Aviation Investigation Final Report

Location:	Sioux City, Iowa	**Incident Number:**	ENG23LA030
Date & Time:	June 17, 2023, 10:59 Local	**Registration:**	N926TT
Aircraft:	GULFSTREAM AEROSPACE G-IV	**Aircraft Damage:**	Minor
Defining Event:	Powerplant sys/comp malf/fail	**Injuries:**	9 None
Flight Conducted Under:	Part 135: Air taxi & commuter - Non-scheduled		

Analysis

The No. 2 (right) engine failure was caused by a spinner fairing separation due to fatigue cracks that originated from the heat affected zone of a tack weld that secured a spacer to the aft side of the fairing. The separated fairing impacted the leading edge of the fan blades and the inner barrel of the fan case and inlet cowl and fractured one fan blade (position 7) at the midspan. The subsequent fan imbalance resulted in severe vibrations that caused an anti-ice air line b-nut connector to back off, the P3 limiter to separate from the fuel flow regulator (FFR) at the mating flange, and a fuel line fracture at the acceleration reset solenoid. The fuel line fracture at the acceleration reset solenoid resulted in a fuel leak that persisted until the airplane landed. There was no evidence of undercowl fire or thermal damage on the engine or nacelle.

The flight crew reported temporary difficulty moving the No. 2 engine fuel shutoff cock (SOC) to the closed position and advancing the No. 1 (left) engine throttle from the idle position following the engine failure. The No. 2 engine fuel SOC and No. 1 engine throttle were cycled multiple times, and the associated linkages to the engine were inspected with no indications of binding, deformation, or other anomalies. Rolls-Royce and Gulfstream reviewed their system designs and did not identify an interlock or other mechanism that would have prevented normal operation during the incident flight.

The operator was in compliance with the regular spinner fairing inspection interval in accordance with the aircraft maintenance manual (AMM) and the last inspection was performed in October 2022, 542.2 hours before the incident flight. The AMM procedures at the time of the inspection did not include a step to remove the spinner fairing from the nose cone to perform a 360 degree visual inspection. The origin of all Rolls-Royce Tay model spinner fairing crack findings to date has been the heat affected zone of the tack welds that secure spacers to the aft side of the fairing, and therefore, early crack detection would have only been

possible if the spinner fairing was removed to inspect the aft side. It is unknown if the crack on the incident spinner fairing had grown to where it was visible on the forward side of the fairing during the October 2022 inspection. The inspection procedures were revised in October 2023 to incorporate removal of the spinner fairing in response to this incident.

Probable Cause and Findings

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

A No. 2 (right) engine failure due to a spinner fairing separation and subsequent impact with the fan blades that resulted in a midspan fracture of one fan blade. The spinner fairing separated as a result of a fatigue crack that originated from the heat affected zone of a tack weld that secured a spacer to the aft side of the fairing. Contributing to the incident was inadequate spinner fairing inspection procedures that did not require removal of the spinner fairing to inspect the aft side for earlier detection of crack indications.

Findings

Aircraft	Air inlet section (core eng) - Failure
Aircraft	Compressor section - Failure
Aircraft	Air inlet section (core eng) - Fatigue/wear/corrosion
Aircraft	Fuel distribution - Failure
Aircraft	(general) - Inadequate inspection

Factual Information

History of Flight

Enroute-change of cruise level	Powerplant sys/comp malf/fail (Defining event)

History of Flight

On June 17, 2023, about 1059 central daylight time (CDT), a Gulfstream G-IV, N926TT, equipped with two Rolls-Royce Tay 611-8 turbofan engines, operated by Planet 9 Private Air, LLC, experienced a No. 2 (right) engine failure shortly after beginning a step climb at FL400. The flight crew secured the No. 2 engine, declared an emergency, and diverted the airplane to Sioux Gateway Airport (SUX), Sioux City, Iowa where they made an uneventful single engine landing. There were no injuries reported. The airplane was operated as a Title 14 *Code of Federal Regulations* Part 135 flight from Philadelphia International Airport (PHL), Philadelphia, Pennsylvania to Charles M. Schulz Sonoma County Airport (STS), Santa Rosa, California.

Damage to the Airplane

There were multiple small impacts on the right wing that extended up to approximately 60 inches forward of the No. 2 engine inlet cowl leading edge lip. One impact on the right wing flap penetrated the wing skin. Additional small impact marks were observed on fuselage inboard of the engine, on the aft right window, and on the leading edge of the right horizontal stabilizer.

Test And Research

No. 2 Engine Nacelle Examination

The No. 2 engine inlet cowl had multiple acoustic liner impact gouges into the honeycomb structure, 360 degrees around the circumference. The impact damage was most severe from the fan blade path leading edge to approximately 12 inches forward of the fan blades. There was a rounded slice at the 8 o'clock position that had an arc length of approximately 15 inches. The inlet cowl had a penetration at the 1 o'clock position that measured approximately 12 inches circumferentially by 7 inches axially at the widest points. The penetration extended axially from the inlet cowl bulkhead to approximately 2 inches forward of the inlet cowl-to-fan case flange (Photo 1). The inlet cowl composite and metal material around the hole was petaled radially outward. There were two additional small inlet cowl penetrations at the 3 o'clock and 10 o'clock positions. The penetration at the 3 o'clock position measured approximately 0.5 inch axially by 2 inches circumferentially and extended forward from the inlet cowl-to-fan case flange. The fan cowl metal and thermal blanket insulation around the hole were displaced radially outward. The

small penetration at the 10 o'clock position was located on the inlet cowl-to-fan case flange. Light was barely visible through the impact and there was no evidence of material escape.

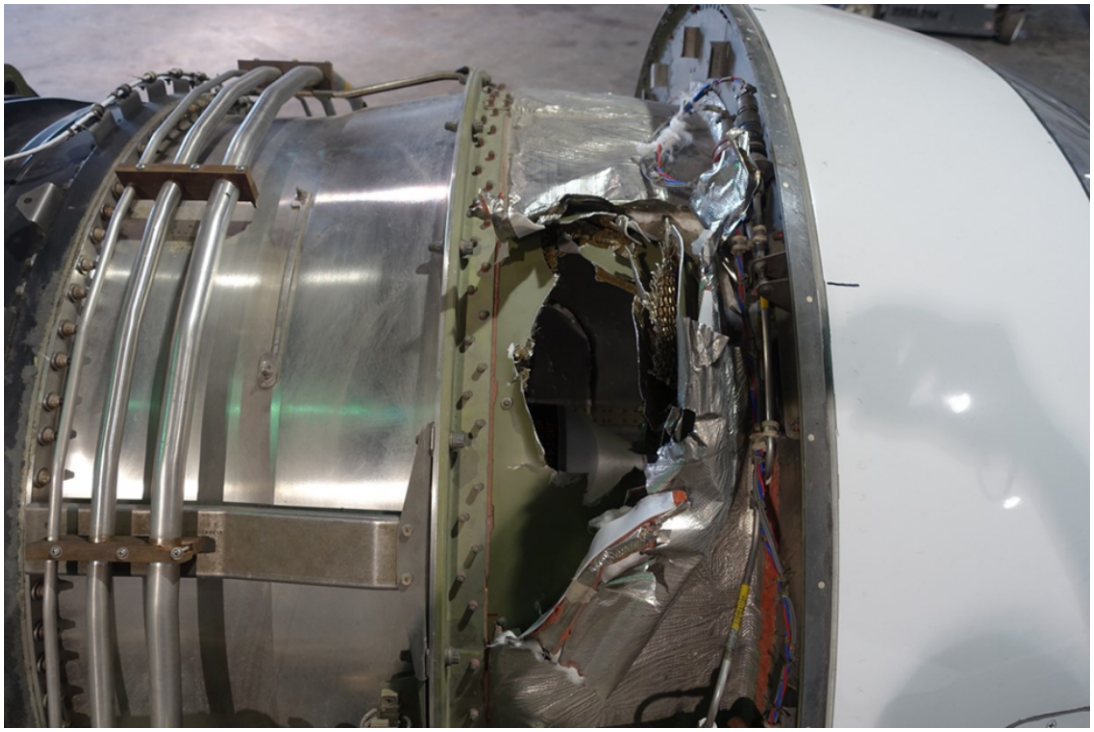

Photo 1- Inlet Cowl Penetration, 1 o'clock Position

No. 2 Engine, Rolls-Royce Tay 611-8, Serial Number, 16870, Examination

The No. 2 engine was removed from the airplane with a forklift crane and placed in a shipping stand for visual examination. There was no evidence of undercowl fire or thermal damage. The fan spinner fairing had separated and was missing. The three fairing attaching bolts had fragments of the fairing still secured under the bolt heads (Photo 2). The fan blades all exhibited leading edge hard body impact damage, tearing, and materials loss along the full blade span (Photo 3). One fan blade, identified as blade position 7 on the blade platform, was separated at the midspan. The released portion of the blade was contained within the fan case and was recovered from the space forward of the fan outlet guide vanes. The fan blade attrition lining had heavy 360 degree rub and impact damage. The ice resistant liner aft of the fan blade plane of rotation also exhibited 360 degree impact damage and was missing material at multiple locations. The visible intermediate pressure compressor (IPC) blades had leading and trailing edge nicks and the blade tips had heavy rub/uneven wear consistent with an impact and operation with a significant out-of-balance.

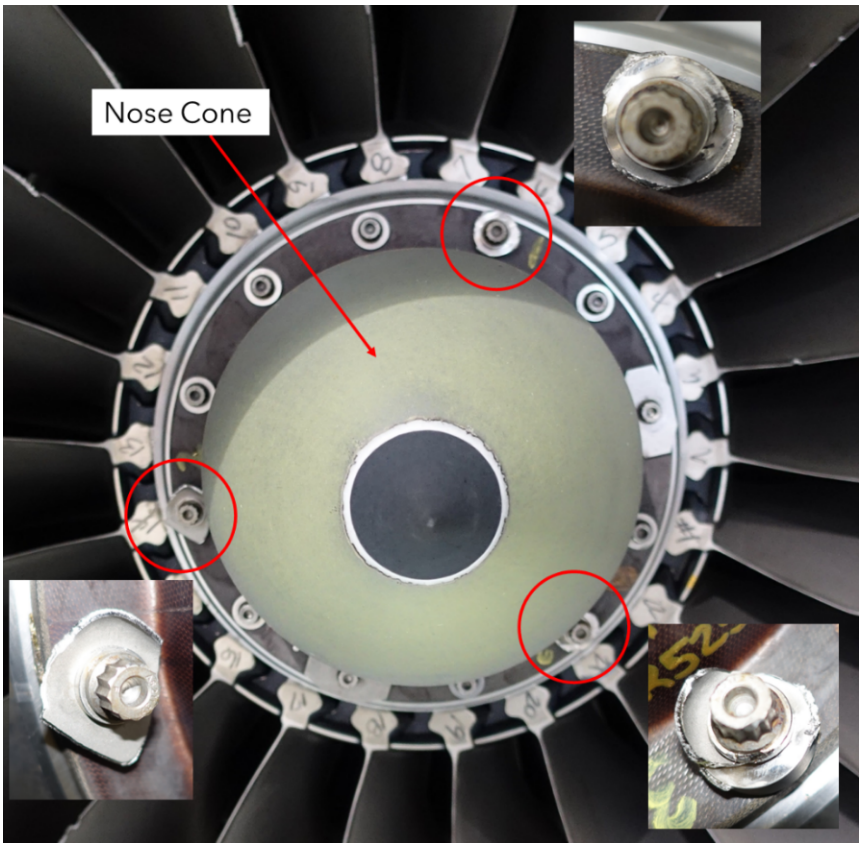

Photo 2- Spinner Fairing Separated, Fairing Fragments Under Attaching Bolts

Photo 3- Fan Blade Damage, Fan Blade Position 7 Midspan Separation

An anti-ice servo air line b-nut connector was backed off at the 2 o’clock position. Immediately below the backed off b-nut connector, the air line was fractured at the boss weld into the main bleed air duct. The P3 limiter, attached to the fuel flow regulator (FFR) and situated at the 7 o'clock position, was separated at the mating flange. There are three connecting bolts holding the component onto the FFR, two of the bolts were broken and one bolt had backed off. A pressure fuel line off the acceleration reset solenoid was fractured. The fractured line was located at the 8 o’clock position on the bypass case. There was no visual evidence of fuel streaking on the left side of the engine.

Materials Analysis

The recovered spinner fairing attaching hardware including the metal fragments under the attaching bolt heads, all fan blades, and the recovered fan blade position 7 fan blade tip fragments were shipped to the Rolls-Royce Deutschland Ltd. & Co. KG Materials Laboratory in Dahlewitz, Germany for failure analysis.

The Materials Laboratory identified fatigue cracks on two of the three bolt hole fixture pockets that initiated in the heat affected zone of the tack welds that hold the fairing spacer in position. The analysis could not determine if the fatigue mode was high cycle fatigue (HCF) or low cycle fatigue (LCF) and was likely a combination of both. The tack welds on each of the three spinner fairing bolt assemblies were greater than 10mm (millimeters) in length with visually good quality and no evidence of weld voids or other anomalies. Fairing bolt assembly 2, spot weld 2 was sectioned to perform a microscopic examination of the fairing and washer material microstructure. The depth of the weld influence was measured approximately 3.6 mm and the microstructure of both the spinner fairing sheet metal or washer experienced significant grain growth, which was considered typical of a normal weld in this location. Scanning Electron Microscopy using Energy Dispersive X-ray Spectroscopy (SEM/EDS) of the spinner fairing identified it to be consistent with Titanium (Ti) 6/4 as specified in the engineering drawing.

The fracture surfaces of fan blade position 7 were approximately 7.56 inches-8.66 inches (192mm-220mm) above the platform. The fracture surfaces were consistent with forced rupture (overload) originating from a leading edge impact. SEM/EDS analysis confirmed the fan blade material was consistent with Ti 6/4 as specified on the part drawing.

Spinner Fairing Modal Analysis Testing

Modal impact testing (hammer test) was performed on a spinner fairing in multiple configurations with and without fan hub and nose cone attaching hardware. The testing identified that the spinner fairing's natural frequency is close to a non-integral fan blade vibration mode that is a high altitude speed related excitation and is transmitted to the spinner fairing through pressure fluctuations. Variables that affect the fan blade vibration mode include fan blade leading edge shape, fan pressure ratio, and fan speed. Rolls-Royce operating history has shown that manufacturing variability causes some fan blade sets to excite the spinner fairing 1st natural frequency while others do not.

The testing also identified a fan blade mode that crosses at 70% N1. The 70% N1 crossing is mostly encountered as a transient during acceleration to takeoff power. It can also occur during ground operations in a crosswind, but there is no evidence of dwell during normal engine operation.

Testing and fleet operational history have also shown that the gap between the spinner fairing, and nose cone can also affect the spinner fairing vibratory response. Rolls-Royce released Notice to Operators (NTO) 38, in August 1997, to recommend replacement of the

nose cone on engines where spinner fairing cracks were identified. Nose cone replacement has been shown to be effective at detuning spinner fairing vibration. In cases where the nose cone has been replaced, there have been no known further instances of fairing cracking.

Spinner Fairing Inspection

Different variants of the Tay engine are used for corporate operations (e.g., Tay 611-8, on Gulfstream G-IV) and regional operations (e.g., Tay 610-15, on Fokker 100), although they all share similar turbomachinery. For the Gulfstream G-IV/TAY611-8, operated by Planet 9 Private Air, LLC (corporate operations), the spinner fairing inspection interval specific by the aircraft maintenance manual (AMM) is every 2000 hours. For regional operations the interval is every 600 cycles.

According to the engine logbook, the No. 2 engine spinner fairing was inspected by Planet 9 Private Air, LLC on October 12, 2022. The engine had accumulated approximately 542.2 hours since the spinner fairing inspection at the time of the incident event. The AMM procedure applicable at the time of the last inspection was 72-00-00, Engine - Inspection/Check, 1. Spinner Fairing- Detailed Inspection, instructed maintenance technicians to inspect for cracks and indentations emanating from spinner fairing bolt holes. The procedure did not call for removal of the spinner fairing from the nose cone.

According to Rolls-Royce, there have been field findings of spinner fairing cracks that have extended through the sheet metal until visible on the forward side of the fairing. The origin of the spinner fairing cracks in each crack findings to date has been the heat affected zone of the tack welds that secure the spacer to the aft side of the fairing and therefore the early stages of crack progression are only visible if the spinner fairing is removed from the nose cone. It is unknown if the spinner fairing crack on the incident engine had grown to where it would have been visible on the forward side of the fairing during the October 2022 inspection.

Corrective Actions

Rolls-Royce released Notice to Operators (NTO) number 155 on October 20, 2023, for all Tay engines. The NTO provided updated nose cone fairing inspection criteria to the engine maintenance manual (EMM) procedure to add an instruction to remove the spinner fairing to allow for inspection of the aft side. The NTO states, “This facilitates earlier detection of cracks by allowing inspection of the welds, where cracks are known to initiate.” A requirement was also added to inspect whenever the fairing is removed from the engine.

The EMM was updated to recommend a one-time inspection of spinner fairings if the engine previously had a fairing replaced due to cracking after 150 hours (corporate operations) or 50 cycles (regional operations).

Rolls-Royce has begun redesign effort on the spinner fairing to replace the welded fairing spacer with a bonded spacer design. As of July 2024, the design concept has been approved and Rolls-Royce is currently working to identify a manufacturer. The redesigned spinner fairing release date is yet to be determined and it will be incorporated through attrition rather than as a mandatory replacement campaign.

Information

Certificate:	**Age:**
Airplane Rating(s):	**Seat Occupied:**
Other Aircraft Rating(s):	**Restraint Used:**
Instrument Rating(s):	**Second Pilot Present:**
Instructor Rating(s):	**Toxicology Performed:**
Medical Certification:	**Last FAA Medical Exam:**
Occupational Pilot:	**Last Flight Review or Equivalent:**
Flight Time:	

Aircraft and Owner/Operator Information

Aircraft Make:	GULFSTREAM AEROSPACE	**Registration:**	N926TT
Model/Series:	G-IV	**Aircraft Category:**	Airplane
Year of Manufacture:	1999	**Amateur Built:**	
Airworthiness Certificate:	Normal	**Serial Number:**	1372
Landing Gear Type:	Retractable - Tricycle	**Seats:**	22
Date/Type of Last Inspection:	June 16, 2023 Continuous airworthiness	**Certified Max Gross Wt.:**	
Time Since Last Inspection:		**Engines:**	2 Turbo fan
Airframe Total Time:	16893.4 Hrs at time of accident	**Engine Manufacturer:**	ROLLS-ROYC
ELT:	Installed, not activated	**Engine Model/Series:**	TAY 611SER
Registered Owner:	SN 1372 LLC	**Rated Power:**	13850 Lbs thrust
Operator:	Planet 9 Private Air, LLC	**Operating Certificate(s) Held:**	On-demand air taxi (135)

Meteorological Information and Flight Plan

Conditions at Accident Site:	Visual (VMC)	**Condition of Light:**	Day
Observation Facility, Elevation:	KSUX	**Distance from Accident Site:**	
Observation Time:		**Direction from Accident Site:**	
Lowest Cloud Condition:	Scattered / 8500 ft AGL	**Visibility**	6 miles
Lowest Ceiling:		**Visibility (RVR):**	
Wind Speed/Gusts:	3 knots /	**Turbulence Type Forecast/Actual:**	/
Wind Direction:		**Turbulence Severity Forecast/Actual:**	/
Altimeter Setting:	29.88 inches Hg	**Temperature/Dew Point:**	23°C / 19°C
Precipitation and Obscuration:			
Departure Point:	Philadelphia, PA (KPHL)	**Type of Flight Plan Filed:**	IFR
Destination:	Sonoma, CA (KSUS)	**Type of Clearance:**	VFR;IFR
Departure Time:		**Type of Airspace:**	

Wreckage and Impact Information

Crew Injuries:	3 None	**Aircraft Damage:**	Minor
Passenger Injuries:	6 None	**Aircraft Fire:**	None
Ground Injuries:		**Aircraft Explosion:**	None
Total Injuries:	9 None	**Latitude, Longitude:**	42.398489,-96.382152(est)

Administrative Information

Investigator In Charge (IIC):	Hunsberger, Robert
Additional Participating Persons:	Matthew Rigsby; FAA AVP-100; Fort Worth, TX Filippo Ventura; Gulfstream; Savannah, GA Nicholas Shepler; Rolls Royce; Indianapolis, IN David Denham; Rolls Royce; Bristol, OF Thomas Karge; BFU- Germany; Braunschweig, OF Henrik Thorsell; Planet 9 Private Air, LLC; London, OF Lisa Fitzsimons; UK-AAIB; Hampshire, OF
Original Publish Date:	July 31, 2024
Last Revision Date:	July 31, 2024
Investigation Class:	Class 3
Note:	The NTSB did not travel to the scene of this incident.
Investigation Docket:	https://data.ntsb.gov/Docket?ProjectID=192429