Aviation Investigation Final Report

Location:	Reno, Nevada	**Accident Number:**	WPR18FA131
Date & Time:	May 1, 2018, 19:31 Local	**Registration:**	N352BT
Aircraft:	AMERICAN AIR RACING LTD THUNDER MUSTANG	**Aircraft Damage:**	Substantial
Defining Event:	Powerplant sys/comp malf/fail	**Injuries:**	1 Fatal
Flight Conducted Under:	Part 91: General aviation - Personal		

Analysis

The airline transport pilot of the high-performance air racing airplane was taking part in an in-flight photography mission with two other airplanes. About 1 hour into the second flight of the day, the group was getting fatigued and decided to return to the departure airport. As the airplanes approached the airport, the accident pilot transmitted a "mayday" call and reported that he was going to land on the runway located directly ahead of his position. The airplane began to descend while performing an S-turn, and touched down beyond the midpoint of the 9,000-ft-long runway at a slightly higher speed than normal. A 4-knot tailwind prevailed on the landing runway about the time of the accident.

A 1,200-ft-long series of propeller strikes on the runway were consistent with the pilot applying heavy braking after touchdown. The airplane veered right as it reached the end of the runway, entered a gravel area, nosed over, and came to rest inverted. Given the airplane's nominal landing distance in addition to the factors that increased that distance on the accident landing, namely, remaining runway at the time of the touchdown, the airplane's higher landing speed, and the tailwind, the pilot would have had very little margin for error before the airplane's landing distance required exceeded the available runway.

The vertical stabilizer collapsed when the airplane nosed over, which resulted in the canopy structure contacting the ground and subsequently failing. As a result, the pilot's head was impinged at an angle against the ground, resulting in airway restriction. The pilot's extraction from the airplane by first responders took about 45 minutes, and during that time, the pilot died of asphyxiation. However, unless he had been repositioned and his breathing enabled almost immediately following the accident, survival would have been unlikely, and based on the airplane's weight and inverted position, an immediate rescue was not possible.

It could not be determined if the canopy bow was designed to be structural in nature; additionally, visual inspection revealed defects that would have further weakened its supporting properties.

Examination of the engine revealed that the coolant pump drive pulley had detached due to fatigue failure of its attachment cap screws. Separation of the pulley resulted in the detachment of the engine's two parallel serpentine drive belts, which drove multiple other engine accessories. This design allowed for a single point of failure, which resulted in a total loss of engine oil pressure, propeller governor control, and auxiliary electrical power. The belts also dislodged a coolant line, resulting in the loss of all engine coolant. With these failures, the engine would have been able to operate for a short duration before experiencing catastrophic failure, negating the pilots ability to perform a go-around, and evidence suggests that it continued to operate at a low power setting during the descent and the landing roll.

Hardness testing of the pulley attachment screws revealed that they were of the proper tensile strength. Substantial fretting damage was present on the pulley contact faces and under the screw contact areas, and thread wear was present in the pulley attachment holes. Evidence of the use of thread locking material was observed; therefore, it is likely that the screws detached due to insufficient tightening at the time of installation. Although the thread locking material used was consistent with the engine manufacturer installation instructions, product literature from the manufacturer of the thread locking material indicated that another type was available that was specifically tailored for pulley applications. Whether the use of the alternate thread locking material would have affected the outcome could not be determined.

The pilot performed all the maintenance work on the engine, which had been overhauled about 20 flight hours before the accident; however, he performed multiple significant maintenance events on the engine between the overhaul and the accident flight, so the precise timing of the pulley installation could not be determined.

The 80-year-old pilot had extensive experience in air racing and the airplane type, and had successfully dealt with multiple loss of engine power events in the airport environment and accident airplane type. However, under the specific circumstances of this failure, the design of the propeller was such that, following the loss of governor control, the propeller would have moved to a blade pitch angle that would have resulted in less drag and a longer gliding profile than the pilot had likely experienced in previous events. No logbooks of his flight experience were recovered; however, evidence suggests that he had cut back on his flying activities during the recent period leading up to the accident. The pilot was likely fatigued from the two flights on the day of the accident and appeared to be experiencing a gradual degradation in his general health, which may have begun to affect his performance.

Although there was evidence that the pilot had used two opioid pain medications at some time before the accident, active drugs and their metabolites were found only in urine. This indicates the active compounds were no longer present in his system and therefore would not have been causing any effects. Overall, there is no evidence the pilot was impaired by a specific medical condition or use of medications or other substances at the time of the accident; however, the subtle impairing effects of withdrawal from the opioid medications cannot be eliminated.

Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this accident to be: The pilot's failure to properly secure the engine coolant pump pulley during recent maintenance, which resulted in a loss of the engine's lubrication, cooling, and propeller control systems, and a forced landing, during which the airplane nosed over. Contributing was the design of the accessory drive system, which allowed for multiple simultaneous failures of critical engine components. Contributing to the pilot's fatal injuries was the inadequate support provided by the airplane's canopy structure, which did not protect him during the relatively innocuous nose-over event.

Findings

Personnel issues	Scheduled/routine maintenance - Pilot
Aircraft	Recip eng liquid cooling - Fatigue/wear/corrosion
Aircraft	Recip eng oil sys - Damaged/degraded
Aircraft	Propeller governor - Damaged/degraded
Aircraft	Recip eng rear section - Design
Aircraft	Flight compartment windows - Capability exceeded

Factual Information

History of Flight

Enroute-descent	Powerplant sys/comp malf/fail (Defining event)
Landing-landing roll	Runway excursion
Landing-landing roll	Nose over/nose down

On May 1, 2018, at 1931 Pacific daylight time, an experimental, amateur-built American Air Racing (AAR) Thunder Mustang (Blue Thunder II), N352BT, sustained substantial damage during a forced landing at Reno/Stead Airport (RTS), Reno, Nevada. The airline transport pilot was fatally injured. The airplane was registered to TM-1 Ltd. and operated as a Title 14 *Code of Federal Regulations* (*CFR*) Part 91 personal flight. Visual meteorological conditions prevailed, and no flight plan was filed for the local flight, which departed about 1815.

The airplane was taking part in an in-flight photography mission with another Thunder Mustang, with the photographs being taken from a Beechcraft Bonanza. This was the second photography flight the group had flown that day. The first flight began about 1500 and lasted about 1 hour.

About 1 hour into the accident flight, which included multiple north-south passes north of the airport, the group agreed that they were beginning to get fatigued and decided to end the mission and return to RTS.

When the airplanes were about 5 miles from the airport, the accident pilot transmitted a "mayday" radio call over the common traffic advisory frequency. The pilot of the other Thunder Mustang asked for a confirmation, and the accident pilot responded again with a mayday call, adding that he intended to land on runway 14. The other pilot watched as the airplane began to descend toward the airport. He saw it overshoot the extended runway 14 centerline, then begin a wide 180° left turn followed by a right turn to rejoin the centerline. By this time, the airplane was midfield and low over the runway, flying at what the second pilot judged to be a high speed. He could not tell if the airplane had touched down or was still floating over the runway in ground effect, and as it approached the end of the runway, it veered off the right side and nosed over.

The airplane came to rest inverted in a gravel area about 20 ft right of the runway edge and 80 ft short of the runway's paved end. The runway surface exhibited a 1,200-ft-long series of intermittent black tire skid marks and intermittent propeller blade gouges leading from the runway centerline to the airplane.

The final stage of the accident sequence was captured by a video camera mounted on the airport operations building at the southeast corner of the airport, about 1,500 ft southwest of the end of runway 14. The camera was facing northeast with a field of view that included the last 2,000 ft of runway 14. When the airplane came into view, it was traveling from left to right with the main landing gear on the runway surface. As it progressed, the tail began to rise and as the airplane passed to the right and out of the camera's view, it had transitioned to a 45° nose-down attitude. The main wreckage was located about 50 ft beyond the point where it exited the camera field of view.

A runway construction crew, along with the other pilots from the photography mission, arrived at the accident site within about 3 minutes, followed a few minutes later by the local fire department. They observed that the vertical stabilizer had folded against the right horizontal stabilizer and that the canopy was shattered by ground impact. The flaps were found in the 43° (full down) position, and the landing gear was extended.

The pilot remained in his seat restrained by his four-point harness. His helmet was impinged against the gravel surface, and his head was tilted forward so that his chin was in contact with his chest. The first pilot to arrive stated that he could initially hear the pilot mumbling, and he reached into the cockpit and asked the pilot if he could turn off any switches, but the pilot did not respond. He did not hear the pilot make any more sounds. A paramedic arrived at the accident site about 11 minutes after the accident, assessed the pilot's condition, and reported that although the pilot initially appeared to be conscious, he became unresponsive after about 2 minutes. The group attempted to lift the airplane up by the wing to relieve the pressure on the pilot, but it was too heavy. Multiple attempts to move and lift the airplane were unsuccessful. The pilot was extracted about 45 minutes after the accident, when the fire department used a combination of lifting devices and dug a hole in the gravel under the cockpit.

Pilot Information

Certificate:	Airline transport; Commercial; Flight engineer; Flight instructor	**Age:**	80,Male
Airplane Rating(s):	Single-engine land; Multi-engine land	**Seat Occupied:**	Front
Other Aircraft Rating(s):	None	**Restraint Used:**	4-point
Instrument Rating(s):	Airplane	**Second Pilot Present:**	No
Instructor Rating(s):	Airplane single-engine; Instrument airplane	**Toxicology Performed:**	Yes
Medical Certification:	Class 2 With waivers/limitations	**Last FAA Medical Exam:**	July 7, 2017
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	
Flight Time:	30000 hours (Total, all aircraft), 326 hours (Total, this make and model), 5.4 hours (Last 24 hours, all aircraft)		

The 80-year-old pilot held an airline transport pilot certificate with a rating for airplane multiengine land, type ratings for the B-707, B-720, B-727, DC-9, and DC-10, and commercial privileges for airplane single-engine land. He held an airframe and powerplant certificate (A&P), with inspection authorization (IA).

The pilot was the sole owner of AAR and employed a crew of three mechanics in part- and full-time capacities. The pilot performed most of the work on the accident airplane, including engine removal and installation. He oversaw and signed off on all work performed, because the other mechanics did not hold Federal Aviation Administration (FAA) mechanic ratings. AAR performed maintenance work for multiple types of aircraft but specialized in the Thunder Mustang due to the owner's experience with the type.

The pilot had extensive flight experience in air racing and reported 30,000 total civilian hours of flight time as of his last FAA medical examination on July 7, 2017.

No pilot logbooks were recovered. The pilot's most recent flight experience was determined from his application as a participant in the Reno National Championship Air Races Pylon Racing Seminar (PRS). The application was dated March 13, 2018, and at that time the pilot reported 326 total hours of flight experience in the accident airplane make and model, of which 287 was in the accident airplane. He reported 34 hours of flight experience in the previous 90 days.

The pilot also owned and flew a Piper PA-34, and according to employees of AAR, these were the only two airplanes he flew. Maintenance logbooks for the PA-34 indicated that it had accumulated 5.4 hours of flight time in the previous 3 months; the accident airplane had accumulated 2.48 hours of flight time during that period.

Employees of AAR along with the pilots involved in the photography mission all stated that the pilot seemed to be his usual self before the accident. Although he needed assistance getting into the airplane, this was not unusual. Employees and the pilot's son all noted what they considered to be normal, "age-related" degradation over the years they had known him, but no recent acceleration or issues of concern. They also stated that he tended to be strong-willed and would not likely disclose any medical concerns. The pilot lived alone; therefore, a meaningful 72-hour history of his activities leading up to the accident could not be determined.

One of the pilots in the photographic mission stated that the accident pilot expressed irritation that the maximum speed of the Bonanza was too slow to allow for stable flight of the Thunder Mustang while photographing it. He also noted that the accident pilot did not appear to be flying with his usual level of precision on both flights, and was not in as close formation as he should have been. Additionally, 2 days before the accident, a friend of the pilot saw the pilot struggle with his balance after leaning over to look at something on the hangar floor. As he stood back up again, he fell back to the ground after trying to avoid the wing strut of an airplane. His friend described the pilot as dizzy and disoriented. He had slight trouble walking after the event, and was unable to lift his foot to get into his golf cart. The pilots son, who was also there, stated that the pilot sometimes experienced these issues if he stood for too long, but on that day, he appeared to be back to normal a short time later.

Aircraft and Owner/Operator Information

Aircraft Make:	AMERICAN AIR RACING LTD	**Registration:**	N352BT
Model/Series:	THUNDER MUSTANG NO SERIES	**Aircraft Category:**	Airplane
Year of Manufacture:	2009	**Amateur Built:**	Yes
Airworthiness Certificate:	Experimental (Special)	**Serial Number:**	JHTM017
Landing Gear Type:	Retractable - Tailwheel	**Seats:**	2
Date/Type of Last Inspection:	March 14, 2018 Condition	**Certified Max Gross Wt.:**	3200 lbs
Time Since Last Inspection:	17 Hrs	**Engines:**	1 Reciprocating
Airframe Total Time:	236.38 Hrs as of last inspection	**Engine Manufacturer:**	Falconer
ELT:	Not installed	**Engine Model/Series:**	V12
Registered Owner:		**Rated Power:**	600 Horsepower
Operator:	On file	**Operating Certificate(s) Held:**	None

The airplane was a kit-built, 3/4-scale replica of the P-51 Mustang, composed primarily of composite materials. The original manufacturer of the kit (Papa 51) formed in the early 1990's and went out of business around 1998-1999. The company assets were subsequently purchased by the Thunder Mustang Builders Group (TBG), and then by an individual in 2012. According to TBG, 37 kits were originally sold, and 15 airplanes were flying at the time of the accident. The accident pilot was a member of the TBG, and had become known as an expert in the type.

The airplane was equipped with a liquid-cooled, fuel injected, 12-cylinder engine manufactured by Ryan Falconer Racing Engines. The engine was based on the Chevrolet "small block" automobile engine and was designed for use in high-performance, custom-built marine, automobile, and aviation applications.

Most of the engine's accessories were mounted on the rear of the engine and included the fuel pump, coolant pump, propeller governor, auxiliary alternator, and both the scavenge and pressure oil pumps. The accessories were driven simultaneously by the engine crankshaft via a parallel pair of Kevlar serpentine belts. The coolant pump was an automotive centrifugal type, driven by the belts via a pulley attached to the pump drive flange.

The primary alternator was also attached to the rear of the engine, but driven by its own dedicated belt. Engine ignition was controlled by independent dual electronic engine control units, both powered simultaneously from the main and auxiliary electrical systems.

The propeller was a 101.5-inch diameter, three-blade, hydraulically (engine oil) operated constant-speed propeller, manufactured by Hartzell Propellers exclusively for installation on Thunder Mustang airplanes. According to Hartzell, the propeller incorporated design features for air racing. Specifically, it included a 60° mechanical high pitch stop, designed such that in the event of oil pressure loss or a propeller governor failure at high airspeed, the propeller would move to the 60° blade angle position (higher than normal operation) and prevent a catastrophic engine overspeed. It did not have full feather capabilities, so that the airplane had "limp home" capability at the 60° blade angle if the engine continued to run. In the event of a total power loss, the 60° blade angle would reduce windmill drag without completely feathering; this would also facilitate airstart attempts if the cause of power loss was corrected. With the throttle at idle while in flight, under normal operation the governor would drive the propeller down to the 22° blade angle position.

The airplane was equipped with retractable main and tailwheel landing gear, operated through a system of electrical, mechanical, and hydraulic components. Hydraulic pressure was provided though a pump mounted to an accessory pad on the forward end of the engine.

The flaps were electrically controlled, and the airplane was equipped with conventional disc brakes, operated on a separate and dedicated hydraulic system.

The pilot owned two Falconer engines for the airplane, serial number 12022, which was the accident engine, and serial number 12023, which was the engine used in air races.

An engine overhaul was completed on the accident engine on March 18, 2016, and it was installed on April 2, 2016. The overhaul facility specialized in manufacturing and rebuilding specialized racing engines, primarily for marine and automobile use. The owner of the overhaul facility stated that the engine came back to him a short time later after sustaining an overheating event. It was repaired and subsequently reinstalled on March 17, 2017.

According to the maintenance logbooks, the last condition inspection on the engine was performed on March 14, 2018, at a time of 17.15 hours since major overhaul (2.48 flight hours before the accident). The owner of the overhaul facility stated that he was aware of the engine being removed two more times by the pilot since he performed the repair work, and that during one of those events, the pilot was trying to swap the cylinder heads with his other race engine; however, he was not able to do so as they had different clearances.

The airplane's flight manual and training guide indicated that the landing distance varied based on numerous factors, the primary being pilot technique. It stated that if a three-point landing was performed, 2,000 ft of runway was adequate, and that a wheel landing required 3,500 ft. It further explained that dynamics including approach speed, density altitude, and obstacle clearance need to be factored for every landing. An entry in the airplane's logbook recorded during the phase 1 flight testing period indicated the VSo speed (the stall speed or the minimum steady flight speed in the landing configuration) was 82 knots.

Meteorological Information and Flight Plan

Conditions at Accident Site:	Visual (VMC)	**Condition of Light:**	Day
Observation Facility, Elevation:	KRTS,5053 ft msl	**Distance from Accident Site:**	1 Nautical Miles
Observation Time:	14:35 Local	**Direction from Accident Site:**	312°
Lowest Cloud Condition:	Clear	**Visibility**	10 miles
Lowest Ceiling:	None	**Visibility (RVR):**	
Wind Speed/Gusts:	4 knots /	**Turbulence Type Forecast/Actual:**	/
Wind Direction:	320°	**Turbulence Severity Forecast/Actual:**	/
Altimeter Setting:	29.9 inches Hg	**Temperature/Dew Point:**	4°C / 1°C
Precipitation and Obscuration:	No Obscuration; No Precipitation		
Departure Point:	Reno, NV (RTS)	**Type of Flight Plan Filed:**	None
Destination:	Reno, NV (RTS)	**Type of Clearance:**	None
Departure Time:	18:15 Local	**Type of Airspace:**	Class E;Class G

At 1935, the automated surface weather observation facility at RTS reported a direct tailwind for runway 14 at 4 knots. Visibility was 10 miles, temperature 4°C, dew point 1°C, and the altimeter setting was 29.91 inches of mercury.

Airport Information

Airport:	RENO/STEAD RTS	**Runway Surface Type:**	Asphalt
Airport Elevation:	5050 ft msl	**Runway Surface Condition:**	Dry
Runway Used:	14	**IFR Approach:**	None
Runway Length/Width:	9000 ft / 150 ft	**VFR Approach/Landing:**	Forced landing

RTS is located at an elevation of 5,050 ft mean sea level (msl) and has two runways: runway 14/32, which is 9,000 ft long, and runway 8/26, which is 7,608 ft long. At the time of the accident, runway 8/26 was being rebuilt and was closed.

The airport did not have any scheduled flight services, and therefore was not operating under the auspices of 14 *CFR* Part 139. As such, there was no requirement that the airport provide onsite aircraft rescue and firefighting (ARFF) services. ARFF were provided by the Reno Fire Department Station 9, located about 1/3 mile south of the airport. Station 9 was equipped with basic aircraft rescue equipment and took part in the most recent airport "tabletop" and driver training exercise in December 2017.

Wreckage and Impact Information

Crew Injuries:	1 Fatal	**Aircraft Damage:**	Substantial
Passenger Injuries:		**Aircraft Fire:**	None
Ground Injuries:	N/A	**Aircraft Explosion:**	None
Total Injuries:	1 Fatal	**Latitude, Longitude:**	39.661388,-119.867774

Flight recorders

The airplane was equipped with a customized data recording system manufactured by 51Aero. The system was configured to process, store, and transmit via telemetry multiple engine and airframe parameters, as well as GPS location.

The unit was undamaged during the accident, and its data was successfully downloaded. The data captured the entire flight, and all the engine parameters.

During the initial north-south passes (Figure 1), the engine was operating at a speed of about 4,050 rpm, while the manifold pressure varied between 10 and 13 inches of mercury, and the exhaust gas temperatures (EGT) were all about 1,300°F.

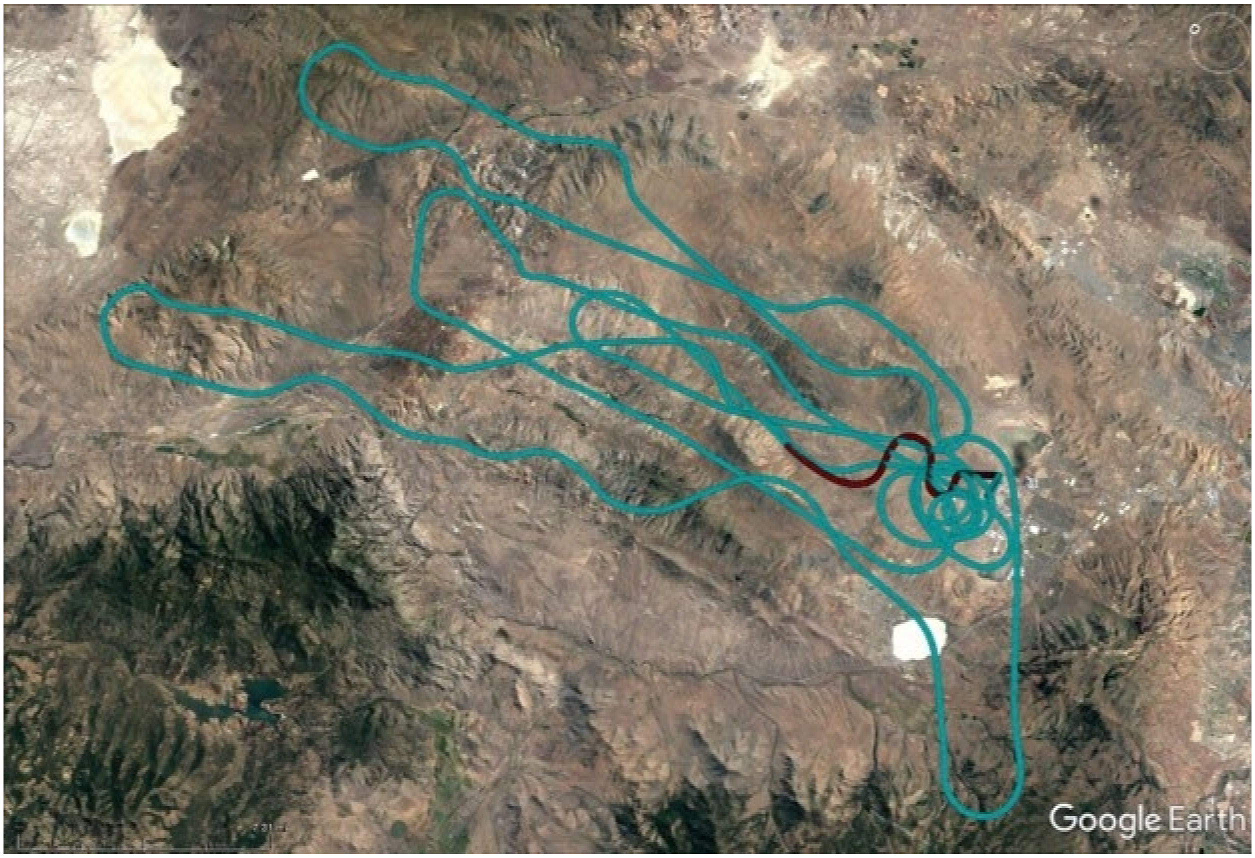

Figure 1 – Entire Flight Track (accident portion highlighted in red)

At 1928, while 4 miles north-northwest of the approach end of runway 14, and at a GPS altitude of 8,460 ft (about 2,800 ft above terrain, and 3,410 ft above the airport elevation), the oil pressure dropped from 72 psi to 0. At that time, the auxiliary alternator current flow dropped from 17 amps to 0 amps, while the current supplied by the auxiliary battery increased from 0 to 9.6 amps. The engine speed dropped to about 2,000 rpm, and the airplane began to descend.

Over the next 130 seconds, the airplane initiated a descending 1.5-mile-wide S-turn (Figure 2). The EGTs had decreased to about 1,000°F, and the airplane arrived about 200 ft agl over the runway, 2,400 ft beyond the landing threshold, while traveling at an indicated airspeed of 139 knots (KIAS).

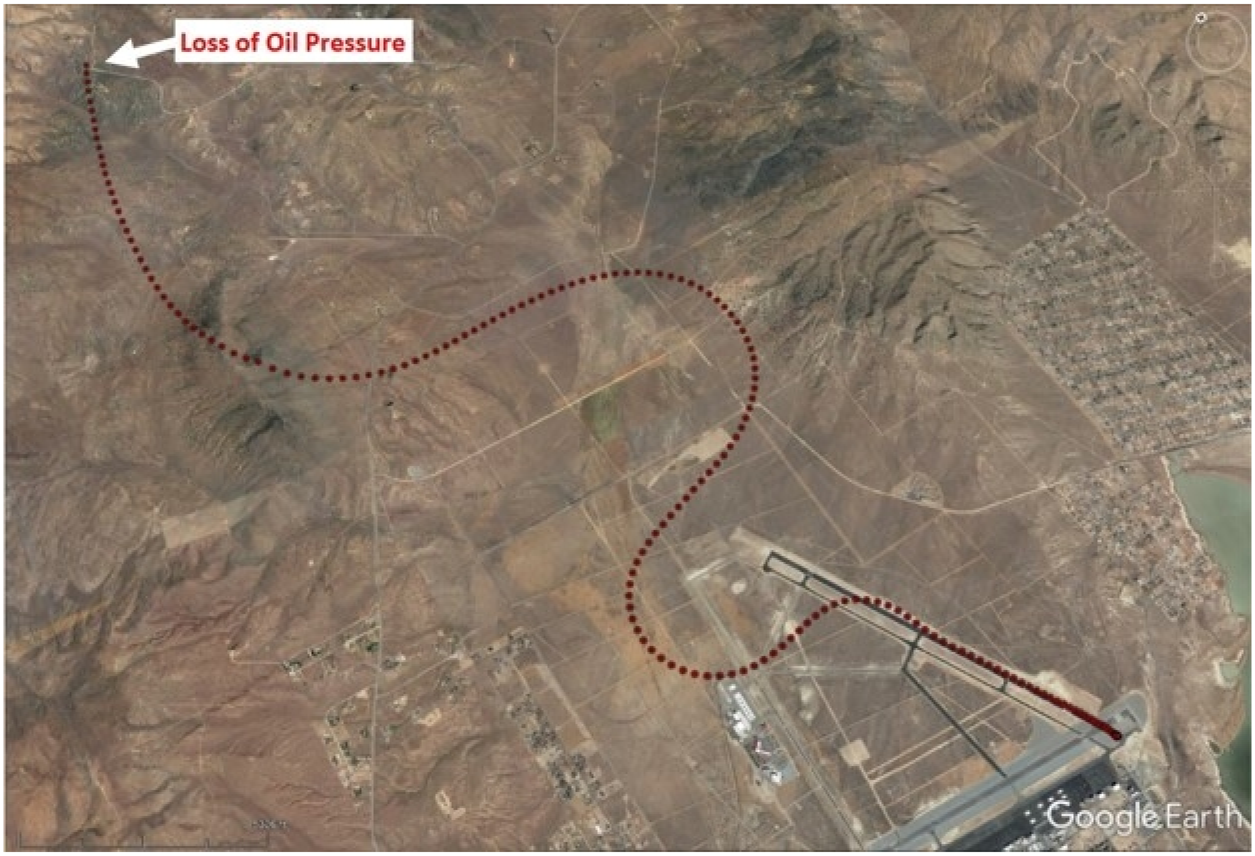

Figure 2 – Accident Fight Track (loss of oil pressure at GPS altitude of 8,460 ft)

The airplane continued to track along the runway centerline and appeared to touch down at a speed of 111 KIAS, just after reaching the runway midpoint, with about 3,250 ft of runway remaining. The airplane continued to decelerate as it continued along the runway until it began to drift right with 350 ft of runway remaining. It traveled another 200 ft before departing the right side of the runway. It entered the adjacent travel area while traveling at 20 KIAS, and nosed over.

Review of the data from the airplane's previous flight revealed that it touched down during landing at a speed of about 100 KIAS, and the ground roll was about 4,600 ft.

Medical and Pathological Information

During the 11 years preceding his last FAA medical examination, the pilot had reported hypertension, glucose intolerance, a knee replacement, and in 2009, back surgery for nerve compression that did not completely relieve the nerve issue. He was left with permanent left ankle weakness (a foot drop) which required use of a brace, after which he was certified with a special issuance FAA medical certificate. In 2012, he received a Statement of Demonstrated Ability (SODA), after successfully completing a medical flight test in a Cessna 172. In 2013, he underwent a repeat procedure to decompress the spinal nerves. His pain improved but his foot drop remained. He continued flying with special issuance medical certificates until 2016, when the FAA decided that a special issuance certificate was no longer necessary.

At the time of the pilot's most recent medical exam, he reported using a combination of lisinopril and hydrochlorothiazide to control his blood pressure. These medications are not considered impairing, and he was issued an FAA second-class medical certificate limited by a requirement he have available glasses for near vision.

According to the autopsy performed by the Washoe County Regional Medical Examiner's Office, Reno, Nevada, the cause of death was positional/traumatic asphyxia.

Moderate coronary artery disease was identified on autopsy with up to 50% stenoses of the mid left anterior descending coronary artery, proximal circumflex coronary artery, and mid right coronary artery identified; however, the remainder of the cardiac exam was unremarkable.

Toxicology testing performed by the FAA's Forensic Sciences Laboratory identified hydrocodone and two of its active metabolites (hydromorphone and dihydrocodeine) in urine, as well as tramadol and its metabolite O-desmethyltramadol. However, testing for hydrocodone in the pilot's peripheral blood was inconclusive and neither of its metabolites were identified in blood. Similarly, tramadol and its metabolite were not identified in blood. Hydrocodone is an opioid pain medication available as a Schedule II controlled substance. Tramadol is an opioid pain medication available as a Schedule IV controlled substance. Both are considered impairing and carry warnings about operating machinery.

Tests and Research

Coolant Pump Pulley Assembly

Postaccident examination revealed that the coolant pump pulley had separated from the pump drive flange. The pulley mounting cap screw heads had detached, leaving their threaded stud ends still in the flange. Both serpentine belts had also detached, along with the top of the engine coolant outlet hose, which was adjacent to the pulley (Figure 3).

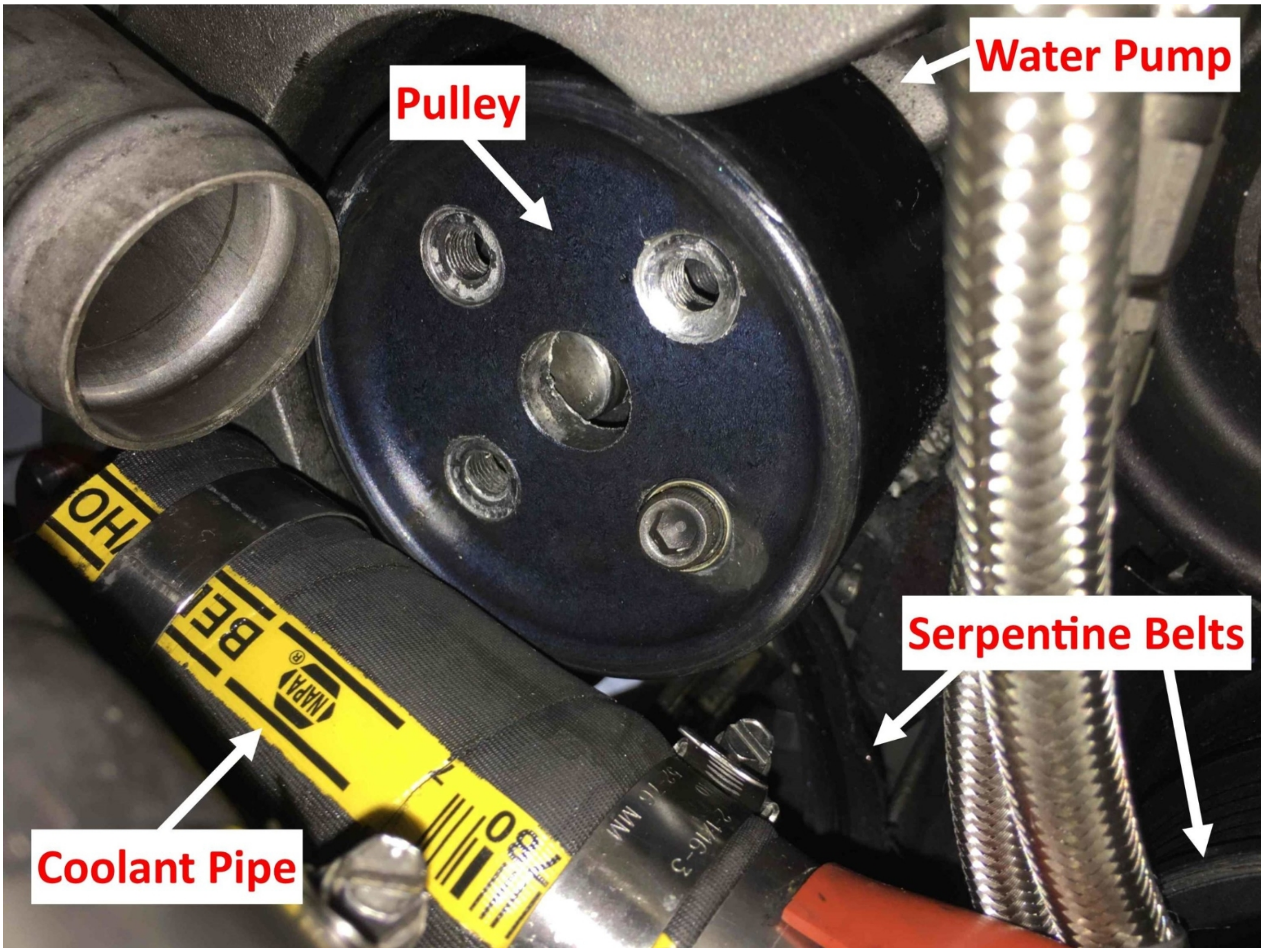

Figure 3 – Detached Coolant Pump Pulley

The coolant pump assembly, pulley, and serpentine belt were examined at the NTSB Materials Laboratory.

The pulley had been attached to the pump drive flange by its four cap screws, the threaded portions of which remained installed in the flange. The flange and corresponding mating surface of the pulley exhibited rough surface features consistent with heavy fretting contact damage. The areas around the bolt holes of the pulley were significantly abraded, consistent with relative-motion contact wear by the washers. Thread impressions were also observed in the bolt holes, consistent with high-force contact with the threads of the attachment screws.

The cap screws were arbitrarily labeled 1 through 4 (Figures 4, 5). Screw 1 had multiple fatigue origins located around its circumference with fracture on multiple planes, a feature consistent with it being the first screw to fracture in the attachment assembly. Screw 2 had relatively prominent crack arrest lines with a fracture origin area located at one side of the screw, features consistent with fatigue fracture under relatively higher cyclic stresses. Screw 3 had small fatigue regions with multiple origins around the circumference, and the remainder of the fracture surface had matte gray features consistent with ductile overstress fracture. Screw 4 had relatively smooth fracture features with crack arrest marks extending across most of the fracture and origins located around much of the circumference.

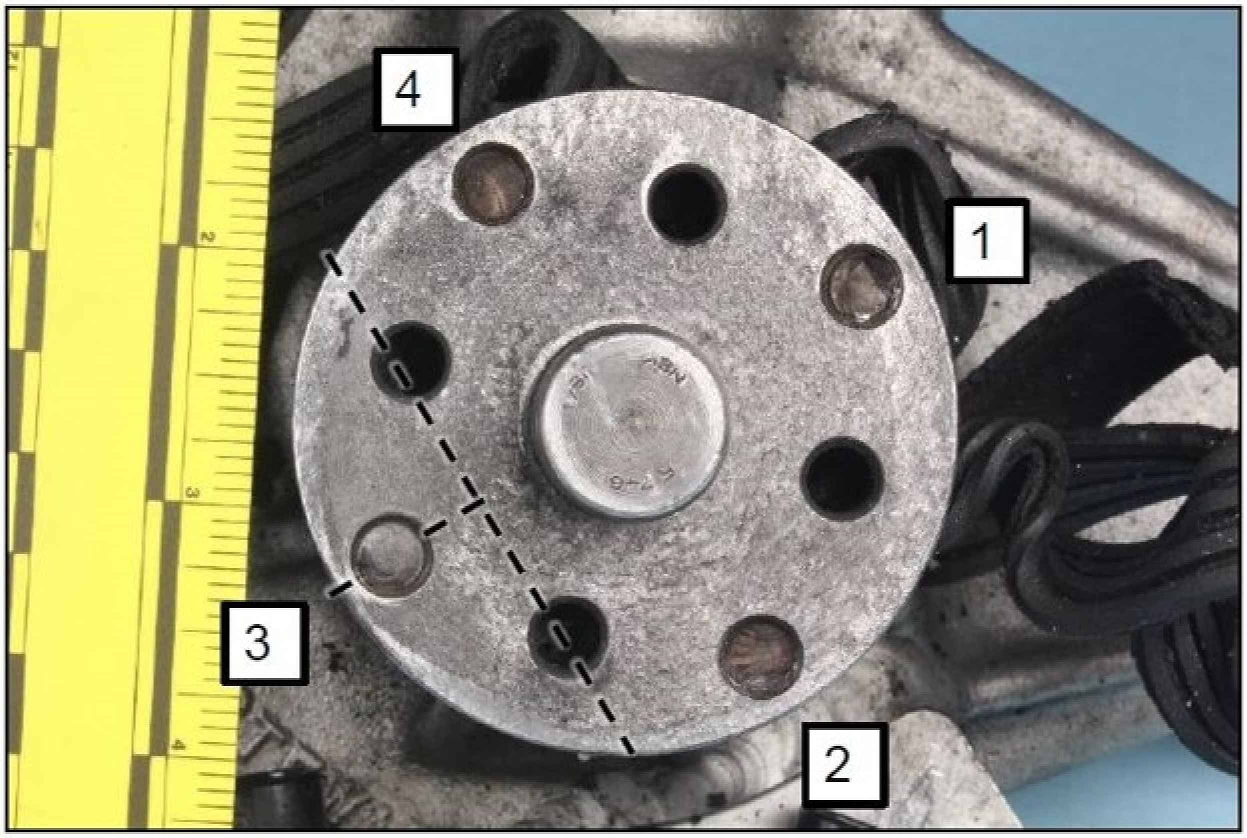

Figure 4 – Coolant Pump Pulley Drive Flange

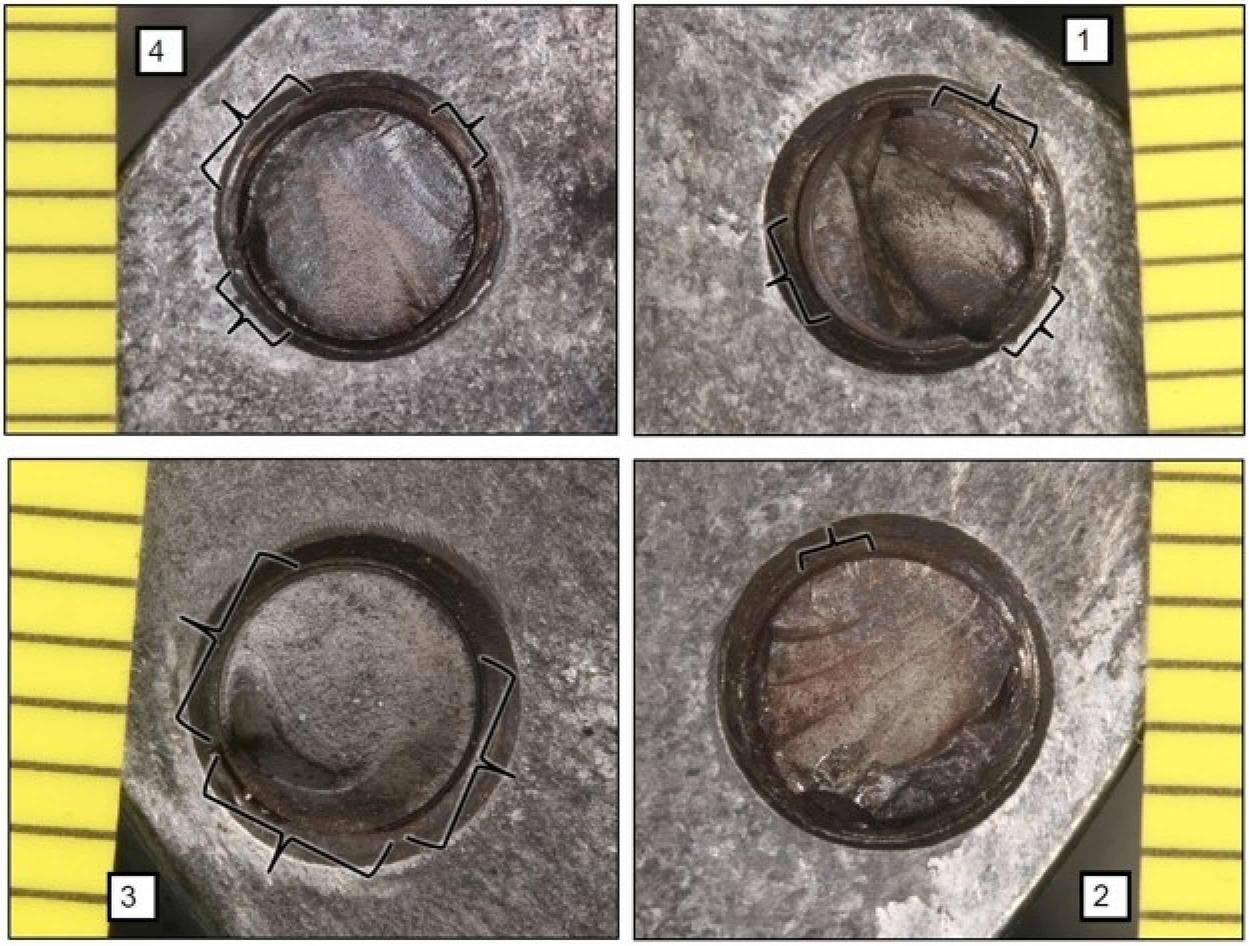

Figure 5 - Coolant Pump Pulley Drive Flange Cap Screws (brackets indicate fatigue origin areas)

The flange screw-hole threads exhibited intermittently dispersed flaky black deposits as well as a coating of powdery orange material consistent with iron oxide.

The black deposits could be removed with little effort, and a sample was examined using a Fourier Transform Infrared (FTIR) spectrometer. The results indicated the material exhibited similarities to oleic acid and Loctite® 242 (blue) thread-locking fluid.

The Falconer engine overhaul manual did not give any specific torque values for the water pump pulley screws, but recommended the use of Loctite 242 throughout. A representative from Falconer Engines stated that 5/16 Grade 8 cap screws were used to attach the pulley to the pump with Loctite on the threads, and a torque of 18 ft-lbs.

According to the owner of the engine overhaul facility, the screws installed after overhaul were a 5/16-24 alloy cap type, similar to Grade 8 caps screws, but rated to a higher tensile strength. He stated that Blue Loctite 242 should be applied to their threads at installation, and the screws should be torqued to 22 to 25 ft lbs. The screws did not have any mechanical safetying provisions.

Review of various online and manufacturing resources indicated recommended torque ranges for 5/16-

24 grade 8 bolts of between 18 and 33 ft-lbs.

According to the Henkel website (manufacturer of Loctite), multiple kinds of Loctite medium-strength blue threadlocker are available including Loctite Threadlocker 242 and Loctite Threadlocker 243. The website further states that Loctite 243 is an "upgraded version of Loctite 242" and is needed for applications including pulley assemblies.

Hardness tests using a Rockwell superficial hardness tester were conducted on both screw 1 and an exemplar screw. The average hardness was 41.7 HRC (61.1 HR30N) and 41.5 HRC (60.8 HR30N), respectively. According to ASTM Standard A370-12a, the measured average hardness values correspond to tensile strengths of approximately 191,000 psi and 192,000 psi respectively. Grade 8 socket head cap screws have a minimum tensile strength of 180,000 psi.

According to the owner of the engine overhaul facility, during an overhaul, the coolant pump pulley is removed, and ancillary hardware, nuts, bolts, screws, are replaced.

The AAR mechanics stated that they had never worked on the coolant pump or associated pulleys, and one mechanic stated that the pilot was the only person he had ever observed replacing the coolant pump.

According to friends of the pilot, he had experienced at least five loss of engine power events in the accident airplane and the Thunder Mustang type since 2003. All transpired during racing events, in the airport environment, with four occurring at RTS. All resulted in successful forced landings with either minor or no damage to the airplane. The most recent occurred in September 2017 when he was performing a qualification flight for the Air Races. On that occasion, the engine lost partial engine power during takeoff and the pilot performed a 180° return to landing.

None of the events were as a result of a failure of the serpentine belt or any of its dependent components.

Similar Pulley Failure

Another pulley failure in a Thunder Mustang equipped with a Falconer 12-cylinder engine was examined by the NTSB Materials Laboratory following an accident (WPR15LA020). In that case, the attachment screws for the crankshaft pulley had unscrewed from their respective attachment holes, resulting in a similar separation of the serpentine belt. In that event, the belt damaged both engine ignition timing sensors, resulting a total loss of power. The engine had been overhauled about 190 flight hours before the accident, and although there was no conclusive evidence of thread locking compound having been used, the reason for the screws backing out could not be definitively determined.

Canopy

The airplane was equipped with a fixed forward windshield secured to the cabin structure and canopy bow. A sliding plexiglass canopy was attached to a carbon fiber/fiberglass frame. The canopy was operated from the inside by a hand-crank, which slid the assembly fore and aft on tracks built onto the fuselage. An external flush-slotted button on the right side of the fuselage was incorporated for manual operation of the canopy to allow access to the airplane. A canopy release handle, operable from inside the airplane, was provided to release the entire canopy from the tracks in the event of an emergency.

Examination revealed that the canopy bow structure had collapsed during the nose-over event, which, along with the failure of the vertical stabilizer, resulted in the canopy fragmenting and the canopy frame and deck resting level and flush with the ground. Neither the pilot nor passenger seats were equipped with any form of head support.

The canopy bow and supporting airframe structure was examined by an FAA Designated Engineering Representative. The engineer noted that plies in the assemblies had sheared adjacent to the mounting screws. She could not find any evidence that either the canopy or windshield bows were designed to be structural elements, and noted sporadic voids and evidence of resin richness within both.

Members of the TBG stated that it was their understanding that the canopy bow was supportive in nature, but no build documentation could be located to indicate this. Since the accident, some Thunder Mustangs have been retrofitted to provide additional rollover support.

Administrative Information

Investigator In Charge (IIC):	Simpson, Eliott
Additional Participating Persons:	Donald F Morgan; Federal Aviation Adminstration FSDO; Reno, NV Les Doud; Hartzell Propeller / Hartzell Engine Technologies; Montgomery, AL Fred Roscher; 51 Aero; Reno, NV
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Note:	The NTSB traveled to the scene of this accident.
Investigation Docket:	https://data.ntsb.gov/Docket?ProjectID=97148