الهيئة العامة للطيران المدني
GENERAL CIVIL AVIATION AUTHORITY

United Arab Emirates

Air Accident Investigation Sector

Serious Incident

– Summary Report –

AAIS Case Nº AIFN/0004/2019

Engine Failure after Takeoff

Operator:	Global Africa Aviation (PVT) Ltd
Make and Model:	McDonnell Douglas MD-11F
Nationality and Registration:	Zimbabwe, Z-GAA
Place of Occurrence:	Al Maktoum International Airport
State of Occurrence:	The United Arab Emirates
Date of Occurrence:	20 January 2019

This Investigation was conducted by the Air Accident Investigation Sector of the United Arab Emirates pursuant to Civil Aviation Law No. 20 of 1991, in compliance with Air Accident and Incident Investigation Regulations, and in conformance with the provisions of Annex 13 to the Convention on International Civil Aviation.

This Investigation was conducted independently and without prejudice. The sole objective of the investigation is to prevent future aircraft accidents and incidents. It is not the purpose of this activity to apportion blame or liability.

The Air Accident Investigation Sector issued this Summary Report in accordance with national and international standards and best practice. Consultation with applicable stakeholders, and consideration of their comments, took place prior to the publication of this Report.

The Summary Report is publicly available at:

http://www.gcaa.gov.ae/en/epublication/pages/investigationReport.aspx

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Investigation Process

The Serious Incident involved a McDonnell Douglas MD-11F aircraft, registration Z-GAA, and was notified by the Al Maktoum International Airport Safety Department to the AAIS Duty Investigator by phone to the Hotline Number +971 50 641 4667.

After the initial on-site Investigation phase, which identified severe damage to the No.1 engine and impact damage to the Aircraft wing, the occurrence was classified as a 'serious incident'.

The scope of this Investigation is limited to the events leading up to the occurrence; no in-depth analysis of non-contributing factors was undertaken.

Notes:

1. Whenever the following words are mentioned in this Report with first capital letter, they shall mean the following:
   - (Aircraft). The aircraft involved in this serious incident
   - (Commander). The commander of the serious incident flight
   - (Copilot). The copilot of the serious incident flight
   - (Incident). The serious incident that is the subject of this Summary Report
   - (Investigation). The investigation into the circumstances of this serious incident
   - (Operator). Global Africa Aviation
   - (Report). This Summary Report.
2. Photos and figures used in this Summary Report are taken from different sources and are adjusted from the original for the sole purpose to improve the clarity of the
3. Report. Modifications to images used in this Summary Report are limited to cropping, magnification, file compression, or enhancement of colour, brightness, contrast, or addition of text boxes, arrows or lines.
4. The format of this Summary Report is an adaptation of Annex 13 Final Report format to the circumstances of this Incident.

Factual Information

History of the Incident

On 20 January 2019, a Global Africa Aviation cargo flight GA3036 operated by a McDonnell Douglas MD-11F Aircraft, registration Z-GAA, departed from Al Maktoum International Airport (OMDW), the United Arab Emirates, destined for Noi Bai International Airport (VVNB), Vietnam.

The Copilot performed the pre-flight walk-around inspection without finding any discrepancies.

The Commander occupied the left seat and was the pilot flying. The Copilot was the pilot monitoring. Two engineers and a loadmaster were seated in the jumpseats in the cockpit.

The Aircraft taxied from parking stand S326 to runway 30, and the take-off roll commenced at 1034 local time and was uneventful. According to the Commander, during the climb at approximately 2,100 feet above ground level (AGL), a loud noise was heard.

Analysis of data downloaded from the Aircraft flight data recorder indicated that following the loud noise, the Aircraft yawed to the left and the No.1 engine exhaust gas temperature started to rise.

The Commander levelled the Aircraft off at 2,800 feet (AGL), retarded the No.1 engine thrust lever, and followed the *quick reference handbook* checklist for an engine failure. He shut the engine down and discharged the No.1 engine fire extinguisher.

The Commander declared a PAN PAN and advised air traffic control (ATC) that GA3036 was returning to OMDW, and requested vectors to runway 30 with a 15 nautical mile final approach. (Figure 1)

Figure 1. Incident flight path [Source: Flightradar 24]

On completing the *After-Take-Off Checklist*, the flight crew prepared the Aircraft for landing by following the *Landing Checklist* and performing a landing briefing.

The Aircraft landed uneventfully on runway 30 after a flight time of 17 minutes.

As a precaution, airport fire services followed the Aircraft to parking stand S326.

No fire was evident during the Incident.

Damage to Aircraft and Property

After the Aircraft was parked at the stand and the engines were shut down, an external inspection of engine No.1 was performed by the flight crew and engineers.

There was no visible damage to the engine cowling, engine intake or fan blades. An inspection of the engine exhaust identified that the low pressure turbine had suffered extensive damage.

Liberated engine debris exited the exhaust case and damaged the acoustic panel. (Figure 2)

Figure 2. Damage to the No.1 engine turbine and exhaust case acoustic panel, and turbine debris

Further impact damage was observed at the left wing inboard flap-hinge fairing and the underside of the left wing outboard flap assembly outboard of wing station 486. Impact marks were evident on the lower surfaces of the left inboard aileron and lower wing panels 541FB and 541JB. The airport ground operation services performed a runway inspection and collected numerous pieces of engine debris from the end of runway 30. No damage to property or to the environment was reported. (Figure 3)

Figure 3. Debris collected from the runway

Personnel Information

The Commander held an Air Transport Pilot License (ATPL) issued by the Civil Aviation Authority of Zimbabwe. He had flown a total of 10,503 flight hours, including 3,914 hours on the McDonnell Douglas MD-11.

The Copilot held an ATPL issued by the Civil Aviation Authority of Zimbabwe. He had flown a total of 13,658 flight hours, including 2,533 hours on the McDonnell Douglas MD-11.

Both pilots held valid aviation medical certificates and had completed their most recent safety and emergency procedures training on 19 October 2018.

Operator Information

The Operator was based in Harare, Zimbabwe, and operated two McDonnell Douglas MD-11F aircraft, certified and registered by the Civil Aviation Authority of Zimbabwe. Both Aircraft were leased from Sky Holding Company LLC which was based in the United States.

The lease contract stipulated that the Operator was responsible for the continuing airworthiness of the Aircraft.

Aircraft Information

The Aircraft was a McDonnell Douglas MD-11F with a maximum take-off weight of 285,990 kg. It was fitted with three Pratt & Whitney PW4000-94 engines and was manufactured in 1992. (Figure 4)

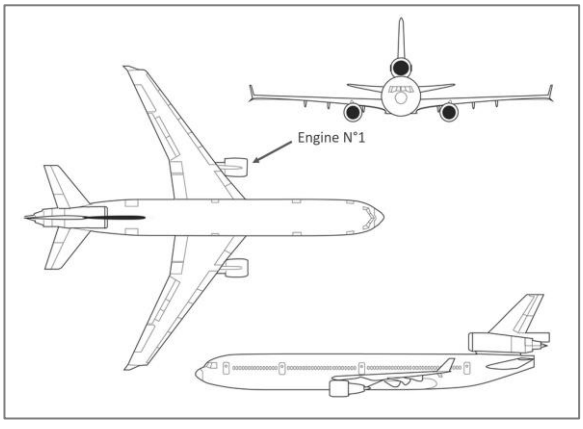

Figure 4. MD-11 engine locations
[Source: Boeing]

Since 1997, the MD-11 aircraft was manufactured by Boeing Commercial Airplanes, a division of the Boeing Company, which currently provides technical support to the operators.

At the time of the Incident, the Aircraft had accumulated 73,964 flight hours on 13,896 flights. The last major check was completed in March 2018, 1,522 hours and 348 flights prior to the Incident flight.

At the time of the Incident, the Aircraft was not carrying any cargo and the take-off weight was 185,074 kg.

General Engine Information

The PW4000 engine is a high-bypass, two-spool, axial flow turbofan engine with a high compression ratio. It is designed with a 16-stage compressor, an annular combustion chamber, and a six-stage turbine. (Figure 5)

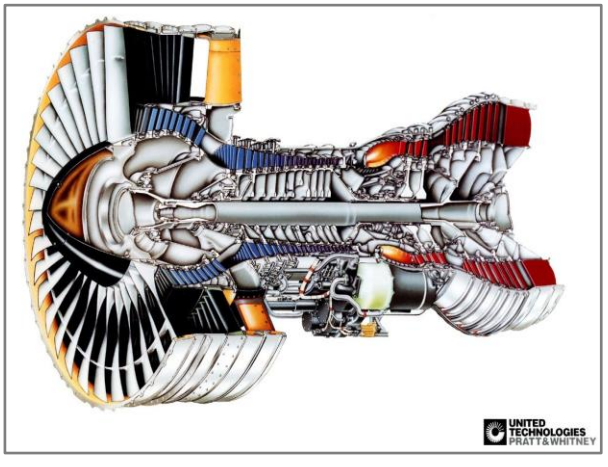

Figure 5. PW400-94 Engine [Source: Pratt & Whitney]

The low pressure system consists of a five-stage low pressure compressor and a four-stage low pressure turbine. The low pressure system is mechanically independent from the high pressure system, which consists of an eleven-stage high pressure compressor and a two-stage high pressure turbine. Each stage consists of a row of rotor blades and a row of stator vanes.

The first stage of the low pressure compressor rotor consists of fan blades which direct air through the fan duct and also direct air into the low pressure compressor.

The duct between the 2nd stage high pressure turbine and the 3rd stage low pressure turbine, the transition duct, contains replaceable outer duct segments to deflect the hot gas exiting the high pressure turbine. (Figure 6)

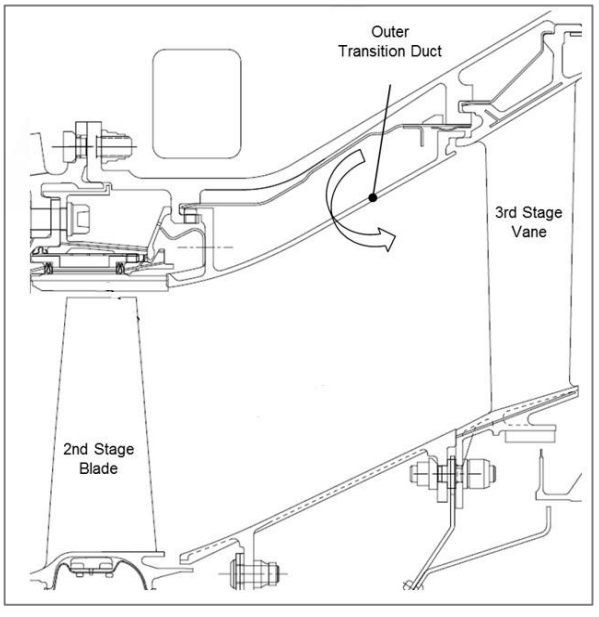

Figure 6. PW4000 Outer transition duct (3rd stage low pressure turbine duct segments) [Source: Pratt & Whitney]

No.1 Engine Information

The engine was installed on 20 March 2011 following a shop visit. It had accumulated 9,114 hours and 2,143 cycles since installation.

Although, at the time of the Incident, the engine had accumulated a total of 61,211 hours and 11,649 cycles since new, some life limited components had been replaced by components with a higher utilization. The low pressure compressor, for example, had accumulated 14,328 cycles at the time of the Incident and was scheduled for a shop visit in 672 cycles.

The Investigation could not determine when the transition duct was fitted to the engine but the records showed that it had accumulated 2,139 cycles more than the engine itself.

According to the Operator, the last scheduled engine boroscope inspection was conducted on 3 November 2018, 440 hours and 96 cycles prior to the Incident.

Engine Failure Procedures

The MD-11 *quick reference handbook*, MD-11 QRH Section 5, dated 15 August 2018, provided the procedures for an engine fire or severe damage.

It requires that after the relevant engine throttle is retarded to 'Idle', the fuel switch is selected to 'off', the engine fire handle is pulled, and the relevant engine fire extinguisher bottle is discharged.

If after 30 seconds the ENGINE_FIRE alert remained displayed, a FIRE DET_FAIL is displayed, or severe engine damage is suspected, a second engine fire extinguisher bottle can be discharged. This was not required for the Incident.

Cockpit Voice Recorder

The Aircraft was fitted with a solid-state cockpit voice recorder (CVR) which was capable of recording approximately 30 minutes of each flight crewmember's microphone communications and also sounds recorded by the cockpit area microphone.

The CVR functioned normally and all recordings continued until the circuit breaker was manually tripped approximately 19 minutes after landing. This resulted in the deletion from the recording of the first six minutes of the incident flight, which included the time of the engine failure.

Aircraft Digital Flight Data Recorder

The Aircraft was fitted with a digital flight data recorder (DFDR). Aircraft and engine data for the Incident flight were recorded and successfully downloaded for analysis.

Aerodrome Information

Al Maktoum International Airport (OMDW) is certificated by the General Civil Aviation Authority of the United Arab Emirates, and is located 40 kilometers south of Dubai city.

The airport had one operational runway available in both directions as runways 30 and 12. From each threshold, both runways had an available maximum take-off length of 4,500 meters.

The airport rescue and firefighting services comply with Category 10 requirements of the Civil Aviation Regulations Part XI – *Aerodrome Emergency Services, Facilities and Equipment*. They also conform to ICAO Annex 14 – *Aerodromes Requirements*.

Communication

The CVR was downloaded and, together with a recording obtained from ATC, provided the Investigation with information regarding communications between the flight crewmembers and ATC.

Although the CVR recording covered only the last eleven minutes of the 17-minute flight, it was observed that the flight crewmember's communications during the incident were calm and clear.

The in-flight checklists were completed efficiently and a landing briefing was conducted.

After landing, the flight crew monitored the engine instruments and confirmed the safe condition of the No.1 engine. The Commander determined that discharging the second engine fire extinguisher was not necessary.

Additional Information

Relevant PW4000 Engine Airworthiness Directive AD 2012-22-16 and Service Bulletin PW4ENG 72-488

The engine manufacturer, Pratt & Whitney, identified that the riveted seal plates on the outer transition duct segments, also known as the 3rd stage low pressure turbine duct segments, may become loose and could be liberated into the low pressure turbine duct due to normal engine vibrations.

As a result, Service Bulletin PW4ENG 72-488, initially issued on 29 October 1993, required the identification and replacement of outer transition duct segments part numbers during the next low pressure turbine disassembly.

On 13 August 2009, revision 3 of the Service Bulletin changed the compliance from Category 8 to Category 6, which reads: "Do when the subassembly (e.g. modules, accessories, components, build groups) is disassembled sufficiently to give access to the changed part and to all changed spare parts."

The requirements of Pratt & Whitney Service Bulletin PW4ENG 72-488 became mandatory in 2012, after the Incident engine had been fitted to the Aircraft, as a result of the requirements of Federal Aviation Administration of the United States (FAA) Airworthiness Directive AD 2012-22-16. (Figure 7)

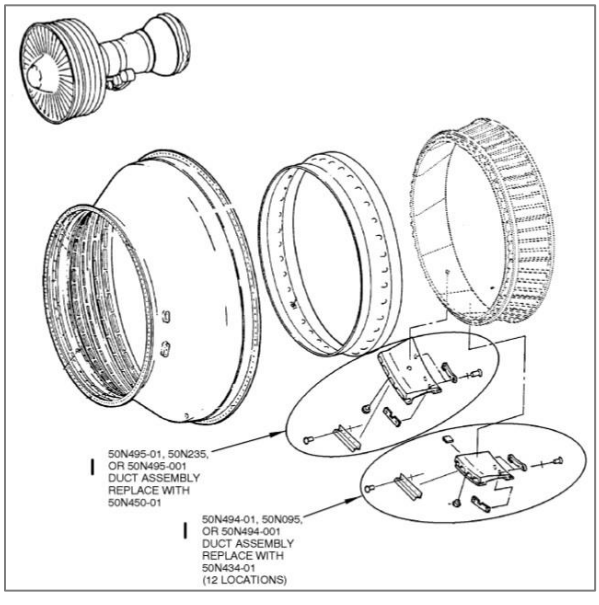

Figure 7. PW4000 3rd stage LPT duct replacement segments as per Service Bulletin [Source: Pratt & Whitney]

Airworthiness Directive AD 2012-22-16 was prompted by 16 previous reports of damaged or failed outer transition duct segments. Damage or failure of these duct segments can lead to "low pressure turbine damage, uncontained engine failures, and damage to the aircraft".

When the Airworthiness Directive was issued, the FAA determined that 151 engines installed on aircraft registered in the United States were affected.

The Airworthiness Directive compliance was specified as the next time the 3rd stage low pressure turbine was exposed during an engine shop visit, or "At the next piece-part exposure after the effective date of this AD". For the purpose of the Airworthiness Directive, the FAA defined a "piece-part exposure" a time, when "the 3rd stage LPT duct segment is removed from the engine and completely disassembled".

The Airworthiness Directive did not specify a compliance date or cycle limitation. However, it prohibited the installation of the pre-Service Bulletin duct segment part numbers.

The Operator tracked the utilization of the duct segments, which were life-limited to 15,000 cycles by the manufacturer, and calculated that at the current utilization, they would reach their life limit in July 2021.

According to the Operator, the duct segments were scheduled for replacement during the next engine shop visit, when some of the major engine components reached their life-limit of 15,000 cycles. The Operator calculated that this would occur on 3 February 2020, based on existing aircraft utilization of approximately 1.5 cycles per day. The outer transition duct segments were to be replaced during this shop visit with 540 cycles remaining.

Engine Damage Report

The Investigation conducted an on-wing boroscope inspection of the Accident engine in consultation with Pratt & Whitney and in accordance with Boeing MD-11 Aircraft Maintenance Manual chapter 72-00-06. The boroscope inspection was recorded and the footage was provided to Pratt & Whitney for analysis.

Pratt & Whitney identified a fragment of the outer transition duct segment resting on the 3rd stage low pressure turbine vanes, as depicted in figure 8, and concluded that the engine damage

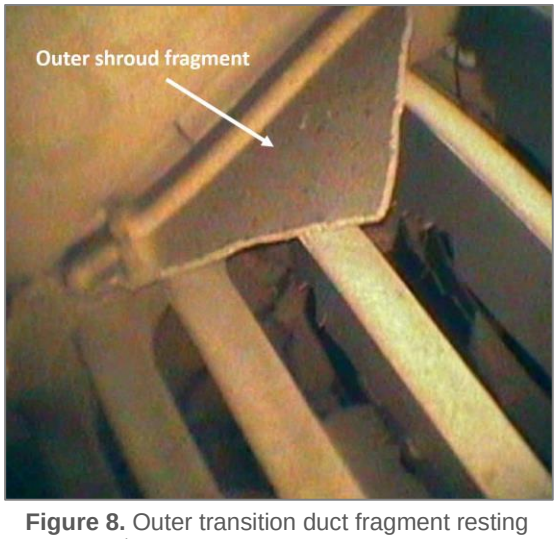

Figure 8. Outer transition duct fragment resting on 3rd stage low pressure turbine vanes

was most likely initiated by a failed outer transition duct segment.

The liberated duct segment initiated secondary damage to the 3rd stage low pressure turbine and, as a consequence, blades and vanes

of subsequent stages of the low pressure turbine were damaged and/or liberated.

Analysis

Flight Crew Performance

The cockpit voice recording and interviews with both flight crewmembers indicated adherence to the emergency procedures in the 17 minutes from takeoff to landing.

Checklists were completed, and communication amongst each crewmember was effective. Communication with ATC was conducted in a calm and efficient way. The Commander's decision to request a long approach provided sufficient time for the flight crew to brief for a missed-approach and the second-engine failure procedures, if these were required.

While the flight crew was assisted by a relatively light Aircraft, visual meteorological conditions during daytime, and the flight crew's alertness as per their self-assessment, the flight crew's management of the Incident emphasized the importance of regular emergency procedures training, 'buying time' to complete tasks, good communication, and strict adherence to emergency procedures.

Engine Failure

The analysis of the boroscope inspection by Pratt & Whitney identified the most likely cause of the engine failure.

The fragment found resting on the 3rd stage low pressure turbine vane was identified as a piece from the outer transition duct segment.

Engine records identified that the duct segments had not been replaced as per the 1993 Service Bulletin recommendations or the 2012 Airworthiness Directive mandated requirement, because at the time of the Incident, the transition duct had not reached its life-limit and, according to the Operator, was scheduled to be accessed in 672 cycles during the next scheduled engine shop visit.

Airworthiness Directive Compliance

Damage and failures of the outer transition duct segments had been documented since 1993 and resulted in Pratt & Whitney Service Bulletin SB PW4ENG 72-488. Airworthiness Directive AD 2012-22-16 followed in 2012, when 16 reports of damaged or failed duct segments were noted.

When the Airworthiness Directive was issued, the FAA estimated that 151 engines installed on US registered aircraft were affected.

The Airworthiness Directive was issued to prevent failure of the transition duct segments, which could lead to "low pressure turbine damage, uncontained engine failure, and damage to the aircraft".

Operators were required to remove duct segments identified by the Airworthiness Directive at the next "piece-part exposure".

At the time of the Incident, the replacement of the duct segments had been recommended 18 years previously with the initial issue of the Service Bulletin. When the Incident engine underwent a compressor overhaul in 2011, the Airworthiness Directive had not yet been published. Therefore, the replacement of the outer duct segments was not scheduled.

When the Airworthiness Directive was issued in 2012, the compliance requirement permitted operation of the suspect outer duct segments until their original service life-limit of 15,000 cycles, unless the transition duct was accessed during an engine shop visit, thus negating the pro-active replacement of the effected duct segments as recommended by the engine manufacturer.

Conclusions

General

From the evidence available, the following findings, causes, and contributing factors were made with respect to this Incident. These shall not be read as apportioning blame or liability to any organization or individual.

- **Findings.** Statements of all significant conditions, events or circumstances in this Incident. The findings are significant steps in this Incident sequence but they are not always causal or indicate deficiencies.
- **Causes.** Actions, omissions, events, conditions, or a combination thereof, which led to this Incident.
- **Contributing factors.** Actions, omissions, events, conditions, or a combination thereof, which, if eliminated, avoided or absent, would have reduced the probability of the Incident occurring, or mitigated the severity of the consequences of the Incident. The identification of contributing factors does not

imply the assignment of fault or the determination of administrative, civil or criminal liability.

Findings

(a) The Aircraft was certificated, equipped and maintained in accordance with the existing requirements of the Civil Aviation Regulations of Zimbabwe.

(b) The Aircraft was certified as being airworthy when dispatched for the flight.

(c) Taxi and takeoff were uneventful.

(d) At approximately 2,100 feet (AGL) both flight crewmembers reported hearing a loud noise.

(e) The flight crew followed the memory items and completed the "Engine Fire or Severe Damage" items from the *quick reference handbook* and engine No.1 was shut down.

(f) The Aircraft landed after 17 minutes without further incident.

(g) Engine turbine debris exited through the exhaust case, causing damage to the exhaust case acoustic panels.

(h) Turbine debris impacted the left wing inboard aileron, lower wing panels 541FB and 541JB, and the flap-hinge fairing resulting in damage to these areas.

(i) The engine failure was initiated by liberation of a 3rd stage low pressure turbine outer transition duct segment.

(j) A Service Bulletin addressing outer transition duct segment failures was issued by the manufacturer in 2009.

(k) Airworthiness Directive AD 2012-22-16 was issued by the FAA in 2012 and addressed outer transition duct segment failures.

(l) The Airworthiness Directive was scheduled for incorporation by the Operator during the next engine overhaul in February 2020.

(m) The outer transition duct segments remaining life at the next engine overhaul was approximately 540 cycles, or 3.6% of the total 15,000-cycle life-limit.

(n) There were no injuries as a result of the Incident.

Causes

The Air Accident Investigation Sector determines that the cause of the Incident was the liberation of an outer transition duct segment, located between the 2nd stage high pressure turbine blades and the 3rd stage low pressure turbine vanes, which initiated secondary engine turbine damage.

Contributing Factors to the Incident

The Air Accident Investigation Sector identifies the following contributing factors to the Incident:

- The Operator's assessment of the likelihood of an outer duct segment failure as described in Service Bulletin SB PW4ENG 72-488, and the decision to omit the duct segment replacement during the 2011 engine shop visit.
- The compliance requirement of the FAA for the replacement of the suspect outer duct segments identified in Airworthiness Directive AD 2012-22-16, which was described as "at the next piece-part exposure". This provided the option to operators to delay compliance with the Airworthiness Directive until the segment life-limits were reached.

Safety Recommendations

General

The safety recommendation listed in this Report is proposed according to paragraph 6.8 of Annex 13 to the Convention on International Civil Aviation, and is based on the conclusions of this Report.

The Air Accident Investigation Sector expects that all safety issues identified by the Investigation are addressed by the receiving States and organizations.

Summary Report Safety Recommendations

An Airworthiness Directive is a critical instrument intended to enhance air safety by mandating aircraft and engine maintenance or modifications to air operators.

The Investigation considers that an Airworthiness Directive compliance requirement that permits an operator to disregard the replacement of suspect parts by a selective overhaul schedule is not appropriate, when the possible consequences were "low pressure

turbine damage, uncontained engine failure, and damage to the airplane".

The Air Accident Investigation Sector recommends that the Federal Aviation Administration of the United States (FAA):

SR59/2020

Conduct a risk assessment and improve the process for determining the Airworthiness Directive compliance requirement which was described as *"next piece-part exposure",* to address the risk of operators selecting overhaul schedules which allow compliance deferral to the component life-limit.

This Summary Report is issued by:
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