Log # 2613

National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: January 15, 1998
In reply refer to: A-97-126 through -128

Honorable Jane F. Garvey
Administrator
Federal Aviation Administration
Washington, D.C. 20591

The National Transportation Safety Board is aware of four uncontained low pressure turbine (LPT) failures involving General Electric Aircraft Engines (GEAE) CF6-6 turbofan engines and two such failures involving GEAE CF6-50 turbofan engines. Five of the failures occurred in revenue service, and one failure occurred on an engine test stand. In each event, it was determined that the Stage 1 LPT disk had separated from the LPT rotor assembly because the Stage 1-2 disk flange bolts were fractured by loose debris tumbling in the cavity between the turbine mid-frame (TMF) and the LPT. The interior surfaces of the TMF LPT cavities also had extensive pockmark damage, which would indicate that the debris had been in the cavities for some time. The pockmark damage in the TMF LPT cavities occurs when the loose debris tumbles and impacts the inner surfaces during low rotational speeds. Although the resultant damage in most of the events has been limited to liberated turbine blade fragments penetrating the core cowl, one event resulted in the rupture of a Stage 1 LPT disk, pieces of which penetrated a fuel tank and initiated a fire.

On March 24, 1996, a GEAE CF6-50 engine on an Air France Boeing 747 had an uncontained failure of the No. 3 engine LPT during engine start at the gate at Charles de Gaulle International Airport, Paris, France. Examination of the engine showed that turbine blade fragments had penetrated the turbine case and core cowling. The investigation by the French Bureau Enquetes-Accidents (BEA) revealed that the Stage 1 LPT disk had separated from the Stage 2 disk flange, and the interior surface of the TMF LPT cavity was pockmarked with nicks and dents. One heavily battered TMF stud bolt and the fractured Stage 1-2 disk flange bolts were found in the cavity (see Figure 1). This engine had reportedly accumulated 612 cycles since the previous overhaul when work was accomplished in the TMF area.

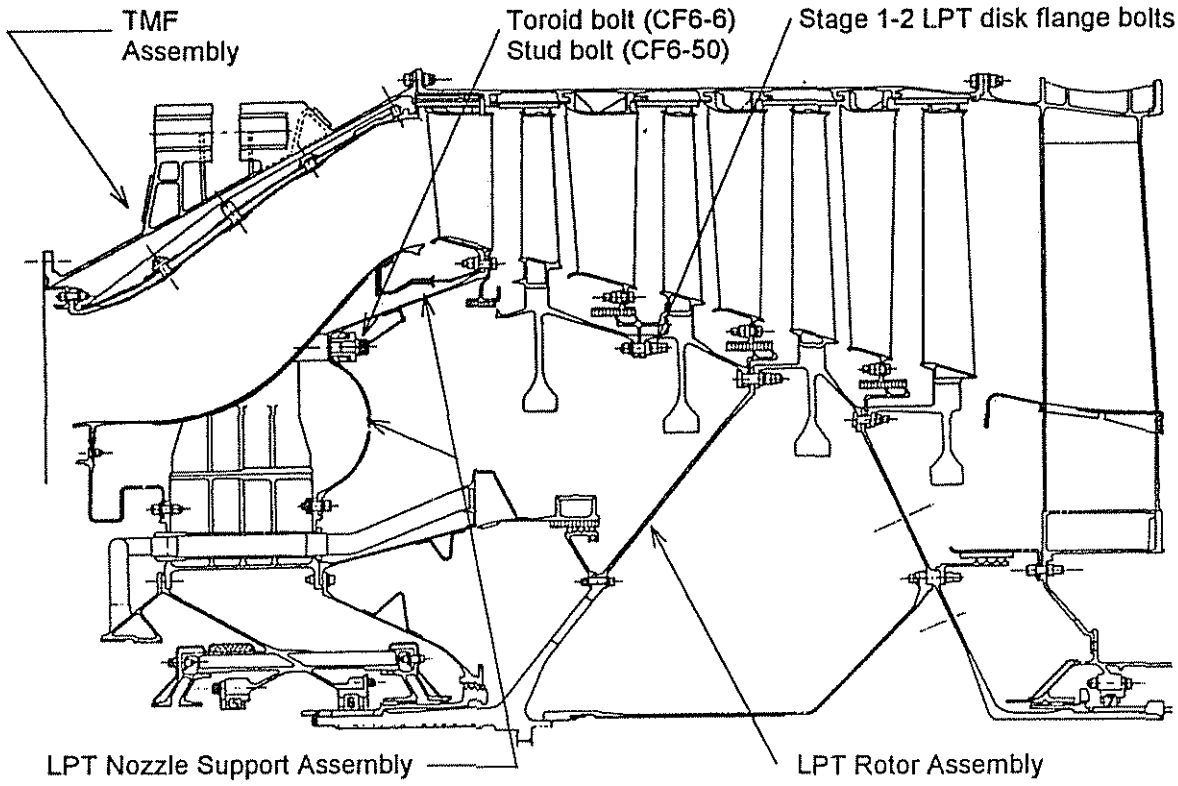

Figure 1. Cross section of low pressure turbine assembly

On May 1, 1995, the center engine of a United Airlines DC-10, equipped with GEAE CF6-6 engines, had an uncontained LPT failure during takeoff at Chicago's O'Hare International Airport.[1] The flightcrew reported that as the center engine N1 speed increased through 48 percent, they heard a "crack," followed by a fire warning light. The flightcrew rejected the takeoff at around 59 knots, discharged one fire bottle, and after ensuring that there was no fire, returned to the gate. Examination of the engine showed that turbine blade fragments had penetrated the turbine case and core cowl. The Safety Board's investigation found that the Stage 1 LPT disk had also separated from the Stage 2 disk, and that the interior of the TMF LPT cavity was heavily pockmarked with nicks and dents. One heavily battered TMF toroid bolt[2] and numerous fractured Stage 1-2 disk flange bolts were found loose in the cavity (see Figure 1). United Airlines records showed that this engine had accumulated 699 cycles since work was accomplished in the TMF area.

In March 1995, a GEAE CF6-6 engine on a Continental Airlines DC-10 had an uncontained LPT failure during takeoff from Narita International Airport, Tokyo, Japan. The flightcrew rejected the takeoff at around 90 knots. Examination of the engine found that the Stage 1 LPT disk had separated from the Stage 2 disk and that turbine blade fragments had penetrated the turbine case and core cowling. Although the cavity had pockmarks, such as those found in the other events, the cause of this damage remains unresolved because all of the toroid

[1] For more detailed information, see Brief of Incident CHI95IA142 (attached).
[2] The toroid refers to the doughnut shape of the inner portion of the LPT nozzle case.

bolts were in place and no foreign objects were found in the TMF LPT cavity. The engine had reportedly accumulated about 600 cycles since the last overhaul.

In 1972, a GEAE CF6-50 engine on an Air Florida DC-10 had an uncontained LPT failure that resulted in a wing fire during a rejected takeoff. The investigation revealed that the Stage 1 LPT disk had burst and that pieces of the disk had penetrated a fuel tank, initiating the fire. Disassembly of the engine showed evidence that a tool had been left in the TMF LPT cavity, breaking the Stage 1-2 disk flange bolts in a manner similar to the other events.

Also in 1972, a GEAE CF6-6 engine on an American Airlines DC-10 had an uncontained LPT failure during taxi. Disassembly of that engine also found evidence that a tool had been left in the TMF LPT cavity, breaking the Stage 1-2 disk flange bolts and releasing the Stage 1 disk.

In the early 1970s, a GEAE CF6-6 engine had an uncontained LPT failure during operation on a test stand. GEAE reported that the uncontained failure had occurred because a tool that had been left in the TMF LPT cavity had fractured the Stage 1-2 disk flange bolts, releasing the Stage 1 disk.

The toroid bolts used in the CF6-6 and the stud bolts used in CF6-50 secure the LPT nozzle support assembly to the TMF (see the cross section of the low pressure turbine shown in Figure 1).

In the CF6-6 engine, there are eight $^{3}/_{8}$-inch double hex head machine toroid bolts installed in threaded holes of the TMF. The bolt passes through a sleeve, sleeve spacer, two shim washers, and a spacer lug. As a result of two CF6-6 engine-contained LPT failures, in which the failure of the toroid bolt safety wire permitted the bolts to back out of the holes and damage the TMF LPT cavity, GEAE issued Service Bulletin (SB) 72-533 on August 27, 1975. The SB added an arm to the spacer lug to attach a second strand of safety wire to the toroid bolt to prevent the bolt from becoming loose (see the exploded view shown in Figure 2). The spacer lug and all of the associated hardware from the toroid bolt, which was found battered in the TMF LPT cavity of the United Airlines CF6-6 engine that failed at O'Hare, could not be identified among the debris that was found in the cavity. An examination of the seven remaining spacer lugs on this engine showed that they had the safety wire arms added, indicating that SB 72-533 had been accomplished.

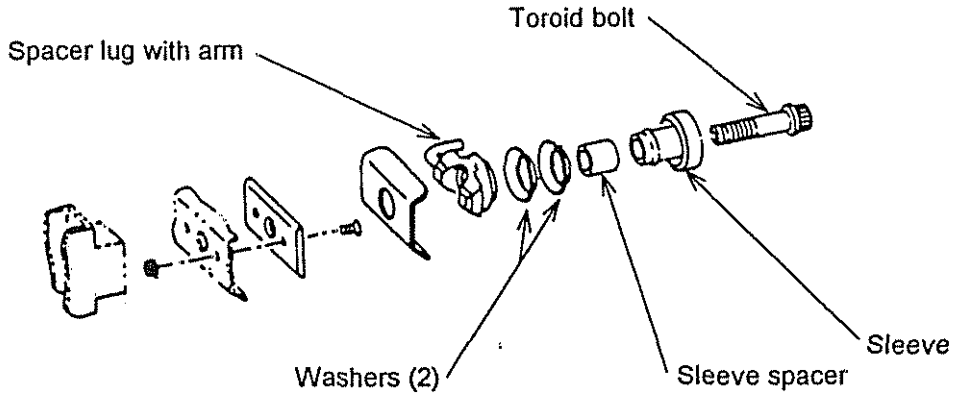

Figure 2. Exploded view of toroid bolt and associated hardware

The $^{3}/_{8}$-inch shouldered stud bolt is also installed into a hole in the TMF in a CF6-50 engine, with the shoulder of the bolt welded to the front side of the TMF. As with the toroid bolt on the CF6-6 engines, the stud bolt contains a similar stack of parts consisting of a sleeve, two shim washers, and the spacer lug; all of these parts are held in place with a self-locking nut. According to GEAE, the stud bolt design used in the CF6-50 engine TMFs was intended to be an improvement over the toroid bolt design for the CF6-6 engine (see the exploded view shown in Figure 3).

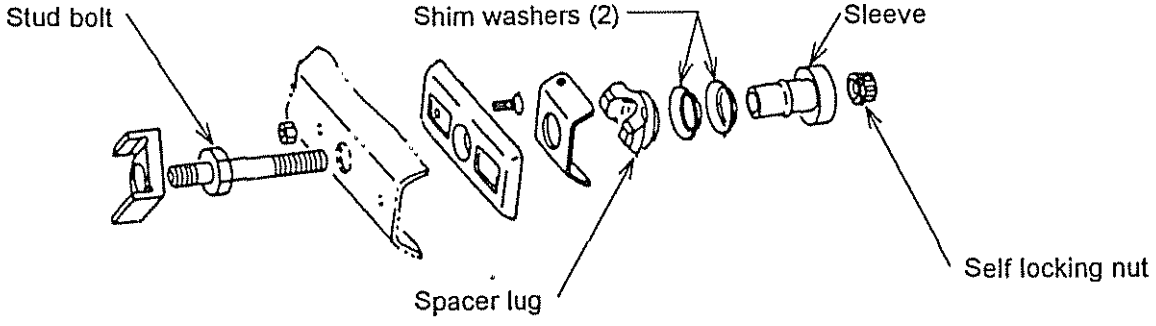

Figure 3. Exploded view of stud bolt and associated hardware

The Safety Board's investigation of the 1995 United Airlines LPT failure and a review of the 1996 Air France LPT failure indicate that introduction of the spacer lug arm for the CF6-6 engine by SB 72-533 and the CF6-50 stud bolt design are inadequate and did not, in the cited events, prevent the CF6-6 toroid bolts or CF6-50 stud bolts from becoming loose in the TMF LPT cavity. Although the damage to the airplane in most of the LPT failures was limited to holes in the engine core cowls, the Air Florida failure resulting in a Stage 1 LPT disk rupture, and pieces of the disk penetrating a fuel tank and initiating a fire, demonstrated that significant damage can occur with the loss of a TMF bolt. Therefore, the Safety Board believes that the FAA should require GEAE to develop an improved retention system for the CF6-6 and CF6-50 engine TMF toroid and stud bolts to prevent the release of the bolts into the TMF LPT cavity.

Additionally, the Safety Board's investigation of each of the events indicates that a loose object, such as a toroid bolt, stud bolt, or a tool, will tumble in the TMF LPT cavity only during

low speed rotation of the engine such as at start and shutdown. The loose objects will most likely become pinned against the rotating LPT rotor from the centrifugal forces of normal operation. The tumbling of the loose objects causes nicks and dents in the TMF LPT cavities, as well as fracturing of the Stage 1-2 LPT disk flange bolts. During low rotor speeds, the tumbling action should be audible from the exterior of the engine, and visible evidence of the impact marks should be apparent in the cavity. An aural (tinkle) test or a borescope examination for loose material in the TMF LPT cavity could identify an impending failure that is preceded by loose parts tumbling in that cavity. Therefore, the Safety Board believes that the FAA should require GEAE to develop and implement a repetitive aural or visual inspection procedure to check for loose material or impact damage in the TMF LPT cavities of CF6-6 and CF6-50 engines; the inspection should be repeated at appropriate intervals until an improved toroid or stud bolt retention system is developed.

A detailed examination of the seven remaining spacer lugs on the United Airlines CF6-6 engine showed that they had cracking in the welds that retained the arm to the base of the lug. United Airlines personnel stated that the CF6-6 TMF toroid bolts, associated hardware, and safety wire are not always replaced or inspected at every maintenance exposure. The CF6-50 engine has stud bolts, which according to GEAE are on-condition maintenance items that normally would not be given detailed inspections unless discrepancies were noted during visual examinations. Therefore, the Safety Board believes that the FAA should require GEAE to revise the CF6-6 engine manual to include an inspection of the toroid bolts and associated hardware, retorquing of the toroid bolts, and replacement of the safety wire that should be accomplished at each maintenance exposure. Further, the FAA should require GEAE to revise the CF6-50 engine manual to include an inspection of the stud bolt and associated hardware and retorquing of the self-locking nut on the stud bolt that should be accomplished at each maintenance exposure.

Therefore, the National Transportation Safety Board recommends that the Federal Aviation Administration:

Require General Electric Aircraft Engines to develop an improved retention system for the CF6-6 and CF6-50 engine turbine mid-frame (TMF) toroid and stud bolts to prevent the release of the bolts into the TMF low pressure turbine cavity. (A-97-126)

Require General Electric Aircraft Engines to develop and implement a repetitive aural or visual inspection procedure to check for loose material or impact damage in turbine mid-frame low pressure turbine cavities of CF6-6 and CF6-50 engines; the inspection should be repeated at appropriate intervals until an improved toroid or stud bolt retention system is developed. (A-97-127)

Require General Electric Aircraft Engine (GEAE) to revise the CF6-6 engine manual to include an inspection of the toroid bolts and associated hardware, retorquing of the toroid bolts, and replacement of the safety wire that should be accomplished at each maintenance exposure. Further, require GEAE to revise the CF6-50 engine manual to include an inspection of the stud bolt and associated

hardware and retorquing of the self-locking nut on the stud bolt that should be accomplished at each maintenance exposure. (A-97-128)

Chairman HALL, Vice Chairman FRANCIS, and Members HAMMERSCHMIDT, GOGLIA, and BLACK concurred in these recommendations.

By: Jim Hall
Chairman

National Transportation Safety Board
Washington, D.C. 20594

Brief of Incident

Adopted 04/18/1996

CHI95IA142
FILE NO. 5033 | 05/01/95 | CHICAGO, IL | AIRCRAFT REG. NO. N1811U | TIME (LOCAL) - 11:20 CDT

MAKE/MODEL - MCDONNELL DOUGLAS DC10-10
ENGINE MAKE/MODEL - CFM CF6-6
AIRCRAFT DAMAGE - Minor
NUMBER OF ENGINES - 3

	FATAL	SERIOUS	MINOR/NONE
CREW	0	0	12
PASS	0	0	180

OPERATING CERTIFICATES - Flag carrier/domestic
NAME OF CARRIER - UNITED AIRLINES
TYPE OF FLIGHT OPERATION - Scheduled
- Domestic
- Passenger

REGULATION FLIGHT CONDUCTED UNDER - 14 CFR 121

LAST DEPARTURE POINT - Same as Incident
DESTINATION - WASHINGTON, DC

AIRPORT PROXIMITY - On airstrip
AIRPORT NAME - O'HARE INTERNATIONAL
RUNWAY IDENTIFICATION - 09L
RUNWAY LENGTH/WIDTH (Feet) - 7967/ 150
RUNWAY SURFACE - Asphalt
RUNWAY SURFACE CONDITION - Dry

CONDITION OF LIGHT - Daylight

WEATHER INFO SOURCE - Weather observation facility

BASIC WEATHER - Visual (VMC)
LOWEST CEILING - None
VISIBILITY - 0015.000 SM
WIND DIR/SPEED - 070 /015 KTS
TEMPERATURE (F) - 51
OBSTR TO VISION - None
PRECIPITATION - None

PILOT-IN-COMMAND AGE - 56

CERTIFICATES/RATINGS
Airline transport, Flight instructor, Flight engineer
Single-engine land, Multiengine land
INSTRUMENT RATINGS
Airplane

FLIGHT TIME (Hours)

TOTAL ALL AIRCRAFT - 19011
LAST 90 DAYS - Unk/Nr
TOTAL MAKE/MODEL - 2909
TOTAL INSTRUMENT TIME - Unk/Nr

The flightcrew reported that during the application of takeoff power, when the throttles were in approximately the vertical position, the numbers 1 and 3 engines were indicating approximately 70% N1. The number 2 engine was indicating about 48% N1 and not accelerating. They heard a "crack" and aborted the takeoff. Examination of the engine revealed that the low pressure turbine (LPT) stage one disk had separated from the LPT rotor at the stage one to two flange joint. Seven intact toroid bolts and sets of associated hardware were recovered. No evidence of fatigue cracking or corrosion (pitting) was noted on any of the bolt pieces recovered from the engine. The shank of one of the toroid bolts exhibited significant damage. The lug arm, used for safetying the bolt, exhibited relatively minor damage. Examination of several of the lug arms revealed "noticeable wear patterns" and "crack arrest positions indicative of fatigue cracking." Statements by UAL maintenance personnel indicate failures of the toroid bolt safeties are occasionally discovered when the engines are disassembled for major overhaul.

CHI95IA142
FILE NO. 5033 05/01/95 CHICAGO,IL AIRCRAFT REG. NO. N1811U TIME (LOCAL) - 11:20 CDT

Occurrence# 1 LOSS OF ENGINE POWER(PARTIAL) - MECH FAILURE/MALF
Phase of Operation TAKEOFF - ABORTED

Findings
1. - 1 ENGINE
2. - TURBINE ASSEMBLY,AIR SEAL - DISCONNECTED
3. - PROCEDURE INADEQUATE - MANUFACTURER

The National Transportation Safety Board determines that the Probable Cause(s) of this Incident was: failure of the safety wire and/or safety wire lug arm on one of the stage one to two disk flange bolts due to an inadequate safetying method.