2. Analysis

2.1 Operation of the aircraft

2.1.1 Pilot qualification, experience, training and operation of the flight

The pilot held an FAA CPL with an appropriate type rating. He was thus licensed to fly the aircraft on a flight in the prevailing conditions, but because he had not fulfilled the takeoff and landing experience requirements in the 90 day period preceding the accident he was not qualified to carry passengers at night.

To operate the Piper Aztec aircraft at night in TCI the pilot would have been required to hold a licence with a valid Multi Engine Instrument Rating. The pilot did not have this qualification and therefore was not allowed to operate under IFR, which he was required to do in TCI airspace at night.

The take off from Providenciales was at sunset and the round-trip flight would have taken at least one hour. Night flight in TCI airspace starts 30 minutes after sunset and it would therefore not have been possible to complete the flight within this time. In the event, because of the delays, the takeoff from South Caicos was at around 1.5 hours after local sunset. At this time, almost complete darkness prevailed away from the area of the airport lights.

The pilot had limited experience on the Piper Aztec aircraft. His previous experience in flight at night was conducted almost exclusively within Florida, USA, and the majority of airports in that region are in locations with extensive cultural lighting. A pilot used to such an environment might not therefore be well prepared for a takeoff into an area without such illumination, for example South Caicos. He had quite possibly never experienced a takeoff at night without at least some environmental lighting.

While the pilot did hold a single engine instrument rating, most or all of his instrument flying hours had been obtained under controlled conditions, during his training course. One of the most difficult aspects of instrument flying is the unexpected transition into and out of flight without external visual references. Although this was a clear night it was dark and, without the benefit of environmental lighting, as soon as he turned the aircraft away from the runway the pilot would have been deprived of any external visual reference. Unless he understood and was prepared for this, maintaining control of the aircraft would be difficult.

Normal good practice in these conditions would be to climb straight ahead and concentrate on achieving stable instrument flight and a safe height before attempting any turning manoeuvre. The early turn he carried out points to a lack of appreciation that he would need to use his instruments for reference once airborne.

The pilot was exposed to bright flood lighting on the parking area before departure and subsequently to the bright runway lights on takeoff. If he had attempted to use his flight instruments as he turned away from the runway his eyes would have been poorly adapted for the relatively low light conditions, therefore he may have had difficulty in seeing the instruments.

2.1.2 Departure turn

The pilot was observed to carry out a turn very shortly after takeoff on departure from Providenciales and seems to have attempted a similar manoeuvre on his subsequent departure from South Caicos. A turn performed immediately after takeoff is an unnecessarily risky manoeuvre even in daylight but in darkness, where flight by sole reference to instruments will be required, it is even more so.

For this departure at night it would be expected that after takeoff a pilot would have focused his attention on the flight instruments and climbed straight ahead; there was no reason for a turn to have been initiated at such an early stage of the flight. Once stabilised in flight by reference to instruments and at a safe height, a turn to the left onto the planned course could then have been made safely.

Witness evidence showed that a turn to the left was carried out almost immediately after leaving the runway. If this manoeuvre was unintentional, then a significant problem would need to have occurred to cause the turn. The nature of such a problem could be a flight control restriction or disconnection, an unintentional engagement of the autopilot, a loss of control following an engine failure, an incapacitation of the pilot or some other unknown factor.

Some of these factors can be discounted in view of the circumstances. The aircraft had just been flown from Providenciales and there was no indication that there had been any control problem on that flight. If the turn shortly after takeoff had been the result of a control problem, it is unlikely that the aircraft would have stayed airborne as long as it did.

If the autopilot had been turned on accidentally it is possible that it would try to turn the aircraft as soon as it became airborne. However it is also probable that the pilot would have noticed that the controls were restricted by the autopilot on his pre-flight control check. Furthermore, evidence from the wreckage examination indicates that the autopilot was OFF.

The wreckage examination found no evidence of powerplant failure and indicated that both powerplants were delivering power at a similar level at the point of impact. Furthermore, witnesses did not report any obvious change in engine sound. If a loss of control had resulted from an engine failure after take off it is unlikely that the aircraft would have continued in flight as long as it did, or that the impact speed would have been as high as it was (Section 2.5).

Similarly, should incapacitation of the pilot have been responsible for the early turn, it would have been unlikely that the aircraft would have continued in flight for as long as it did.

The reason why the pilot would carry out an intentional early turn could not be determined but it is possible that the presence of friends on board the aircraft and spectators at the airport may have contributed to his decision to do so. With his relative lack of experience he may not have appreciated the risks associated with such a manoeuvre. He had made a similar turn on departure from Providenciales in good visual conditions and possibly did not realise the effect that darkness would have on the difficulty of such a manoeuvre. In conclusion, it is most likely that the turn after takeoff was made intentionally.

2.1.3 Effects of alcohol

Traces of alcohol were found in the toxicological samples from the pilot but, given the levels of ethanol present in the samples, it was not possible to conclude whether or not alcohol had been consumed by the pilot before the flight.

It should however be considered whether, if a relatively small amount of alcohol was present in the pilot's system before the flight, it could have affected his ability to safely conduct the flight. There are two possible effects of alcohol which may have had an influence in these circumstances. One is the effect upon behaviour, where even small levels of alcohol are known to increase confidence and, in these circumstances, this could have influenced the pilot's decision to continue the flight in darkness following the delayed departure. The other effect is that the presence of alcohol could have increased the pilot's susceptibility to spatial disorientation.

2.2 Spatial disorientation

The impact attitude and speed at which the aircraft crashed (Section 2.5) indicated that a loss of control in flight had occurred. The most likely reason for this was that the pilot suffered from spatial disorientation; this is borne out by a number of different factors.

The pilot may have been unaware of, or may not have considered, the effect of the lack of environmental lighting to the north of the airfield and that he would need to fly with sole reference to his instruments. The evidence indicated that he had no recent experience of flight at night or of instrument flight. In any case his previous experience in both was relatively low and for instrument flight had taken place only on single engine aircraft. The greater complexity involved in flying a multi-engine aircraft would have added to the difficulty of instrument flight. Such flying requires specific training and frequent practice to remain proficient and safe.

The decision to turn at an early stage after takeoff, before he could have achieved stable instrument flight, would have prevented his then being able to adapt to flight by sole reference to instruments when it was required. The forces due the to acceleration during takeoff and the forces due to the left turn could both have contributed to create a somatogravic illusion of a nose up attitude. The pilot would then instinctively have pushed the nose of the aircraft down. If he attempted to refer to his instruments there would have been a conflict with his physical sensations, leading to disorientation, which he would have been unlikely to be able to resolve given his level of experience and lack of recent practice.

2.3 Commercial and private flights

The additional requirements for the operation of a commercial air transport flight above those for a private flight are designed to ensure a level of oversight and regulation with a view to safeguarding public safety.

The distinction between private and commercial transport operations can be complicated, is often not well known by members of the public, and the passengers on this flight may well not have been aware of any distinction. They may reasonably have thought that the pilot was suitably qualified and sufficiently experienced to conduct the flight safely and could legitimately accept money for the flight. It could not be determined whether or not they knew that the typical charter price for such a flight was US $450, higher than the price they had apparently agreed to pay.

The evidence indicated that the pilot had agreed to carry out the flight on the basis that he would be paid. Were the flight to have been operated as a private flight on a cost sharing basis, direct costs only would have been shared. The direct costs for operating this flight, approximately $100, would have been considerably less than the $300 which was said to be the agreed amount, thus the flight did not meet the requirements for cost sharing. Furthermore the original intention was to carry five passengers, a number which would also have precluded cost sharing. In any case it is unlikely that the pilot was aware of the rules on cost sharing since the rules were specific to operation under the terms of the UK ANO (OT) and he had only been trained in FAA regulations. Thus the fee that was reportedly arranged for the flight could only have been on a commercial basis and the pilot was not entitled to carry out a commercial flight within TCI airspace.

2.4 Reasons for attempting the flight

Whether or not the pilot knew that in accepting money for the flight he was in contravention of the TCI regulations is not certain. He should, however, have been aware that he was not allowed to carry passengers at night under the terms of his FAA licence. It is necessary to consider some of the possible pressures on him in order to understand why he attempted to do so

The pilot had borrowed a substantial amount of money to purchase the aircraft, and it was his stated intention to earn money by flying it. He would not have been able to operate legitimately in TCI until he had obtained the appropriate licence and an AOC. However, the incentive of being paid to carry out the flight would have exerted a financial pressure and is possibly one reason why he accepted the flight originally.

The delay to the departure from South Caicos ensured that the takeoff would be made in darkness and the pilot should have cancelled the flight. However, a number of self-imposed pressures, other than financial, may have influenced him to continue. He may have been conscious that the people gathered at the airport were expecting to see him takeoff in his newly-acquired aircraft. In addition, his passengers were at the airport expecting to travel; it may have been difficult, and could have involved a loss of face, to explain to them that he could not fly them at night.

2.5 Accident Site and Wreckage Evidence

2.5.1 General

South Caicos is a relatively small island and the facilities available for inspection of the site and recovery and local inspection of the wreckage were understandably limited. However, it proved possible to carry out an effective recovery and a detailed and comprehensive investigation of the wreckage. This was assisted by good co-operation by the aircraft, engine and propeller manufacturers. Effective work by the recovery team meant that a large percentage of the aircraft, estimated at 90-95%, was recovered and a substantial amount of evidence was obtained from the accident site and the wreckage.

2.5.2 Accident Site

The evidence from the wreckage location showed that N444DA crashed into the sea in shallow water on the Caicos Bank approximately 1 nm to the north-west of the start of Runway 11 at South Caicos Airport. The accident site was around 0.5 nm from the local shore. Wreckage found embedded in the sand at just two positions indicated that both powerplants had struck the seabed but that most of the structural damage to the aircraft had resulted from impact with the water.

2.5.3 Impact Parameters

The pattern of wreckage distribution at the accident site indicated that the aircraft had been travelling in a north-north-easterly direction at the time of impact (Figure 2). The distribution of the wreckage also showed that that the aircraft had been generally upright when it struck the sea. Multiple features of the damage revealed by the structural layout in the hangar, in particular the characteristics of the structural deformation in a number of areas, indicated that it had been pitched around 10-20° nose down and banked around 20-40° right at impact. Markings on the attitude indicator from the cockpit positively indicated that the aircraft attitude had been around 15-20° nose down pitch and 25-30° right bank.

The appreciable degree of structural break-up that occurred indicated that the aircraft had been travelling at relatively high speed at the time of impact, estimated at 150-200 kt. Positive evidence from instrument markings indicated that the airspeed had been close to 185 kt. The combined evidence from the characteristics of the wreckage distribution and structural damage and from the instrument markings suggested that the aircraft had been descending at around 20-25° to the horizontal.

It was clear from the evidence that the accident was not survivable.

2.5.4 Aircraft Configuration

Witness markings on the flap position indicator in the cockpit suggested that flaps had been in the retracted position at impact and this was reinforced by the markings on the flap surfaces, which also indicated that there had been no flap asymmetry.

Combined evidence from the light bulbs from the landing gear position indicator captions positively showed that the landing gear had been in the retracted position. The lack of evidence from one of the landing gear caption bulbs indicated that it had not received sufficient shock loading to provide an indication.

2.5.5 Flight Controls

Wreckage markings provided some indications suggesting that the rudder and ailerons were approximately neutral at impact.

While a few parts of the flight control systems could not be identified, most of the components were available for inspection. No signs of pre-impact failure were found. With the mechanical type of control systems used on the aircraft the possibility of a control jam could not be totally dismissed. However, the control channels were independent and in the event of the seizure of one primary control channel the function could generally be substituted by another primary control (eg rudder, if ailerons were jammed) or a trim system (eg pitch trim, if the stabilator were jammed). Thus, unless a seizure of one channel occurred while a substantial displacement of the control from neutral were present, the aircraft would probably remain controllable. No previous problems with the flight control system had been reported and it was judged from the overall evidence to be improbable that malfunction of the flight controls had contributed to the accident.

Combined evidence from three indicator light bulbs associated with the auto-pilot selector showed that the auto-pilot had been off at impact. This was in accordance with the expectation that the auto-pilot would not have been selected on so soon after takeoff.

2.5.6 Powerplant

2.5.6.1 Powerplant Anomalies

A number of anomalies with the engines and propellers were found, some of which had been present before the accident, and were considered in detail during the investigation.

The rupture of the diaphragm in the fuel flow divider, as occurred on both engines, was reportedly an unusual occurrence in service. It was thus highly unlikely that both diaphragms had ruptured before the accident. Nonetheless, consideration was given to the possibility of diaphragm rupture before impact. While it appeared unlikely that this would have caused significant power loss from the associated engine, the available evidence did not allow the possibility to be totally eliminated. However, other evidence, indicating relatively high power levels on both powerplants for most of the flight and symmetrical power at impact (Section 2.5.6.2), indicated that pre-impact power loss as a result of diaphragm rupture had not occurred.

Additionally, rupturing of the diaphragm was known to result in some crash situations, due to excessive pressure generated by inertial forces on fuel in the pipelines. It was therefore judged likely that the ruptures had resulted at impact, and signified that appreciable quantities of fuel had been present in the high pressure fuel system of both engines at the time.

Furthermore, the evidence indicated that the low tightening torque present in both clamping nuts of both magnetos of the right engine had probably resulted from crash forces. Had the condition had been present before impact it was likely that a reduction in power, rather than stoppage of the engine, would have resulted if the nuts had been loose enough to allow one or both magnetos to displace from its set position. However, neither the frettage not detachment of the nuts due to vibration that would be expected if the condition had been present before impact had occurred. Additionally, other evidence indicated that there had not been a significant power loss during the flight (Section 2.5.6.2). It was therefore concluded that the low torque had resulted from crash forces.

The damage to the components of the drive unit for the left magneto of the left engine and the absence of a split pin intended to secure the right magneto shaft nut of this engine resulted from assembly errors. However, neither anomaly would have affected the operation of the engine. Similarly, the lack of an oil feed hole in the accessory gearbox casing of both engines was not in accordance with the engine manufacturer's instructions but had not affected engine operation.

The crushing of the crankcase shim on the right engine, clearly the result of an assembly error, was a potentially serious fault but in this case again had not affected engine operation.

The loose washer in the right propeller mechanism was a further instance of incorrect assembly, although the evidence indicated that it had not affected the operation of the propeller in the power-on range and had not contributed to the accident. However, this anomaly could have had serious consequences in the event of a shutdown of the right engine. In such a situation it would not have been possible to fully feather the propeller, as required in order to minimise aerodynamic drag from the blades. Thus the aircraft's climb performance with the right engine shutdown would be reduced and the asymmetric yawing moment on the aircraft would be increased, increasing the minimum airspeed at which the aircraft would remain controllable.

This assembly error was clearly likely to have resulted on the last occasion on which the relevant part of the propeller mechanism had been assembled. This had possibly been during adjustment of the stop shims after rig testing following propeller overhaul. The fact that the mis-assembly had not been corrected indicated that no subsequent check measurement of the blade angles achieved with feather selected had been made, following running either on a rig or after installation of the propeller on the aircraft. While this was apparently normal practice, the lack of a check following final assembly did not appear acceptable, as demonstrated by this case. It has therefore been recommended that the FAA require that, before flight, variable-pitch propellers receive a full functional ground check following final assembly or re-assembly.

Thus, positive evidence was found that a substantial number of engine and propeller assembly errors were present before the accident, as follows:

Powerplant	**Component**	**Anomaly**
Left	Left Magneto	Drive unit mis-assembled
Left	Right Magneto	Shaft nut split pin absent
Left	Accessory Gearbox Casing	Oil feed hole for oil pump absent
Right	Crankcase	Shim mis-assembled
Right	Propeller mechanism	Washer mis-assembled
Right	Accessory Gearbox Casing	Oil feed hole for oil pump absent

While none of the anomalies appeared to have contributed to the accident, some of them could have had serious potential consequences. Their presence clearly indicated an inadequate standard of quality control during repair/overhaul. It has therefore been recommended that the FAA take measures aimed at ensuring an adequate standard of quality control during repair and overhaul operations on light aircraft engines and propellers.

2.5.6.2 Power

Positive signs of powerplant rotation at impact were not found on the engine components, but with this type of impact it could be expected that forces on the propeller blades on initial contact with the water could cause rapid engine stoppage. Experience showed that in similar circumstances, with engines rotating and delivering power, it was not unusual for such signs to be absent if the engine remained intact.

Signs suggesting that both engines were operating at impact were given by engine indicator features, with indications of normal oil temperature for the left engine and normal oil pressure for both engines.

Impact and corrosion damage precluded functional testing of most engine fuel and ignition system components and of the propeller pitch change mechanisms. However, the twisting and forward bending deformation of one of the blades on each propeller was characteristic of the effects of overload forces on the blade generated by initial blade contact with the water while at a positive relative angle of attack. The features therefore showed that both propellers had been rotating and delivering power at initial impact. It was judged likely that the rearward bending nearer the root of both blades on each propeller had occurred during the break-up, after the engines had rapidly slowed or stopped. The limited degree of forward blade bending could have been because the propellers were not delivering high power or because the relatively steep descent caused rapid engine stoppage at impact.

A particularly notable feature was the congruence between the deformation of the left and right pair of propeller blades, strongly indicating that the power level being delivered by the two engines and propellers at impact had been similar. Markings found on the pitch change mechanism of each propeller were indicative of a blade angle of around 20°, equivalent to a low power level, given the relatively high airspeed. While the markings were not considered highly positive, the power level they suggested was generally consistent with the extent of the propeller blade deformation.

No evidence was available to indicate the point in the flight at which the final power level had been set; it was possible that the pilot had reduced the power setting shortly before impact. The relatively high impact speed, achieved comparatively shortly after takeoff, was notable and performance considerations indicated that the power delivered by both engines had been at a relatively high level for most of the flight.

Thus it was concluded that the two engines had been delivering approximately equal power, probably in the low-mid power range, at the point of impact, and that engine power had been at a relatively high level for most of the flight.

2.5.7 Aircraft Structure

The detailed examination revealed no signs that any parts had separated from the aircraft before impact, or that structural failure or foreign object impact had occurred. All doors and hatches were present and the evidence indicated that all were in the latched closed position at impact. Signs were found that the pilot's seat had been latched securely at a mid position on its rails. It was clear that no fire had occurred on the aircraft.

2.5.8 Systems

The instrument witness markings suggesting that the charging rate of the aircraft's electrical system was consistent with normal operation of the system. Additionally, the eyewitness reports of external aircraft lights visible suggested that there had not been a major electrical system failure. The positive evidence that at least some instrument panel and landing gear caption bulbs had been illuminated at impact reinforced this conclusion. Thus it was unlikely that a failure of the aircraft's electrical system had contributed to the accident.

The absence of signs of pre-impact damage to both vacuum pumps, coupled with the evidence that both engines were operating at impact, and the evidence on the vacuum system indicator of a normal level of system pressure indicated that a vacuum system failure had not contributed to the accident. This was reinforced by the consistency of the indications given by the attitude indicator with the attitude initially determined from the overall examination of the aircraft wreckage. Thus it appeared highly unlikely that failure of either the aircraft's vacuum system or the attitude indicator had contributed to the accident.

There was positive evidence that some of the instrument panel lighting bulbs had been illuminated at impact. The fracture of the filament of one of the recovered instrument panel illumination bulbs may have been the result of it having failed, or lost its power supply, before the accident. However, it would not be expected that this would cause a significant problem. It was also possible that the filament had been illuminated at initial impact but had received insufficient shock loading to stretch and had suffered the failure later in the aircraft break-up sequence.

The setting of the instrument panel lighting could not be established but an inadequate illumination level would inevitably have been immediately apparent, and likely to have been corrected, before takeoff.

2.5.9 Summary

In summary, the impact parameters were approximately as follows:

Track	-	North-north-easterly
Airspeed	-	185 kt
Descent Angle	-	20-25° to the horizontal
Pitch Angle	-	15-20° nose down
Bank Angle	-	25-30° right wing down

The configuration and probable condition of the aircraft was as follows:

Landing gear	-	Retracted
Flaps	-	Retracted
Powerplants	-	Left and right delivering similar power, at an approximately mid-low power level. Both powerplants had delivered relatively high power during most of the flight.
Doors and hatches	-	Closed
Electrical System	-	Functioning
Vacuum System	-	Functioning
Instrument Lighting	-	At least part of the system functioning, illumination level unknown
Attitude Indicator	-	Indicating correctly

As is usual with this type of investigation, it was not possible to totally dismiss the possibility of pre-impact failure or malfunction of the aircraft. However, a broad and detailed investigation revealed a substantial body of evidence. This provided no signs of a failure, malfunction or anomaly of the aircraft or its equipment likely to have been relevant to the cause of the accident. The evidence indicated that the accident had probably resulted from spatial disorientation of the pilot leading to a loss of control.