INCIDENT

Aircraft Type and Registration:	Fokker F27-500, EI-SMF
No & Type of Engines:	2 Rolls-Royce Dart 532-7 turboprop engines
Category:	1.1
Year of Manufacture:	1984
Date & Time (UTC):	8 September 2004 at 0114 hrs
Location:	Stansted Airport, Essex
Type of Flight:	Public Transport (Non revenue)
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Overheat and turbine damage to left engine
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	46 years
Commander's Flying Experience:	2,730 hours (of which 1,700 were on type) Last 90 days - 60 hours Last 28 days - 28 hours
Information Source:	AAIB Field Investigation

Synopsis

At approximately 75 kt on takeoff from Runway 05 at Stansted the aircraft deviated to the right but was recovered to the centreline by a reduction in power and use of rudder. When power was re-applied to continue the takeoff the aircraft turned significantly to the left and the takeoff was abandoned. As the aircraft came to a stop external indications lead the commander to believe that the left engine was on fire. The Airfield Fire and Rescue Service attended the scene and the left engine was successfully shutdown without further incident. Subsequent examination revealed that the left engine turbine had burnt out as a result of the left propeller being hung on the flight fine pitch stop at the time the throttle was re-opened. Furthermore, a defect was discovered in the Nose Wheel Steering (NWS) follow-up control valve that caused vibration of the NWS and damaged the dowel pins in the steering gearbox leading to erratic changes in the NWS datum making the aircraft difficult to steer.

History of flight

The crew positioned the aircraft from Paris to Exeter for a return cargo only flight to Stansted. The crew had noted a higher than normal level of vibration from the right engine but this was deemed to be acceptable and no source of the vibration could be identified during the subsequent ground inspection. The only 'Deferred Defect' recorded in the Technical Log and of relevance to the incident was: 'Nose wheel steering very sensitive' necessitating it to be operated in accordance with the Minimum Equipment List (MEL).

The flight from Exeter was normal and the aircraft landed at Stansted at 2309 hrs. The commander carried out the 'turn-round' inspection and supervised the refuelling whilst the First Officer (FO) remained on the aircraft preparing for the return flight to Exeter. The commander was to be the Pilot Flying (PF) for the sector. After a normal engine start the aircraft was pushed back off stand at 0002 hrs and taxied to hold at point 'HA1' for a flapless, rolling, dry (no water methenol injection) takeoff from Runway 05. The ATIS, timed at 2350 hrs, gave the surface wind as 050°/09 kt, visibility 10 km, few clouds at 900 feet, temperature 13°, dew point 12°C and a QNH 1034 mb.

Having held briefly to allow another aircraft to land, the aircraft lined up and held to allow the landing aircraft to clear the runway. When cleared for takeoff the commander increased power with his right hand whilst keeping his left on the nose wheel steering control. When the engines were stable he moved both power levers to the fully forward position setting take-off power which was confirmed by the FO. The aircraft accelerated normally but the nosewheel steering seemed sluggish. The FO called "60 kt" and confirmed both ASIs were indicating correctly. The commander removed his left hand from the steering control to the control column and shortly after the aircraft deviated sharply to the right migrating towards the edge of the runway. The commander reacted to the situation by applying left rudder and reducing power; more on the left engine than on the right.

Having contained the yaw to the right the commander re-applied full power but as he did so the aircraft yawed to the left, crossed the runway centreline and began to move towards the left side of the runway. The FO was unable to check the engine instruments but seeing the move to the left called "STOP STOP". The commander had however, already started to retard the power levers. Ground Fine pitch was selected and using positive braking the aircraft was brought to a stop. As the aircraft slowed the commander became aware of an orange glow originating outside the cockpit over his left shoulder. He believed this to be a fire in the left engine for he could see sparks emanating from the engine jet pipe. When the aircraft stopped the commander applied the parking brakes, the FO informed ATC of the situation and the Rescue and Fire Fighting Service (RFFS) attended the scene immediately. Meanwhile the commander moved the left engine fuel cock lever into the propeller feather gate and the left engine ran down; the sparks reducing as it did so. The crew could not recall the exact Jet Pipe Temperature (JPT) but they noted that the left engine JPT was indicating approximately 1,000°C rather than the normal 400°C.

Minimum Equipment List (MEL) requirements

The nose wheel steering was recorded in the technical log as being 'very sensitive' but was not placed as inoperative although the entry did require the aircraft to be operated in accordance with the MEL. The crew had noticed this 'very sensitive' tendency during previous taxiing but had been able to compensate satisfactorily with differential braking. No problems had been experienced during the previous takeoff or landing rolls.

The MEL permits operation of the aircraft with the nose wheel steering inoperative providing the following conditions are met:

Nose Wheel steering is selected 'OFF'
Take-off distance is increased by 10%.
Maximum crosswind is limited to 10 kt, and
The a/c may continue the flight or a series of flights but shall not depart an airport where repairs or replacements can be made.

Engine investigation

Arrangements were made to remove the left engine for detailed examination. However, whilst the engine was being removed, checks on the steering found that the Follow-Up Control Valve (FUCV) was defective, and this was also removed for investigation.

Although an engine fire had been reported, inspection of the aircraft on the apron found no evidence of fire, but metallic debris in the left engine jet pipe indicated that an engine overheat condition had occurred. Additionally, a large quantity of oil had flowed from the engine from around the reduction gearbox but this had not ignited.

The engine, serial 13209, was subjected to a strip examination and some items were tested under the supervision of AAIB. The engine could not be turned, however, when the compressor and turbine were separated the compressor was free to turn but the turbine was seized. Progressive dismantling of the turbine assembly showed that the High Pressure (HP) nozzle guide vanes were in a satisfactory condition and free of debris. It was apparent from the loose pieces of the turbine blades lodged between the Low Pressure (LP) nozzle guide vanes however, that the temperature had exceeded the threshold at which the Intermediate Pressure (IP) turbine blades begin to melt. The LP turbine blades had extensive impact damage to the aerofoil leading edges. The IP nozzle guide vanes had impact damage as a result of the molten release of the HP turbine blades. Residue of the HP blades was found adhered to the HP nozzle guide vane and HP blade path. Crystallised HP blade material was also found distributed as a powder in all turbine stages. After removing the HP disc, the HP shaft and location bearing were removed and dismantled. The bearing was found to be intact and free to rotate.

Oil pressure filter and scavenge filters were found to be free of contamination. A check of the fuel burners for condition and flow rates was carried out, and this was found to be typical of an engine returned for routine overhaul. The Fuel Control Unit (FCU) control settings were satisfactory and the fuel pump was found to operate satisfactorily. The Propeller Control Unit (PCU) was rig tested, and the governor was found to be slightly out of tolerance.

It therefore appeared that the engine had experienced a turbine burnout due to incorrect fuel air mixture ratio, however there was no significant defect in the engine's fuel system and no engine defect related reason for the burnout was established.

The observed oil leak was attributed to the continued operation of the feathering pump after the engine had been shut down. This resulted in oil leakage because the scavenge pump was no longer operating and the reduction gearbox therefore overfilled.

Turboprop engines and constant speed propellers

The combination of a turboprop engine, such as the Dart, and a constant speed propeller such as that fitted to this engine, requires that a system of safety devices known as propeller pitch stops be fitted to prevent the propeller from accidentally entering a fine pitch condition in cruising flight. When the aircraft is on the ground, at low speed, these stops must be withdrawn to allow sufficient air to pass through the engine. The fuel air mixture of a turboprop engine is always lean, so if insufficient air is available, the mixture will become progressively richer and gas temperatures in the turbine will rise very rapidly. It is possible to overheat and burn out a turbine in a second or two if the throttle is advanced too rapidly while the engine is at a low speed and the propeller is hung on a pitch stop.

In 1997, because of the frequency of this kind of occurrence, Rolls-Royce re-issued a Notice To Operators (NTO) of Dart engines (NTO 1106) which highlighted the importance of strict adherence to the manufacturer's Aircraft Flight Manual (AFM) requirements in order to avoid engine burnout.

Follow-up control valve (FUCV) investigation

During the initial rectification of the aircraft and replacement of the engine, the steering system FUCV was removed as unserviceable. Subsequently the Centralisation Control Valve (CCV) was also changed, and a further change of the FUCV also occurred during repeated attempts at rectification of the Nose Wheel Steering (NWS).

The FUCV had been suspected because, when the steering was checked, the FUCV was found to have an incorrectly functioning lever spring. This spring normally provides centralisation of the valve spool. In this case the gap between the levers of the spring was much larger than expected, allowing considerable free play of the valve spool. In a correctly functioning FUCV the steering demand from the tiller operates against the lever spring tension and in doing so causes pressurised air to be progressively metered to the steering actuator. This in turn causes the follow up mechanism to cancel the demand at the FUCV when the desired NWS angle has been reached (Figure 1). Operation of the system is therefore smooth and progressive. The defect found would cause maximum pressurised air to be applied at any slight steering demand, with a tendency for the mechanism to oscillate between the relaxed constraints of the lever spring. This condition would have caused vibration of the NWS.

The FUCV, part number AC62276, carried the serial number AB140. The data plate on the FUCV was engraved 'Mod:6'. It appeared that the '6' had previously been a '5' and had been altered by further hand engraving.

A Mod 5 (Issue 5) valve differs from its predecessors by the incorporation of the manufacturer's modification C2050. This modification changed the selector drum, pin, spring and spring housing of the valve to a later standard. The purpose of the modification was to improve the service life of the spring.

To raise the FUCV to Mod 6 (Issue 6) required the incorporation of a further modification; C2631. Modification C2631 simply removed a set screw in the spring housing that was previously used to adjust the spring. Following modification C2050, no spring adjustment was required.

The FUCV bore markings which showed it had last been overhauled in Florida, U.S.A. It carried the date '6-2003'. The spring housing did not contain a set screw, in accordance with a post mod C2631 condition. However, the selector drum was marked with the part number ACM26505, which was a 'pre-mod 5' part. Part numbers were not found on the spring or spring housing, but the spring appeared to have been deformed to allow it to fit inside the spring housing, which was too small for it. This had the effect of preventing the spring from centering the valve spool.

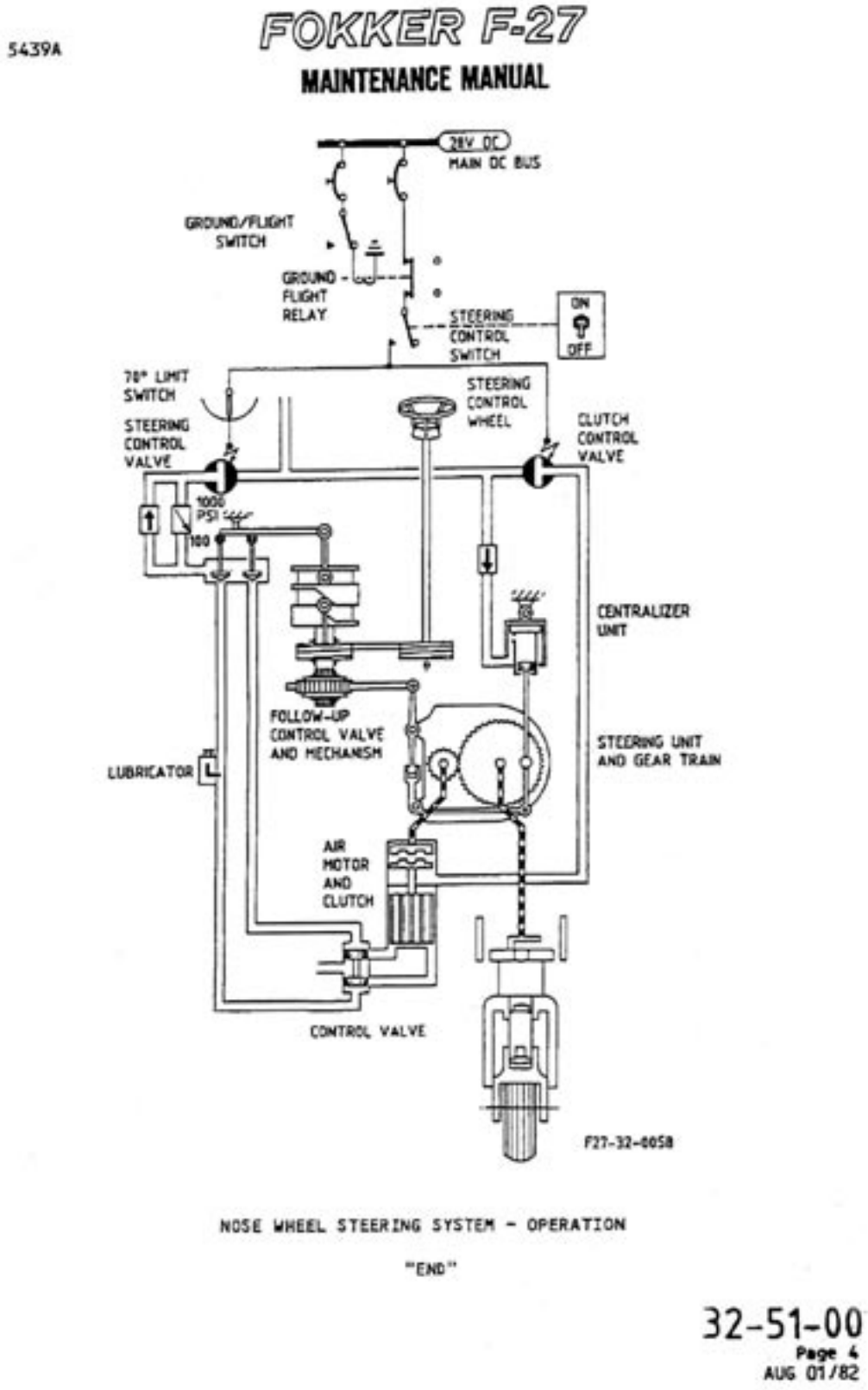
The most likely explanation for this appeared to be that while the FUCV was in a 'pre-mod 5' state, it was incorrectly fitted with a 'post-mod 5' spring, and 'Mod 5' engraved on the plate. Subsequently mod C2631 was also embodied. However, it was not possible to determine when these events took place.

History of the FUCV and NWS technical log entries

FUCV serial AB140 was overhauled in the USA during June 2003, and held in a supplier's store until it was supplied to the operator. It was fitted to the aircraft on 26 August 2004, as part of rectification work input for a NWS defect. On 6 September 2004 a further NWS defect was recorded as 'extremely sensitive with a centre notch – very difficult to steer'. The CCV was changed as a rectification action. The same day a second entry was recorded as 'Nose wheel steering very sensitive'. A 'Carried Forward Defect' was raised to permit continued operation in accordance with the Minimum Equipment list (MEL) section 32-50-01'. The MEL permitted continued operation with the NWS selected to 'OFF'. The subject incident occurred two days later.

Further incident

A further incident occurred on 18 November 2004 when the operator's F27 Fleet Captain was handling the aircraft. During taxi, there was a sharp uncommanded pull to the left followed by a violent turn right requiring maximum braking to stop the aircraft. The departure was discontinued and the aircraft was grounded for further investigation. The previous day some difficulties with NWS vibration and uncommanded steering inputs had arisen, but flight operations had continued.


5439A
FOKKER F-27
MAINTENANCE MANUAL
28V DC
MAIN DC BUS
GROUND/FLIGHT
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SWITCH
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78° LIMIT
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STEERING UNIT
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AND
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CONTROL VALVE
F27-32-0058
NOSE WHEEL STEERING SYSTEM - OPERATION
"END"
32-51-00
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Figure 1

Steering gearbox investigation

Following the incident on 18 November, the aircraft was placed on maintenance indefinitely until the cause of the steering problems could be positively identified. Since most of the components other than the nose landing gear and steering gearbox had already been replaced, the investigation focussed on these components.

The Nose Landing Gear and Steering Gearbox were separated. (Figure 2). Four dowel pins, three of which were broken, located the steering gearbox. It is unusual for these pins to break, but if they are broken or distorted they can permit the steering gearbox to rotate relative to the nose gear itself, and thus induce a steering error on a random or erratic basis. The Steering Gearbox was despatched for investigation and overhaul. The survey and test report stated that the unit had a broken housing tube assembly, a damaged gasket and was supplied with a missing grommet and plate. When these parts were repaired and replaced, the unit functioned satisfactorily. The four dowel pins were not recovered at the time and were subsequently unavailable for investigation.

Subsequent to this work, the aircraft was returned to service and operated without further reports regarding the NWS.

Analysis

Flight crew actions

The crew did not consider the nose wheel steering to be inoperative and therefore did not apply the requirements of the MEL to place the nose wheel steering selector switch to 'OFF' or apply any of the other requirements. The taxi to Runway 05 at Stansted had been achieved without difficulty using the combination of nose wheel steering and differential braking. The rolling takeoff was normal with directional control being maintained using the nose wheel steering up to 60 kt. At that point, and when the PF removed his hand from the steering control, the aircraft continued to accelerate rapidly but at about 75 kt it deviated to the right. In order to prevent the aircraft departing the right side of the runway the commander reduced power, applied left rudder and was able to manoeuvre the aircraft back to the runway centreline. He had not realised that when he retarded the left engine power lever he had moved it to, or near, the idle position.

Having reduced power to that degree, the left propeller blades would have remained at the 20° angle limited by the flight fine pitch stop. It is essential, when at idle power, that the power lever is moved into the ground fine range to withdraw the stop and allow the propeller to move to the ground fine setting of 0°. At 0° propeller angle, when the power lever is advanced, the engine is able to overcome propeller drag and increase engine and propeller RPM without exceeding the engine Jet Pipe Temperature (JPT). At a 20° propeller angle however, the engine is not able to overcome the drag without exceeding the engine JPT. The right engine power lever was not retarded to the same degree and when its power lever was advanced, the engine and propeller accelerated causing the aircraft to yaw to the left at which point the takeoff was abandoned.

Engineering

Although it was not possible to determine conclusively the pitch angle of the left propeller relative to the flight fine pitch stop, the data shows that it is very likely that the propeller was hung on the stop at the time the throttle was re-opened. This would have resulted in the almost instantaneous burnout of the turbine, and is confirmed by the very high JPT observed by the crew.

The defect in the FUCV would have caused vibration of the NWS, and some difficulty with steering the aircraft. It would also have caused large forces to be repeatedly applied to the steering gearbox and nose landing gear. These forces could have damaged the dowel pins in the steering gearbox and would lead to erratic changes in

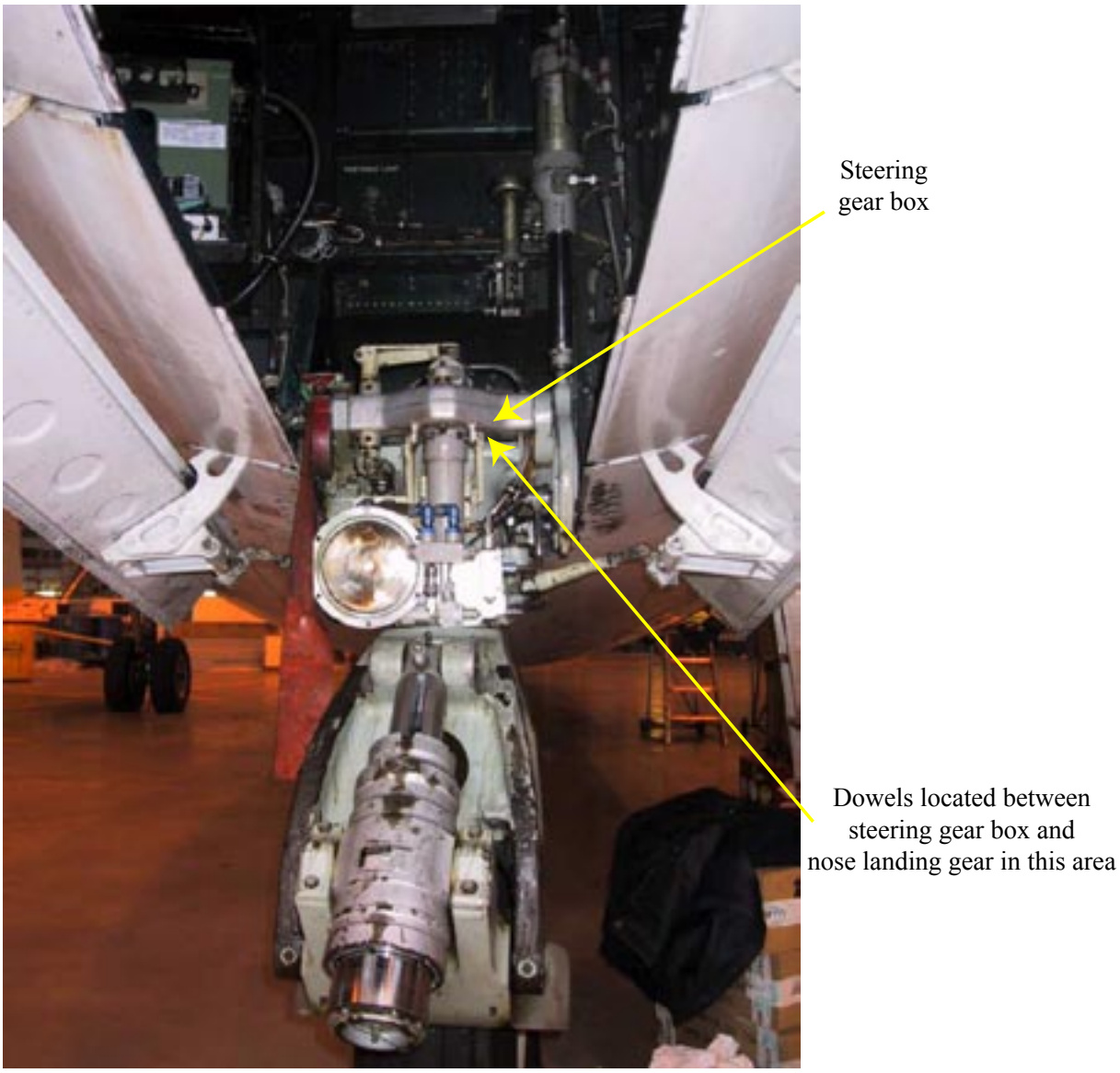

Figure 2
F27 Nose Landing Gear

the NWS datum. Unfortunately, attempts to recover the dowel pins were unsuccessful, so this possibility could not be confirmed from their condition. Even so, the only two faults found throughout the investigation concerned the FUCV and the dowel pins, and while the former could have caused the latter, the opposite is not true.

Conclusion

The subsequent technical investigation found that the engine burnout occurred because the left throttle had been retarded when directional control was lost. The engine had slowed, but the propeller was almost certainly above the flight fine pitch stop. Almost immediately after this the left throttle was re-opened, causing the turbine to overheat. The steering problem had been due to defects in the FUCV and the Steering Gearbox. The right engine did not overheat because it had been handled somewhat differently in an attempt to regain directional control. Selecting the nose wheel steering switch to 'OFF' may not have prevented this incident.