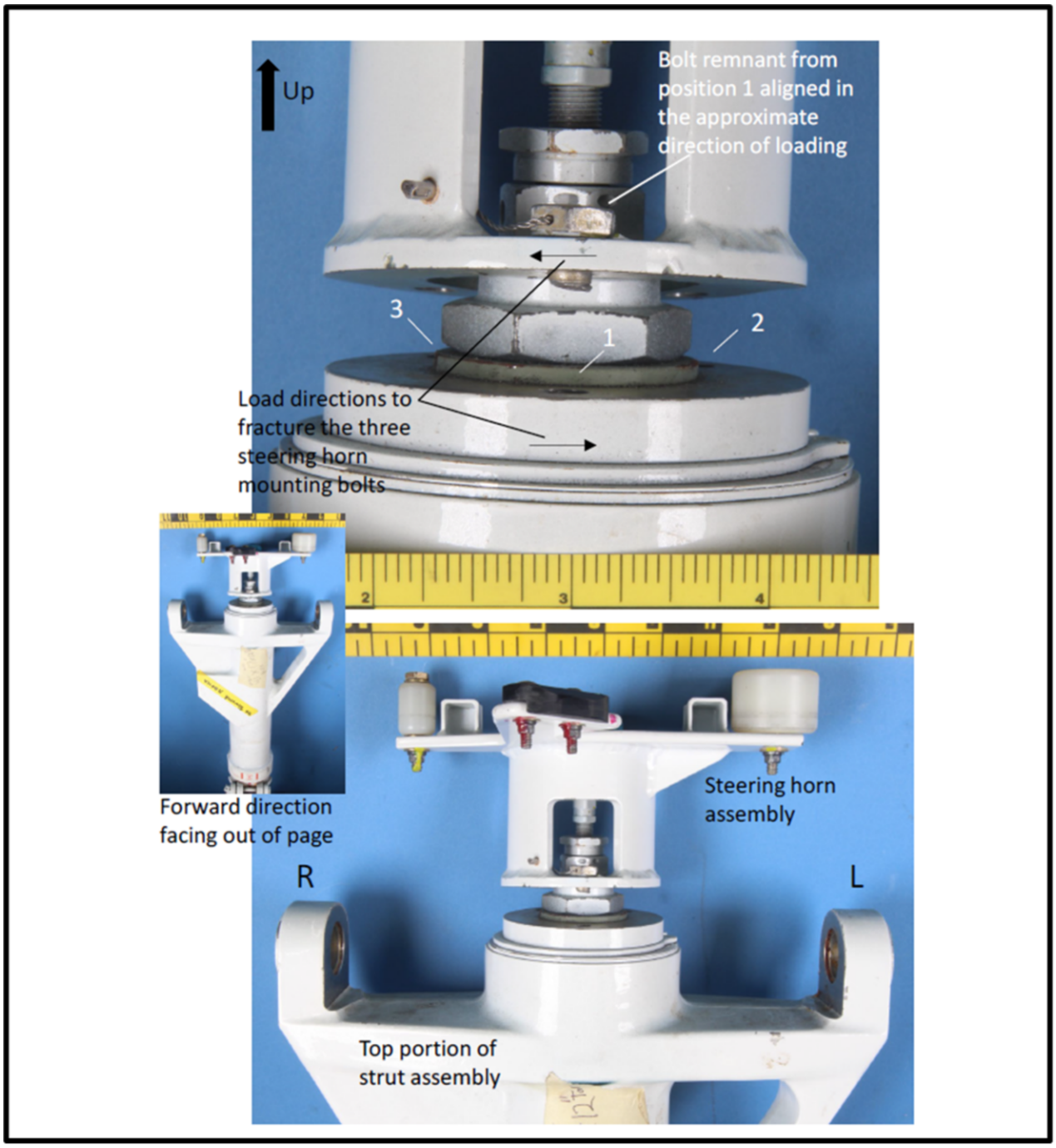

Figure 2 - Photographs of the steering horn placed near the top of the strut on the NLG assembly.

The NLG tire pressure was measured at 91 pounds per square inch (psi). According to manufacturer guidance, NLG tire pressure should measure between 92 and 97 psi; however, a 5% loss in pressure was acceptable. Mechanical damage was noted on the right turn mechanical stops on the trunnion and strut and to the aft face of the left side of the steering arm that served as the left turn mechanical stop. Wear marks were observed on the paint on the forward faces of the steering arm where they interfaced with the steering horn pads and rollers.

Examination of the NLG assembly, steering horn, steering arm, steering bungee, left MLG torque links and the left MLG torque links apex bolt revealed that the steering horn exhibited deformation to the base and top plate and the left large roller bolt/axle was bent forward about 7°. The fractured bolt head from the forward attachment bolt remained attached to the steering horn by safety wire.

Paint was missing on the NLG assembly's right machined mechanical stops on the trunnion and strut assemblies, and the surface texture of the trunnion stop was embossed on the surface of the strut stop. The aft face of the steering arm left flange exhibited a witness mark that matched the location and shape of the steering arm mount plate on the engine mount (see figure 3).

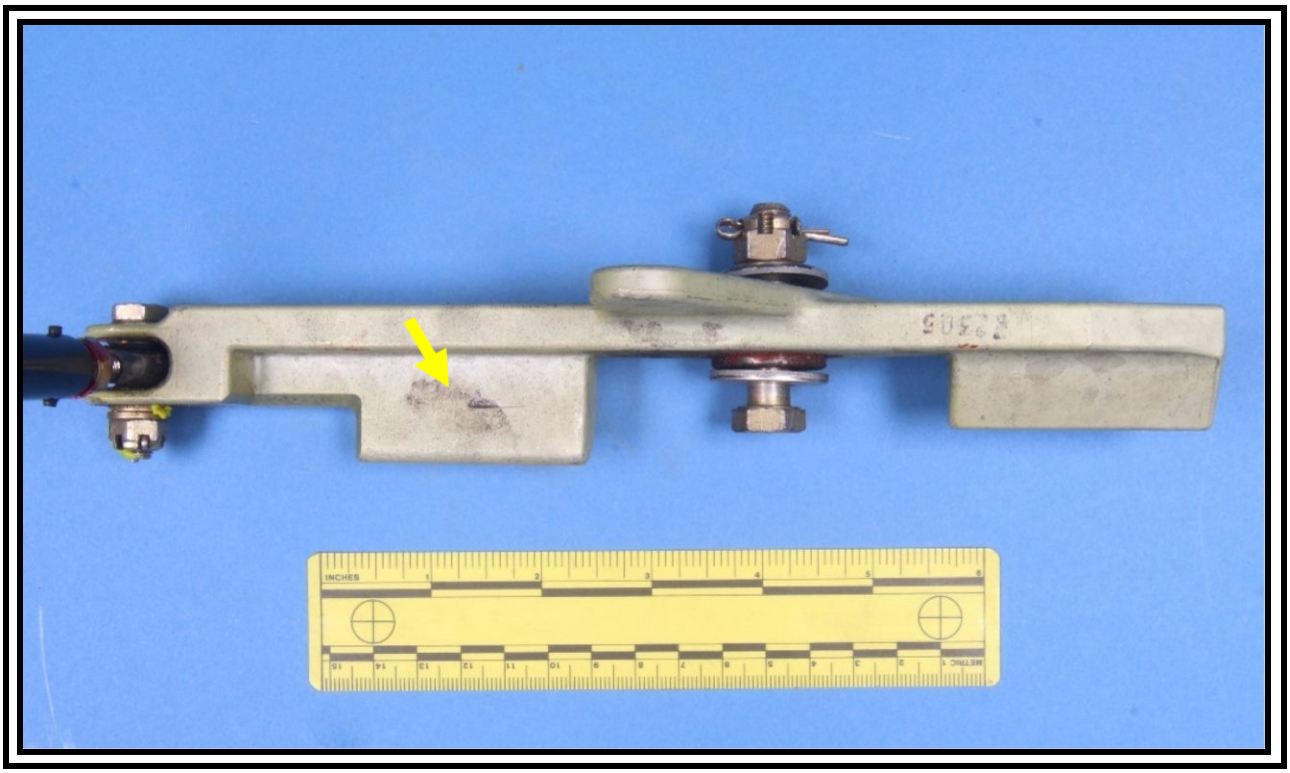

Figure 3 - A photograph of the steering arm showing a witness mark consistent (yellow arrow) with it contacting engine mount plate.

The left MLG torque links apex bolt was found installed in the upper torque link, but the torque links were separated at the apex. The apex bolt's nut and cotter pin were not recovered. Examination of the left MLG torque links apex bolt found thread deformation between the cotter pin hole and the tip of the bolt, and a remnant of a stripped nut thread was observed immediately adjacent to the bolt grip.

Runway and Ground Scars Examination

During examination of the runway, tire marks were visible and traced back to the touchdown point on the runway, which indicated that the MLG touched down about 620 ft from the runway threshold and was about 4 ft left of the centerline. The NLG tire marks were traced back to the land-and-hold short operation lines (used when operating on runway 09) about 770 ft from the runway 27 threshold.

Examination of the runway revealed distinct tire marks from the NLG and both MLG on the runway extending from the touchdown point toward where the airplane exited the right side of the runway, as

shown in figure 4. Both MLG tire marks showed four parallel lines with spaces between them consistent with the tire tread patterns and the tires rolling with brakes applied. The left MLG tire marks were darker than the right MLG tire marks with no tread pattern, consistent with a skidding tire. A short dark skid mark was found preceding the hold lines in line with the continuous NLG tire marks. The marks became darker and arced to the right along their length. The tire markings indicated that the airplane departed the right side of the runway centered about 1,140 ft from the threshold.

Figure 4 – Tire marks on runway 27.

The ground scars in the grass from the runway departure point to where the airplane came to rest included disturbed areas where the right MLG traveled, were continuous from the edge of the runway to where the airplane came to rest; trenching where the left MLG traveled; and heavy trenching where the NLG traveled. A ground scar near where the airplane came to rest was consistent with a left wing strike.

Tests and Research

Airframe Manufacturer Tow Test

A simulated tow test was conducted to document the interference points in the NLG steering system, the witness marks created, the failure sequence of the bolts, and the forces required to fracture the bolts. The NLG strut was rotated left until the steering arm's left flange aft face contacted the steering arm mount plate on the engine mount. The simulated left turning force of about 194 lbs was applied, and it produced a moment of about 8,560 in-lbs when the aft left bolt attaching the steering horn to the strut fractured. A slight separation occurred between the aft left portion of the steering horn base and the

strut, but the NLG was still steerable from the steering arm through the steering horn. A left turning of about 144 lbs was then applied and produced a moment about 6,354 in-lbs when the aft right bolt fractured. A larger separation between the aft portion of the steering horn base and the strut occurred, and the steering horn base exhibited deformation. The steering horn remained attached to the strut; however, the inputs required to achieve rotation of the NLG strut increased substantially. The 35-lb force was then applied, which produced a moment of about 1,544 in-lbs when the forward bolt fractured, and the steering horn was completely separated from the strut. Examination of the steering arm left flange aft face after the test revealed a witness mark where the steering arm contacted the engine mount.

Administrative Information

Investigator In Charge (IIC):	Spencer, Lynn
Additional Participating Persons:	Karen Lunde; FAA/FSDO; Orlando, FL Robert Martellotti; Piper Aircraft, Inc.; Vero Beach, FL
Original Publish Date:	July 15, 2021
Last Revision Date:	
Investigation Class:	Class 3
Note:	The NTSB did not travel to the scene of this accident.
Investigation Docket:	https://data.ntsb.gov/Docket?ProjectID=101528