Accident

Aircraft Type and Registration:	De Havilland Canada DHC-6-300 Twin Otter, VP-FBC	
No & Type of Engines:	2 Pratt & Whitney PT6A-27 engines	
Year of Manufacture:	1982 (Serial no: MSN787)	
Date & Time (UTC):	23 January 2023 at 1600 hrs	
Location:	E322, Mount Lymburner field location at the north-west end of the Ellsworth Mountains, Antarctica	
Type of Flight:	Private	
Persons on Board:	Crew - 2	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Damage to fairing around the landing gear, and upper and lower forward bulkhead	
Commander's Licence:	Commercial Pilot's Licence	
Commander's Age:	33 years	
Commander's Flying Experience:	5,438 hours (of which 3,223 were on type) Last 90 days - 174 hours Last 28 days - 58 hours	
Information Source:	Aircraft Accident Report Form submitted by the commander	

Synopsis

On departure from an unprepared landing site the nose landing gear of the aircraft struck a small ice ridge. Once airborne, the commander noticed that attitude information was misaligned and there was some minor disruption within the cockpit near the rudder pedals. He diverted to an unmanned landing site nearby where he assessed the damage. Considering that the aircraft was safe to fly he flew the aircraft to a field station, two hours flight time to the north.

On landing at the field station, further damage was found to have occurred to the nose fairing around the landing gear and the lower bulkhead forward of the cockpit.

History of the flight

In support of polar research in the Antarctic, the commander was tasked to take a field team to a new location, designated Station E322 (Mount Lymburner), at the north-west end of the Ellsworth Mountains, in Ellsworth Land, Antarctica. He was accompanied by a field guide; a second aircraft with an engineer on board was tasked to follow-on a few hours later.

The commander assessed the weather at the location as “good” and briefed the task. A nearby unmanned fuel depot with a prepared landing surface, named Castle, was nominated as a diversion.

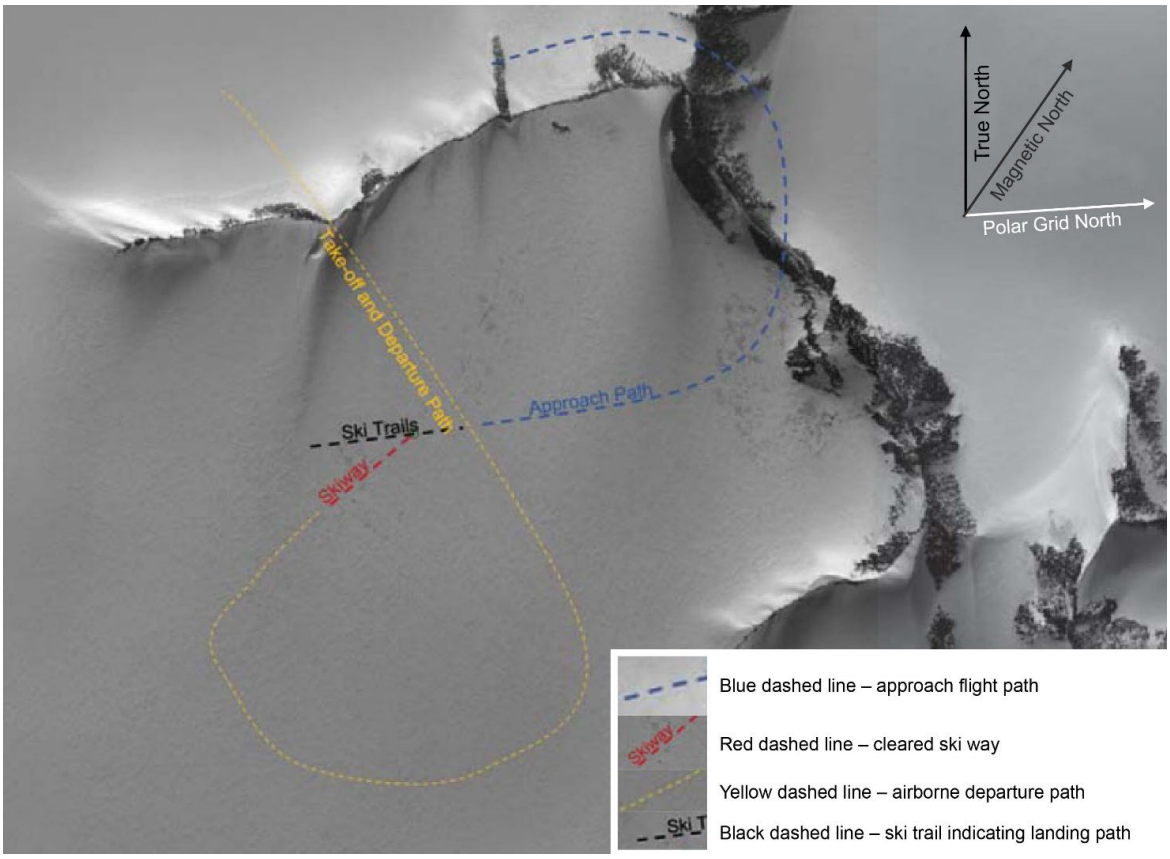

Figure 1

Station E322 location beside Mount Lymburner, Ellsworth Mountains (Google Earth)

On reaching Station E322, he assessed it in accordance with the company’s operating procedures and identified landing and takeoff routes away from the ridge on a plateau (Figure 1). The commander flew a steep approach through a col and assessed the surface by flying a “trail”[1] before making a further approach to land. The aircraft landed without incident.

The direction of the ice ridges (also known as sastrugi[2]) was more apparent when on the ground. Consequently, the commander prepared a skiway[3] of 800 m, about 20° off the direction in which he had landed but in line with the direction of the sastrugi (Figure 2), for the following aircraft to land. He marked the skiway with bamboo poles.

Footnote

1 A trail involves flying along the length and in the direction of the intended landing run by touching down the skis of the main landing gear onto the surface but keeping the nose off the surface with the weight of the aircraft borne by the wing.

2 See sub-section on Sastrugi.

3 A skiway is a snow strip marked by flags and the surface prepared to prevent the potential for damage to aircraft during takeoff or landing. This is achieved through the removal of sastrugi and use of other measures such as visual markers.

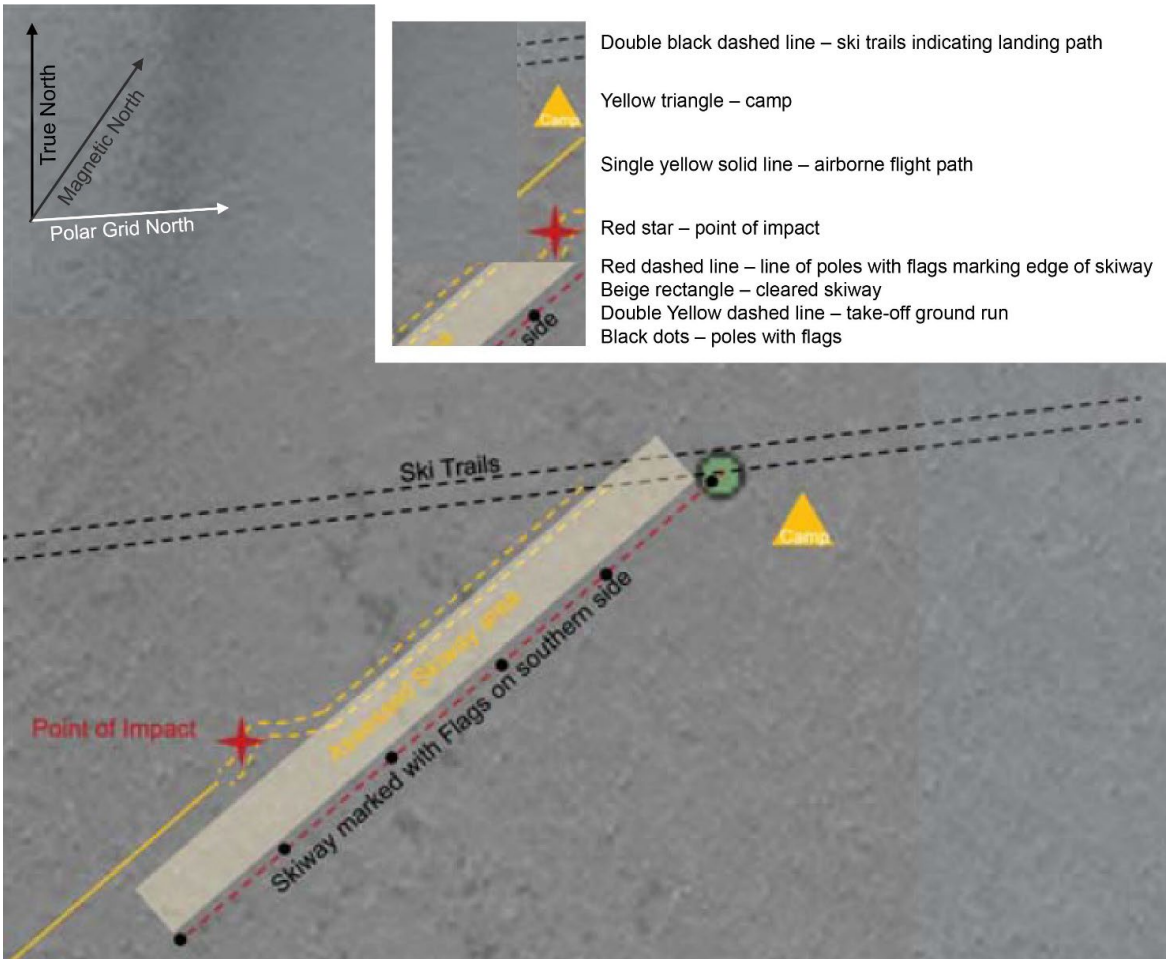

Figure 2

Station E322 landing site with ski trails and cleared skiway shown (© Google Earth)

The commander stated that, while he would normally depart using the same trail made when landing, he elected to depart using the skiway. He reported that almost at the point of rotation during takeoff, he felt the right ski sink, pulling the nose of the aircraft to the right. Although he tried to correct this using differential power and rudder, a large impact was felt on the nose ski; it was at this point the aircraft became airborne. The field guide subsequently told the operator that he considered the impact unremarkable.

On completion of the after takeoff check list, the commander noticed that the standby artificial indicator showed a 40° bank while the aircraft was level and that attitude indication of the No 1 primary flight display seemed slightly off alignment. He also noticed that the covers around the rudder pedals were dislodged.

Considering his diversion options, the commander determined that, although he had sufficient fuel to return to the ice runway at Sky Blu field station, it would not be sufficient to ensure the aircraft landed with fuel remaining above the mandatory minimum reserve. He was also concerned about having sufficient fuel in uncertain and rapidly changeable weather conditions. Following a low-speed handling check, the commander therefore

elected to land at Castle, which had a known smooth prepared surface, where the current weather was known to be good and there was fuel.

After an uneventful landing, the commander assessed the damage to the aircraft. He considered that no major structures were compromised, and that the aircraft was safe to fly. While the follow-on aircraft may have provided further support from the engineer on board, the commander was conscious that the location was very remote and unsupported and that any need to secure the aircraft would require personnel to stay on-site. Consequently, he determined that the best option was to fly a single sector back to Sky Blu where there was infrastructure to support personnel and access to engineering support. He did not consult the chief pilot on this decision. He refuelled the aircraft and flew it back to Sky Blu without further incident. Upon landing, the engineer based at Sky Blu confirmed damage to the forward bulkhead and the fairing around the nose landing gear.

Station E322 and other operator sites

The landing site at Station E322 was an unprepared location beside Mount Lymburner on the north-western tip of the Ellsworth mountains, about 260 nm to the south-west of Sky Blu (Figure 3). The surface consisted of compacted snow forming an ice shelf. The commander reported that the trail indicated a hard surface but with small sastrugi and that the landing run felt like landing on a rough grass airfield.

The fuel depot called Castle, at latitude 76°55' S, has a skiway and is about 40 nm from E322. It is unmanned with minimum stocks of fuel. The commander commented that its location was extremely remote and subject to strong katabatic winds and temperatures below minus 40°C.

Sky Blu field station is situated in Eastern Ellsworth Land. It has a blue ice[4] runway, up to 1,200 m long and 50 m wide permanently marked by flags. The camp is manned during the summer, including a licensed engineer. Facilities consist of a large semi-permanent hut, tents, and weather monitoring equipment. There is an ice cavern garage for storage of equipment. Its purpose is to provide supplies, fuel, and people in support of “deep field” operations to the interior of the Antarctic.

Rothera air facility is the largest research station and the main base for the air unit. It is situated in the south-east of Adelaide Island on the Antarctic peninsula and acts as the main airbridge to and from Antarctica. It is about 900 nm to the site at E322.

Footnote

[4] A blue ice runway is a naturally occurring strip of ice that is kept smooth and snow-free for wheeled landings.

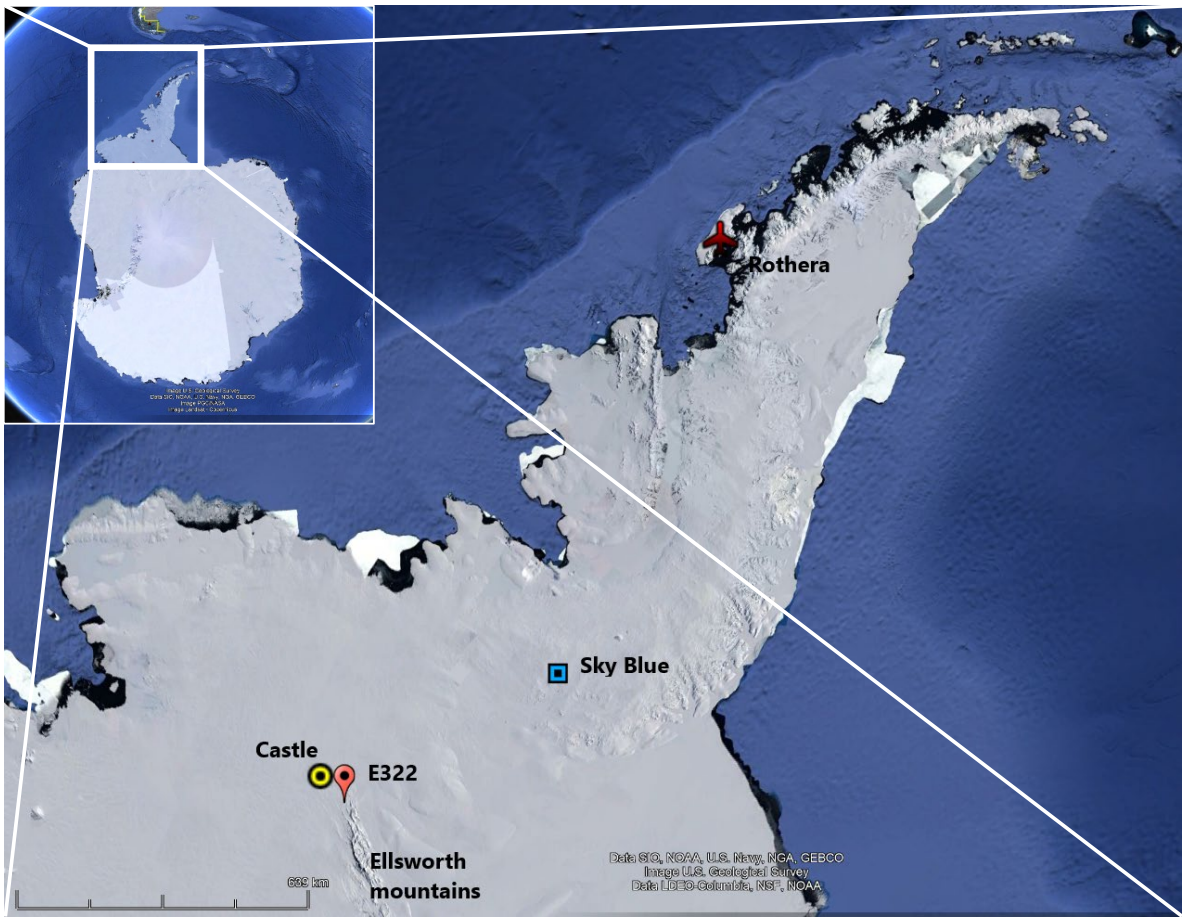

Figure 3

Ellsworth land showing station E322 and other operator sites (© Google Earth)

Aircraft examination

On landing at Castle, the commander inspected the aircraft and assessed the damage to the external nose gear and surrounding aircraft skin (Figure 4), nose baggage bay, avionics and hydraulic bays. He checked the flying controls, including the rudder and elevator, of which the pulleys are attached to the forward bulkhead at station 60. While he determined that this bulkhead looked torn and buckled, he determined all the flying controls were undamaged and there were no control restrictions. The engine nacelles and main landing gear also appeared undamaged.

Figure 4

Damage to aircraft skin around the nose gear (photo taken after landing at Sky Blu)

On landing at Sky Blu, the aircraft was inspected by a licensed engineer who confirmed damage to the upper and lower forward bulkhead at station 60 (Figure 5). The commander noted that the damage appeared to be worse than he had observed at Castle.

Figure 5

Station 60 upper bulkhead damage (photo taken after landing at Sky Blu)

The type certificate holder issued a Repair Engineering Order for a temporary repair to the nose and bulkhead structure, allowing a ferry flight with a maximum of two cycles and eight flying hours.

Aircraft information

The twin turboprop De Havilland Canada DHC-6-300 Twin Otter (DHC-6) is a short takeoff and landing utility aircraft with a high wing and fixed tricycle landing gear. The version operated in Antarctica is wheel and ski-equipped for operation on snow, ice and other types of hard runway.

Figure 6

DHC 6-300 Twin Otter with ski landing gear (image courtesy of the operator)

Station 60 forward bulkhead

The forward bulkhead at station 60, to which the nosewheel landing gear is connected, separates the nose compartment from the flight compartment. The operator and commander stated that this area is known to be liable to damage in the event of an impact on the nosewheel landing gear.

Meteorology

The weather forecasting for the task was based on satellite pictures and on model data but without any observation on the ground from a Met Office operational forecaster. The commander reported that, at the time of the accident, visibility at the landing site was unlimited, with a few high-level clouds and good contrast. The sun was just above the horizon in the south-west, and the winds were calm. The Antarctic summer ends and the winter begins in March.

Communications

High Frequency (HF) radios are the primary means of communication between aircraft and Rothera. Two HF systems are installed on each aircraft. Manned remote locations also have access to an HF system, but it is not routinely monitored. Each aircraft also carries two satellite phones, which cater for voice calls and provide text messaging facilities.

The operator reported HF transmissions and reception were "generally good in the region" but that the satellite phone coverage was "patchy", and calls could be broken "like a bad mobile call" where only every other word is heard.

Personnel

The commander had flown in excess of 2,000 hours in command on type and was working towards a Part 66 engineering licence. The operator recognised that the commander had considerable polar flying experience combined with strong technical knowledge of engineering, the aircraft and its structures.

Survivability

The operator's procedures recognised that many factors, including weather or technical issues, might affect the transport of loads to a new field site. It stated that:

> *'…the first load into the field must contain all the necessary equipment to live comfortably and safely in the field.'*

It provided a list of equipment that must be placed on the first aircraft to a site. The commander stated that the safety equipment provided was designed for the Antarctic summer. He observed that it was sufficient to be able to survive, though not in comfort for any length of time.

Commander's decision-making

The commander stated that, following his examination of the damage, he assessed the aircraft as safe to fly. He was concerned about the remoteness of the location with its extreme environment and the challenge of bringing engineering support to recover the aircraft before the end of the Antarctic summer. Conversely, Sky Blu offered a safer location for the personnel and support, including a licensed engineer for the further recovery of the aircraft to Rothera.

Organisational information

The operator

The aircraft operation is part of a research-driven organisation for polar science and operations. It is responsible for providing safe and effective airborne logistics and science capability in support of UK and collaborating nations' science activity, primarily in Antarctica.

The DHC-6 is one of the operator's two types and operates in the Antarctic from October through to March each year. Landing on unprepared snow sites using ski landing gear, it transports people, fuel, skidoos, sledges, food and scientific equipment to remote camps, to lay depots and stockpile fuel for field science parties.

Operator investigation

The operator's own safety investigation found that the accident occurred because the aircraft's ground roll diverged from the cleared skiway and struck a sastrugi.

The investigation indicated that other pilots would have reacted in the same or a similar way if presented with the same scenario. It found that whilst the pilot had considered the potential for damage occurring on the subsequent takeoff or landing, he may not have considered the potential for further damage occurring during the cruise phase.

The commander expressed that it would have been difficult to explain a nuanced and complicated situation over the satellite phones and that decisions made remotely may have been less effective. Consequently, the operator considered there was a strong psychological barrier to communicating with engineering and management personnel.

The investigation also highlighted the tension between keeping the risk to personnel within tolerable levels and the need to protect high value assets while reducing the exposure of personnel to an extremely hostile environment. The operator recognised that there could be rare occasions where decision-making would require a balance to be struck between safety and airworthiness compliance. It concluded there may be circumstances in which it would be appropriate to fly a damaged aircraft if this minimised the exposure of personnel and assets to immediate risks, or if it was required to meet international obligations for the protection of the Antarctic environment. The operator commented that *'some degree of flexibility may be required if an engineering fix is available but cannot be achieved at a remote site…'* but '… *if necessary, assets would be abandoned if the risk to personnel, or the cost of recovery (financial, environmental, human effort) is too great to bear.'*

The operator reviewed:

- The barriers (perceived or actual) to open communication between pilots and management.
- The existing risk assessment process and communication channels for occurrences which result in damage to aircraft in remote locations.
- The level of autonomy required and accepted by pilots and management in certain circumstances regarding in-field / dynamic decision-making.
- The existing processes and practises in place for new sites including a review of training.

As a consequence, the operator adopted the use of low orbit commercial satellites for communications which has improved their quality and reliability.

It has developed a 'field checklist' to guide the decision-making process to recover damaged or unserviceable aircraft from remote locations, defining the process of assessment and the level at which decisions should be made.

It established that existing processes and training for new sites were *'sufficient and satisfactory*'.

Additionally, during the annual review of operations for 2023, the operator held discussions with pilots on remote decision-making, levels of autonomy for commanders and the confidence with which commanders had the confidence to raise safety concerns. These discussions are to be repeated in the annual review of operations in 2024.

Other information

Sastrugi

Sastrugi, or zastrugi[5], are small ice features which resemble frozen waves formed by erosion of snow by wind. They are found in polar regions, and are distinguished by upwind-facing points, resembling anvils, which move downwind as the surface erodes. When landing at an unprepared landing site in Antarctica, Sastrugi are a key threat.

Site recce

The operator's procedure in its field operations manual for the setting up of a skiway stated that it should be aligned with the prevailing wind direction, 500 m long and 30 m wide marked by black flags along one longitudinal edge every 50 m, and with contrast bags placed in each of the four corners. It also stated that large sastrugi would need to be flattened, and both thresholds should be clear of obstructions with any camp positioned more than 200 m away.

National regulations

Antarctic regulations and permits require the operator to take all necessary actions to remove the aircraft in order to meet its obligations under the Antarctic treaties to minimise the potential for environmental impact and damage. However, the operator stated it is also implicitly recognised:

> *'That recovery may not be possible in all circumstances, particularly if the process of removing it is more damaging than leaving it in situ. Therefore, should an aircraft not be in a position to be flown but personnel are recoverable, its location, ease of retrieval, cost (in terms of to the environment – carbon footprint, etc), carriage of D[angerous] G[oods] (inc. fuel), and so on, should all be considered in the round.'*

Footnote

[5] The word comes from the Russian and means 'small ridges'.

Operational control

The operator is authorised to conduct general aviation operations and is required to comply with the rules laid down in Overseas Territories Aviation Requirements (OTAR) 125. OTAR 125.55 states:

> *'The pilot-in-command shall have responsibility for operational control.*
>
> *Note: Operational Control is the exercise of authority over the initiation, continuation, diversion or termination of a flight in the interest of the safety of the aircraft and the regularity and efficiency of the flight.'*

The operator's air operations manual (AOM)

> *2.1.2 Flight Authorisation*
>
> *All flights must be approved and authorised by the Chief Pilot. …. If changes from the scheduled flights are required, with the exception of flights for the purpose of saving life or other emergency, further authorisation must be sought before making the flight. …. Whenever an [mandatory occurrence report] MOR or [occurrence report] OR is required which relates to an aircraft operational error on the part of the flight crew and/or significant technical fault the flight crew are required to gain approval from the Chief Pilot before operating any company aircraft.'*

Commander's responsibilities

The operator's AOM permits a commander to deviate from its own procedures for the purposes of saving life or in an emergency. It further defined the scope of the commander's authority and responsibilities and authority with the focus on safety. It stated:

> *'2.3.4 Responsibility for Flights*
>
> *The responsibility for a flight, once authorised by the Chief Pilot, devolves to the PIC before departure….*
>
> *In flight, the final authority as to the disposition of his aircraft rests with the PIC who shall responsibly co-operate with operational and maintenance personnel. He shall base any decision on all aspects of the operational requirements and consequences regarding the aircraft, its passengers/cargo, and crew paying particular attention to safety.*
>
> *When the PIC accepts the aircraft…, he acknowledges he… will conduct the flight in accordance with the rules and regulations as described in the [operator's] AOM and any other National Regulations if more restrictive. He may deviate from any regulations in the interest of safety. Such a deviation must be reported using the Mandatory Occurrence Reporting procedure as described in this manual.'*

Analysis

The accident occurred during the ground roll of the takeoff run at a new unmanned deep field site as a result of the aircraft diverging from the skiway that the commander had previously cleared. Once airborne, on noticing some flight instruments were misaligned, together with some disruption to the cockpit structure, the commander decided to land at a nearby unmanned fuel depot to inspect for damage. Assessing the aircraft was safe to fly and conscious of the hostile environment and remote location, he made the decision to fly to a field site where there was better on-site protection and support for the crew and the aircraft.

Detection of Lateral movement

The cause of the aircraft diverging from the cleared skiway could not be determined. The conditions in the Antarctic, with its absence of topographical features, monochrome landscape and low contrast environment, can make it difficult to detect lateral movement.

The operator sought to mitigate this threat by marking the skiway with flags down one edge and contrast bags placed at each of the four corners. It has reviewed its procedures for preparing a skiway and considered that they were '*sufficient and satisfactory*'.

Decision to fly to Sky Blu

The commander was faced with either remaining at the location with its extremely hostile environment and the concomitant risks and challenges or flying the damaged aircraft to a field site with better engineering support and protection for personnel.

The commander had extensive experience in polar aviation operations. He was also able to draw upon his technical knowledge of the aircraft. He assessed the aircraft was safe to fly and decided that it was safer to fly to a field site about two hours flight time away, where there was better support.

Operational control

The operator had procedures for the exercise of operational control, requiring authorisation from the chief pilot '*with the exception of flights for the purpose of saving life or other emergency*'. The commander, faced with the team remaining in a remote and hostile location, acted within his authority in accordance with OTAR125.155 and the operator's AOM to act in '*in the interests of safety*'.

Communication with management

The commander highlighted a strong psychological barrier to communicate the situation with management. This arose from the difficulty he perceived he would encounter to relay the nature of the situation by satellite phone and his concern that any decisions made remotely may have been less effective.

The operator, while considering the communication channels to be adequate, acknowledged that effective communications were a very real barrier. This psychological barrier would probably have been exacerbated by the commander's awareness of the remoteness and extreme environment of the location and the consequence for personnel and the aircraft.

However, the decision not to discuss the situation with management missed the opportunity to discuss the situation with others including the potential threat of further damage occurring to the aircraft during the cruise phase of the subsequent flight.

Operator actions

The operator has developed a process to guide decision-making and escalation to management to promote effective decision-making at the right level according to the circumstances. It also reviewed its processes for preparing a skiway and the training for ski landing and taking off.

Conclusion

The accident occurred during the ground roll of the takeoff run as a result of the aircraft diverging from the skiway at a new unmanned site. The reason for the aircraft diverging from the cleared skiway could not be determined. However, the environmental conditions may have contributed to a loss of visual acuity by the commander.

The commander found himself in a situation with a genuine concern for risk to personnel. Drawing upon his engineering and technical knowledge of the aircraft, he assessed it was safe to fly, and decided to fly to a field site where there was better environmental protection and support for both personnel and the aircraft.

He considered that involving others, who were remote from the situation, in the decision-making process, may have resulted in a less optimum outcome. However, the decision not to communicate with management about the situation missed the opportunity to discuss the situation with others including the potential threat of further damage occurring during the cruise phase of the subsequent flight.

The operator recognised that there could be rare occasions where safety would take priority over airworthiness compliance, and it may occasionally be appropriate to fly a damaged aircraft if this minimised the risk to personnel and assets, or if it was required to meet international obligations for the protection of the Antarctic environment.

Safety actions

The operator took the following safety action:

It adopted the use of low orbit commercial satellites for communications, which improved quality and reliability.

It developed a ‘field checklist’ to guide the decision-making process when recovering damaged or unserviceable aircraft from remote locations. It would only be used in circumstances where the non-routine protection of life, assets or the environment conflicted with defined and well-established airworthiness and engineering requirements.

It reviewed existing processes and training for new sites and established that they were ‘sufficient and satisfactory’.

During the annual review of operations for 2023, it held discussions with pilots on remote decision-making, levels of autonomy for commanders and the confidence they had to raise safety concerns. These discussions would be repeated in the annual review of operations in 2024.