民航意外調查機構

AAIA

Air Accident Investigation Authority

Abnormal Runway Contact (ARC)

Investigation Report

Incident

Bombardier BD-700-2A12, N899ST

Hong Kong International Airport

Hong Kong

27 October 2022

IVR-2026-01

AAIA Investigations

Pursuant to Annex 13 to the Convention on International Civil Aviation and the Hong Kong Civil Aviation (Investigation of Accidents) Regulations (Cap. 448B), the sole objective of the investigation and the Investigation Report is the prevention of accidents and incidents. It is not the purpose of the investigation to apportion blame or liability.

The Chief Inspector instigated an inspector's investigation into the incident in accordance with the provisions in Cap. 448B.

This incident investigation report contains information of an occurrence involving a Bombardier BD-700-2A12, registration N899ST, managed by Forindo Pte Limited, Singapore, on 27 October 2022.

The National Transportation Safety Board of the United States of America (NTSB), being the investigation authority representing the State of Registry, the Transportation Safety Board of Canada (TSB), being the investigation authority representing the State of Design and State of Manufacture, the Transport Safety Investigation Bureau (TSIB) of Singapore, being the investigation authority on request by the AAIA, provided assistance to the investigation.

This Investigation Report supersedes all previous Preliminary Report and Interim Statements concerning this incident investigation.

All times in this Investigation Report are in Hong Kong Local Time unless otherwise stated.

Hong Kong Local Time is Coordinated Universal Time (UTC) + 8 hours.

Chief Accident and Safety Investigator

Air Accident Investigation Authority

Transport and Logistics Bureau

Hong Kong

April 2026

Synopsis

On 27 October 2022, the Bombardier BD-700-2A12 (registration N899ST), managed by Forindo Pte Ltd., departed Nanjing (NKG) for Hong Kong (HKG) with three flight crew members and two passengers on board, suffered from thrust reverser doors damage during landing at the Hong Kong International Airport.

During the landing on Runway 07R at about 2122 hours, the pilot deployed the thrust reverser, and the lower thrust reverser doors of both engines made contact with the runway, causing damage to these doors.

Damage was noticed when the Pilot-in-Command (PIC) conducted a post-flight walkaround check at the apron of Hong Kong Business Aviation Centre (HKBAC).

The investigation found that following the mainwheel touchdown, the aircraft's de-rotation was delayed by the pilot's continued aft sidestick input. The aircraft then entered a low speed/high angle of attack (AoA) situation which, when combined with the selection of maximum reverse thrust, induced an upward pitching moment. Consequently, the aircraft pitched up, causing both lower thrust reverser doors to contact the runway.

There was no other damage to the aircraft and no injury to any person.

The investigation team has made three safety recommendations.

Contents

1. FACTUAL INFORMATION

1.1. History of the Flight

(1) On 27 October 2022, the Bombardier BD-700-2A12 (registration N899ST), managed by Forindo Pte Limited, Singapore, departed Nanjing International Airport (ZSNJ) for a private flight to Hong Kong International Airport (VHHH).

(2) The PIC was the Pilot Flying (PF) in the left-hand seat. The other captain was the Pilot Monitoring (PM) in the right-hand seat[1].

(3) The PF was using the Head Up Display[2] (HUD).

(4) The aircraft conducted an Instrument Landing System (ILS) approach to Runway (RWY) 07R at approximately 2122 hours.

(5) The pitch angle in the approach was normal.

(6) After mainwheel touchdown and before the nosewheel touchdown, maximum reverse thrust was selected.

(7) The aircraft then attained a high nose attitude which resulted in the lower thrust reverser doors coming into contact with the runway surface.

(8) As the aircraft pitched up and the PM called 'Nose High', the PF pushed forward on the sidestick.

(9) The aircraft simultaneously drifted right of the centreline which the PF corrected.

(10) The rest of the landing rollout was normal and no abnormal noise was noticed by either the flight crew or the passengers.

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[1] PM and PF are procedurally assigned roles with specifically assigned duties at specific stages of a flight. The PF does most of the flying, except in defined circumstances. The PM carries out support duties and monitors the PF's actions and the aircraft's flight path. The PIC remains overall responsible for the safe execution of all tasks.

[2] Head Up Display is an instrument to present information to the pilot in the line of their external forward vision which projects key flight instrument data onto a small 'see-through' screen positioned just in front of the pilot line of sight looking ahead out of the aircraft.

(11) Post flight inspection by the flight crew at the apron of the HKBAC identified damage on the lower thrust reverser doors on both engines.

(12) The PF requested HKBAC to advise Hong Kong Air Traffic Control (ATC) to inspect the runway.

1.2. Injuries to Persons

There were two pilots, one flight attendant, and two passengers on board the aircraft. There was no injury to any person involved in the flight or to any third party.

<table>
<tr><th colspan="7">Injuries to Persons</th></tr>
<tr><td>Persons on board:</td><td>Crew</td><td>3</td><td>Passengers</td><td>2</td><td rowspan="2">Others</td><td rowspan="2">0</td></tr>
<tr><td>Injuries</td><td>Crew</td><td>0</td><td>Passengers</td><td>0</td></tr>
</table>

Table 1: Injuries to Persons

1.3. Damage - Aircraft

The lower thrust reverser doors of both engines were damaged. The details are included in Section 1.12.

1.4. Other Damage

There was no other damage to objects or the runway surface.

1.5. Personnel Information

1.5.1. Flight Crew

(1) Both pilots held valid licences and medical certificates.

(2) Both the PF and the PM reported that they were well rested prior to the flight.

(3) The PF had completed a proficiency check in August 2022.

(4) The PM had completed a proficiency check in September 2022.

(5) The flight crew information is in Section 6.2.

1.6. Aircraft Information

1.6.1. Aircraft

(1) Officially designated as the BD-700-2A12, the aircraft is marketed as the Global 7500[3]. It is an ultra-long-range aircraft, with executive interior business jet designed to carry up to 19 passengers. It is 33.88 metres long and has 39 degrees sweptback wings with wingspan of 31.7 metres.

(2) The flight control system provides Fly-by-Wire[4] (FBW) control and monitoring in the pitch, roll and yaw axes. Pitch control is provided by a movable horizontal stabilizer (HSTAB) and two elevators. Each wing has two ailerons and three multifunction spoilers (MFS) for roll control. The MFSs also provide speed brake control and, together with the ground spoilers (GSs), provide ground lift dumping (GLD). The rudder controls the yaw axis.

(3) The high-lift system consists of four slat and two flap surfaces on each wing, commanded by a SLAT / FLAP lever on the centre pedestal. Provision is made for backup extension using an alternate slat / flap control. High lift is not part of the FBW system.

(4) Pilot pitch and roll commands are input through two sidesticks, located on the side consoles, which operate independently. The sidesticks are not mechanically coupled and no feedback is provided to the opposite sidestick.

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[3] Operational information provided for flight crew uses the title ‘Global 7500’

[4] Fly-by-Wire is the generally accepted term for those flight control systems which use computers to process the flight control inputs made by the pilot or autopilot, and send corresponding electrical signals to the flight control surface actuators. This arrangement replaces mechanical linkage and means that the pilot inputs do not directly move the control surfaces. Instead, inputs are read by a computer that in turn determines how to move the control surfaces.

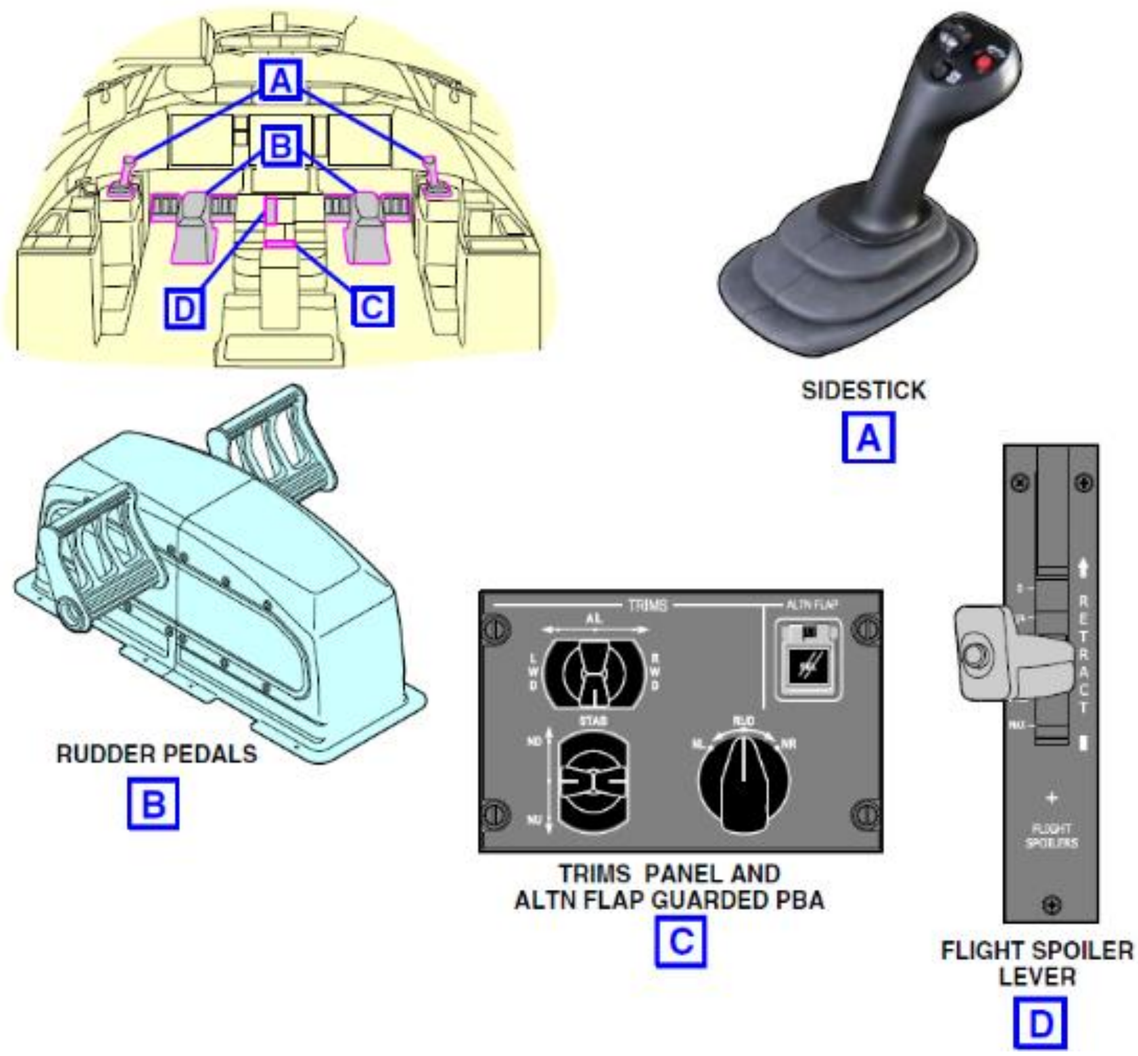

Figure 1: Pilot Flight Controls

Source: BD-700-2A12 Flight Crew Operating Manual[5] *(FCOM) Volume 2*

[5] Aircraft manufacturers issue manuals to instruct crew how to operate an aircraft type safely. The FCOM provides descriptions of the aircraft systems and crew procedures.

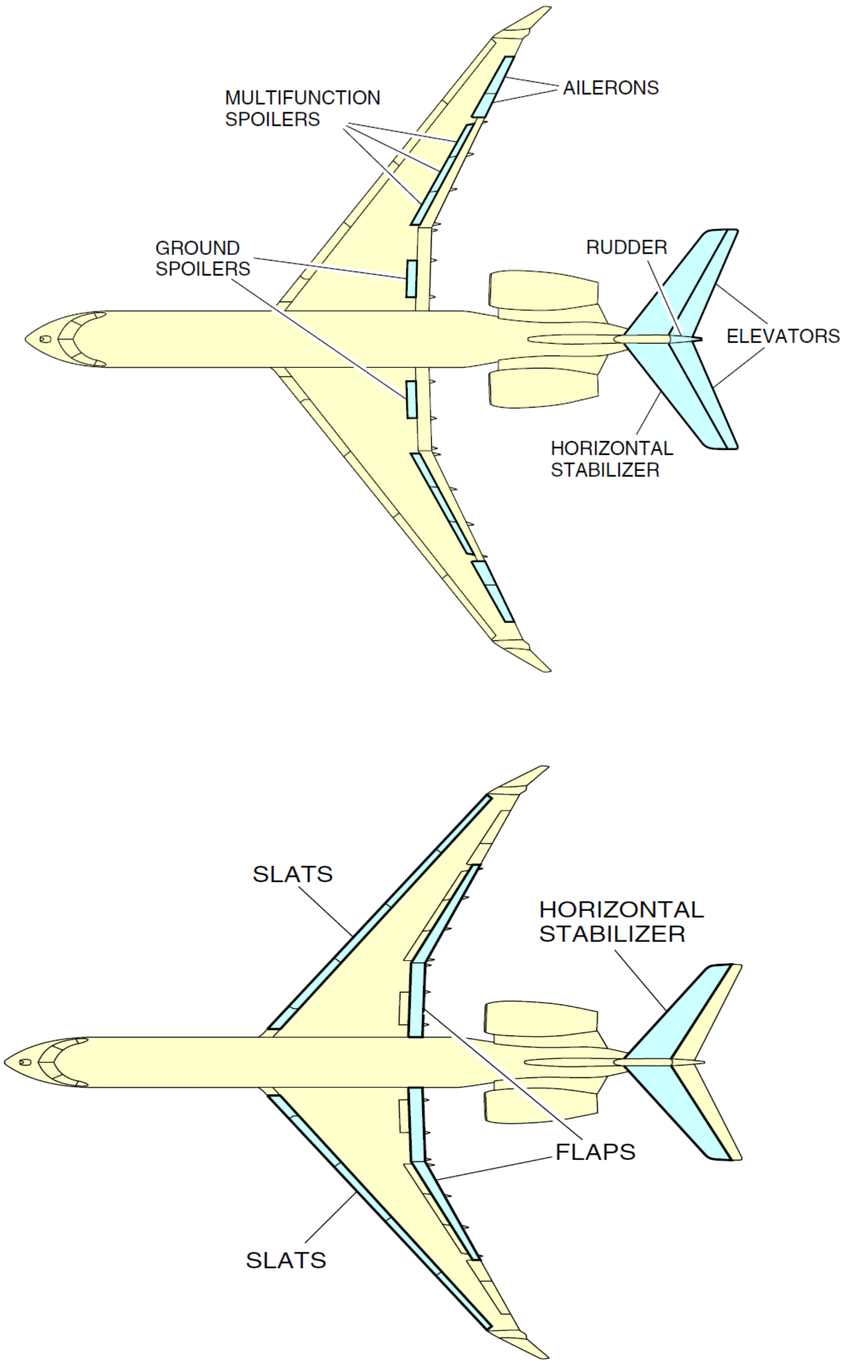

Figure 2: Flight Control Surfaces

Source: BD-700-2A12 Flight Crew Operating Manual (FCOM) Volume 2

(5) The FBW system converts pilot commands into aircraft control surface positions. Computers capture pilot control inputs, convert them to electronic signals, and transmit them to electronic units which command actuation of the control surfaces.

(6) The FBW system has a normal mode of operation and three direct modes. The FBW system defaults to the normal mode of operation which provides full control law automation[6] and flight envelope protection.

(7) FBW normal mode control laws (CLAWS) provide conventional flare characteristics for landing. As speed decreases in the flare, aft sidestick pressure is required to maintain or increase pitch angle.

(8) The CLAWS gradually transition from air to ground mode after landing and are characterized by:

(a) speed trim is disabled

(b) automatic HSTAB trimming is disabled

(c) control in pitch, roll, and yaw transitions to direct authority

(d) nose-up pitch angle limit is reduced to 17.5 degrees

(e) automatic elevator nose-down is commanded as the GSs deploy

(9) On ground, the MFS and GS automatically deploy to dump lift during the landing rollout, or during a rejected takeoff.

(10) If FBW normal mode cannot be supported or is not available due to failures, the FBW automatically enters the direct mode appropriate to the failure conditions. In FBW direct mode, envelope and structural protections are reduced to the extent which depends on the reason for the direct mode. Additionally, the path from pilot input to control surface actuation is designed to minimize the effect of failed components including flight control computers.

(11) The Non-Normal Procedures (Flight Controls) in the Aircraft Flight Manual state that a slight pitch up may occur with the thrust reverser deployment after mainwheel touchdown, where the protection from the FBW system is downgraded.

(12) The pitch angle limits for tail strike are as follows:

[6] FBW normal mode control laws provide various functions in pitch, roll, and yaw to assist in airplane control.

(a) 15.5 degrees for compressed landing gear

(b) 16.9 degrees for fully extended gear

(13) There was no pitch angle limit prescribed for aircraft configuration with the thrust reverser doors deployed.

(14) The aircraft has a digital glass cockpit design, with four large LCD displays. Also, the HUD displays data from the commander's flight instruments. The HUD is rotated down from its stowed position in the ceiling panel above the left windscreen for use. The co-pilot's position is not fitted with a HUD.

(15) The aircraft details are described in Section 6.3.

1.6.2. Engine

(1) The aircraft is powered by two General Electric Passport 20-19 high bypass dual-rotor, axial-flow turbofan aft-mounted engines. The engine is equipped with a dual channel Next Gen Full-Authority Digital Engine Control (FADEC) control system which provides enhanced fault isolation and capability for engine functionality and diagnostics. The engines provide thrust, electrical power, bleed air, and hydraulic power for aircraft systems operation.

(2) The engine is equipped with a clamshell-type thrust reverser. When deployed, it helps deceleration during landings and rejected takeoffs (RTO). The reverse thrust is provided by diverting the engine airflow through the upper and lower doors of the thrust reverser.

(3) When the thrust reverser is deployed, the thrust levers can be pulled into the reverse range. The FADEC controls the reverse thrust to remain within engine limits, and adjusts the N1[7] automatically. In a non-RTO scenario, maximum N1 shall be set to 83.9% N1, and maximum static N1 decreases to 35% N1 with ramp down from 100 knots to 50 knots forward speed.

(4) The thrust reverser doors pivot to block the rearward flow of combined core gas and fan discharge, deflecting and changing the direction of the discharge gas. The upper and lower doors are opened and closed using a hydraulic actuator on each door.

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[7] N1 is the rotational speed of the low pressure turbine and compressor spool expressed as a percentage of the maximum normal operating revolutions per minutes of the spool.

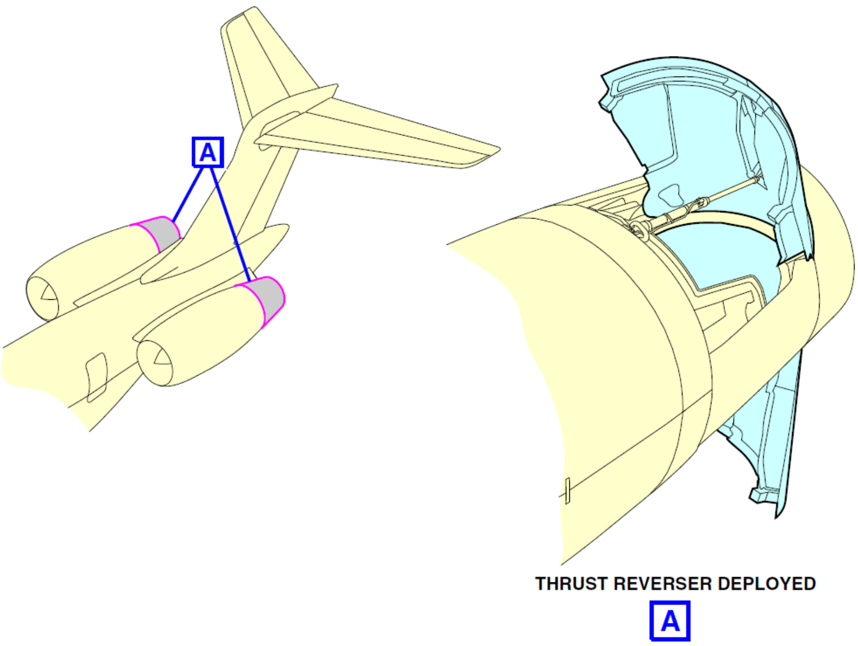


Figure 3: Thrust Reverser in Deployed Position

Source: BD-700-2A12 Flight Crew Operating Manual (FCOM) Volume 2

(5) In the stowed position, the thrust reverser functions as the primary exhaust nozzle to direct and focus core exhaust gas and fan airflow.

(6) The FADEC controls the thrust reverser actuation system, preventing deployment in flight.

(7) An interlocking mechanism makes sure that the upper and lower doors deploy simultaneously and secures the doors when stowed.

1.6.3. Maintenance History

There was no reported defect which affected the airworthiness of the aircraft before the incident flight.

1.7. Meteorological Factors

The meteorological aerodrome weather report for VHHH at 2100 hours indicated that the wind was from 100 degrees at 7 knots. The visibility was 10 kilometres or more. There was no cloud below 5,000 feet and no significant weather at or in the vicinity of the aerodrome. The runway condition was dry.

1.8. Aids to Navigation

Ground-based navigation aids and aerodrome visual ground aids were not a factor in this incident.

1.9. Communications

The aircraft was equipped with Very High Frequency (VHF) radio communication systems. All VHF radios were serviceable. All communications between Hong Kong ATC and the flight crew were recorded by the Voice Recording System of Hong Kong ATC.

1.10. Aerodrome Information

The information on the arrival aerodrome is listed in Section 6.4.

1.11. Flight Recorders

(1) The aircraft was equipped with a Digital Flight Data Recorder (DFDR) and a Cockpit Voice Recorder (CVR).

(2) The DFDR and CVR were functional. The data was downloaded successfully from the two recorders for the investigation. Flight data was available for the entire event flight and previous flights prior to the event.

(3) The following factual information of the event flight was established from the flight data in relation to the landing rollout phase.

- (a) Flight spoilers were retracted, and slats/flaps were fully extended.
- (b) Both the left and the right main gears touched down at about the same time.
- (c) The aircraft pitch angle was approximately 7.5 degrees when the mainwheel touched down.
- (d) Shortly after the mainwheel touchdown, the PF selected reverse thrust and moved the levers to about 22.5 degrees in the reverse range.

(e) N1 of both engines went up to about 85 % accordingly.

(f) After the mainwheel touchdown, back pressure was applied to the left sidestick, moving it to about 10 degrees. A pitch angle of about 6-7 degrees was registered for around 6 seconds.

(g) The aircraft pitch angle then increased to approximately 14 degrees.

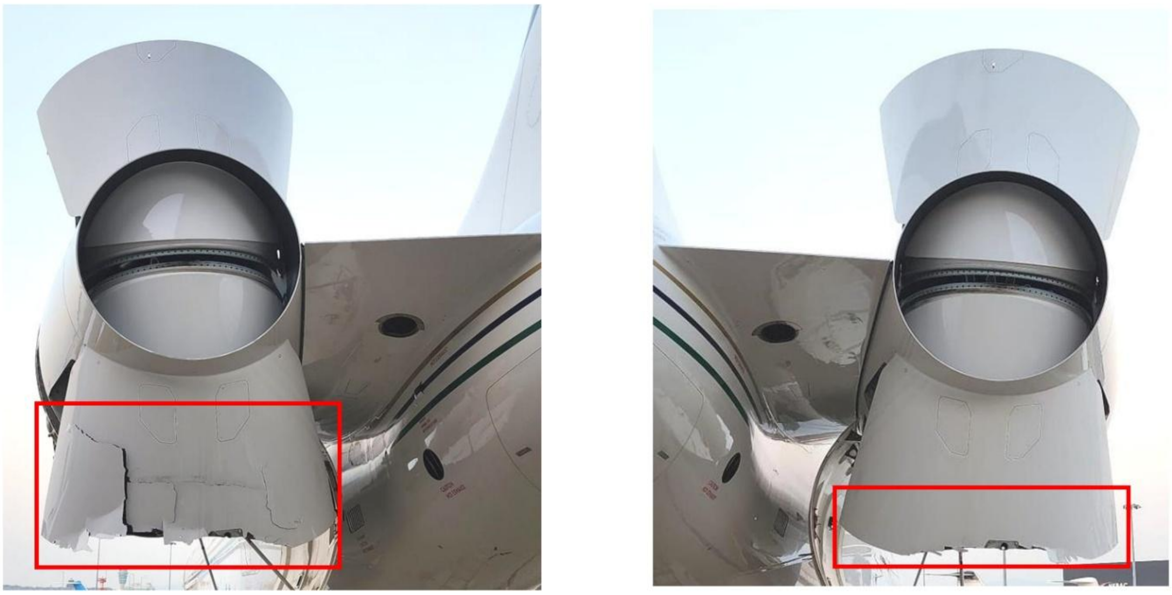
(h) The PF pushed the sidestick forward to lower the aircraft nose.

(i) The thrust levers were moved back to idle at about the same time. Approximately 6 seconds later, the nosewheels also touched down.

(j) Auto-braking was not used and manual brakes were not applied before the nosewheel touched down.

1.12. Wreckage and Impact

(1) The lower thrust reverser doors of both engines were damaged when touching the runway on landing.



Left Engine Lower Reverser Door   Right Engine Lower Reverser Door

Photo 1: Damage on Lower Thrust Reverser Doors (view from rear)

(2) There was no other damage to the aircraft during the incident.

1.13. Medical/Pathological Information

No medical or pathological investigations were conducted as a result of this occurrence, nor were they required.

1.14. Smoke, Fire, and Fumes

Not applicable.

1.15. Survival Aspects

Not applicable.

1.16. Tests and Research

1.16.1. Flight Evaluation at Flight Crew Training Facility

(1) With prior arrangements with Bombardier, a visit was made by the AAIA to a Bombardier's approved training facility where the after touchdown techniques were discussed taking into account the unique FBW de-rotation of the nose wheel feature. Two major areas were reviewed:

(a) The timing to deploy the thrust reverser during aircraft de-rotation and the interface between the FBW on various flight controls. In particular,

(i) The normal sequence/time to select the reverse thrust in relation to the lowering of nosewheel.

(ii) The technique described in the FCOM for FBW air-to-ground transition control in relation to autobrake, thrust reverser and ground spoilers deployment.

(iii) PM monitoring and call out events during touchdown such as extension of spoilers and, selection of reverse thrust, and calling out the N1% indication.

(b) The taught technique regarding FBW de-rotation of the conversion training from other aircraft type to the BD-700-2A12 was discussed. There was no specified technique on when to select the thrust reverser and that pilots were taught the BD-700-2A12 had a different technique regarding de-rotation due to the FBW.

(2) To support the review, the training facility provided a simulator and with a Bombardier test pilot flying, attempts were made to replicate the incident flight. Landings were made to deploy the thrust reverser after landing at various aircraft pitch angles within the flight envelope to check if there was any pitch up effect induced by the reverse thrust, but it was not possible to replicate the pitch up effect caused by the reverse thrust during landing.

1.16.2. Computer Simulations by Bombardier

(1) In order to further understand the aerodynamic effects in relation to the deployment of the thrust reverser at greater than zero AoA as observed in the flight data, as well as attempt to determine why the pitch up effect was not able to be replicated in the simulator, Bombardier also conducted a series of computer simulations[8].

(2) A simulation model was developed to simulate the situation where the thrust reverser would be deployed after nosewheel touchdown.

(3) According to Bombardier, a BD-700-2A12 simulation model update was required to reproduce the aircraft behaviour observed on the event flight as the event was flown in an area that had limited flight test data validation. As such, the simulator was not initially equipped with the data to recreate this particular manoeuvre of the event flight.

(4) Bombardier modified the simulation model to specifically cover the following two major effects:

(a) Pitching moment in relation to the deployment of the thrust reverser.

(i) Observation (1) - When the AoA is near to zero degree, the reverse thrust would produce pitch down effect.

(ii) Observation (2) - There was a significant pitch up effect observed as the AoA increased. This effect became more pronounced when the AoA was greater than 7 degrees. The slower the aircraft and the higher the AoA (i.e. low speed/high AoA situation), the more pronounced the aircraft pitch up moment would be due to the reverse thrust.

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[8] Bombardier provided Factual & Simulation Analysis Report (ASIO-2023-ML-033) and Engineering Simulation Model Update Report (ASIO-2023-ML-034) to the AAIA.

(b) Elevator effectiveness in relation to the deployment of the thrust reverser

(i) Observation (1) - The simulation demonstrated that the elevator effectiveness was reduced at higher AoA when the thrust reverser were deployed.

1.17. Organisation, Management, System Safety

1.17.1. Transport Canada Civil Aviation (TCCA)

The TCCA is the regulatory authority responsible for the airworthiness and environmental certification of all aeronautical products, parts, and appliances designed, manufactured, maintained or used by persons under the regulatory oversight of Canada. It carries out the functions and tasks of the State of Design and State of Manufacture of the Bombardier BD-700-2A12 aircraft.

1.17.2. Federal Aviation Administration (FAA)

The FAA is the regulatory authority responsible for the airworthiness and environmental certification of all aeronautical products, parts, and appliances designed, manufactured, maintained or used by persons under the regulatory oversight of the United States. It carries out the functions and tasks of the State of Design and State of Manufacture of the General Electric Passport 20-19 engines.

1.17.3. The Aircraft Management Company

Forindo Pte Limited[9] was incorporated in 1977 and registered in Singapore.

1.18. Additional Information

1.18.1. FCOM Recommended Operational Procedures and Techniques (ROPAT)

(1) The FCOM contains a separate section inserted by Bombardier termed Recommended Operational Procedures and Techniques (ROPAT). This was added in November 2020 as an advisory and is intended to

[9] Forindo Pte Limited was the company which managed the aircraft at the time of the Incident.

complement the FCOM and provide recommendations and procedural guidance for the safe and efficient operation of the BD-700-2A12.

(2) The guidance related to touchdown is extracted from the ROPAT as follows.

(a) To ensure sufficient clearance from wing tip to the ground during landing, the FCOM recommends a pitch angle of 7 to 8 degrees at touchdown.

(b) At touchdown, the GLD system extends all spoilers automatically. The ROPAT recommends that the aft sidestick should be relaxed to neutral. The FBW control laws will de−rotate the aircraft for nosewheel touchdown.

(c) Automatic elevator nose−down is commanded as the GSs deploy.

(d) This transition is transparent to the pilot flying.

(e) After touchdown, the thrust reverser should be deployed as required.

(f) If thrust reverse is initiated before nosewheel touchdown, pitch inputs would be required to "fly" the desired pitch and smoothly touch down the nosewheels.

(g) After mainwheel touchdown, if the thrust reverser is deployed prior to nosewheel touchdown, the autothrottle disengagement aural will be heard as the autothrottles disengage.

(h) If Autobraking is active at touchdown, the deceleration will ramp up smoothly to achieve the selected deceleration rate.

(i) Autobrake, when selected, will activate upon mainwheel touchdown. Small aft pitch input may be required to smoothly lower the nosewheel to the landing surface.

1.19. Useful or Effective Investigation Techniques

Not applicable.

2. Safety Analysis

The Safety Analysis provides a detailed discussion of the safety factors identified during the investigation, providing the evidence required to establish the findings, causes, contributing factors and the safety recommendations.

2.1. Introduction

Apart from considering a number of flight operations, technical and environmental factors, the safety analysis will discuss the pilot handling techniques during the landing rollout with reference to the prescribed operating procedures and the aircraft handling characteristics.

2.2. Flight Operations

2.2.1. Crew Qualification

The flight crew were licensed and qualified for the flight in accordance with licensing requirements of the United States of America.

2.2.2. Weather

The prevailing weather conditions were generally fine for the flight and were not a factor in this incident.

2.2.3. Use of HUD

No evidence was found that the use of HUD had any material effect on this incident.

2.2.4. Aids to Navigation

There was no report of abnormal operation of any ground-based navigation aids or aerodrome visual ground aids.

2.2.5. Communications

All communications between the Hong Kong ATC and the aircraft were clear and there was no report of any defective radio communication system in the cockpit.

2.3. Pilot Handling Techniques – Landing Rollout

(1) Selected flight data related to the landing rollout in Hong Kong is presented in 1.11. The data confirmed that the aircraft was in the correct landing configuration.

(2) The initial touchdown was generally smooth, with both the left and right main gears touching down simultaneously. Aircraft pitch angle was approximately 7.5 degrees when the thrust reverser was selected.

(3) After the mainwheel touchdown, back pressure was applied to the PF's sidestick, moving it to approximately 10 degrees and then aircraft pitch angle rapidly increased from 6-7 degrees to approximately 14 degrees. In response to the sudden pitch up, the PF pushed the sidestick forward to lower the aircraft's nose.

(4) From a handling perspective, the PF maintained a high nose angle after touchdown. Examination of the flight recorder readouts from the previous flights[10] confirmed this technique.

(5) This handling technique delayed the aircraft from de-rotating as it decelerated and created a precursor to the subsequent event when combined with the pronounced pitch up effect associated with a low speed/high AoA situation after the maximum reverse thrust was applied.

2.4. Operation Procedures

2.4.1. Tailstrike Limits

(1) The FCOM states that aircraft pitch angle limit for tail strike is 15.5 degrees for compressed landing gear and 16.9 degrees for fully extended landing gear.

(2) The flight data analysis revealed that the lower thrust reverser doors of both engines made contact with the runway surface. The maximum pitch angle of the aircraft was approximately 14.4 degrees (nose-up) after touchdown.

(3) In this scenario, the contact between the thrust reverser doors and the runway occurred before the nose-up pitch angle of the aircraft reached the pitch angle limits specified in FCOM.

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[10] A total of nine flights was analyzed by the AAIA in which the PIC involved was the Pilot Flying (PF) in five of these flights.

(4) There was no pitch angle limit prescribed for aircraft configuration with the thrust reverser door deployed.

(5) Without specifying the geometry limit related to the lower thrust reverser door, the flight crew may not be aware of this hazard, especially if this limit is more restrictive (i.e. lower) than the tail strike limits. Given that this is an inherent characteristic of the flight handling, it is crucial for the manufacturer to explicitly communicate this information to the pilot community[11].

2.4.2. FCOM/ROPAT Procedures for Touchdown

(1) The FCOM recommends a pitch angle of 7 to 8 degrees for touchdown. After the mainwheel touchdown, the sidestick should be relaxed to the neutral position, allowing the FBW control laws to de-rotate the aircraft for nosewheel touchdown.

(2) In the meantime, the ROPAT suggests that flight crews may need to apply pitch inputs from a piloting perspective in order to achieve the desired outcome when deploying the thrust reverser and autobrake [ROPAT Vol 1 05-01-153 (A)], rather than maintaining a neutral position on the sidestick and allowing the FBW control laws to de-rotate the aircraft for nosewheel touchdown as suggested in the FCOM.

(3) From a training perspective, there is no specified technique when to select the thrust reverser and that pilots are taught the BD-700-2A12 has a different technique regarding de-rotation due to the FBW.

(4) There was the possibility of confusion due to differing advice for the FBW nosewheel de-rotation as outlined in both the FCOM and the ROPAT, combining with the absence of a consistent training curricula.

2.5. Aircraft Handling Characteristics

(1) According to the Bombardier’s computer simulation (1.16.2), the pitch effect due to deploying the thrust reverser primarily resulted in a downward pitch when the AoA was close to zero. However, it transitioned into an upward pitch when the AoA reached higher values. This pitch up effect intensified rapidly as the AoA exceeded 7 degrees after touchdown.

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[11] Refer to Safety Recommendation SR-2023-07

(2) The Non-Normal Procedures (Flight Controls) in the Aircraft Flight Manual states that a slight pitch up may occur with the thrust reverser deployment after mainwheel touchdown, where the protection from the FBW system is downgraded.

(3) From the incident landing and computer simulations, it has been observed that the pitch up phenomenon, caused by application of maximum reverse thrust while maintaining a high pitch attitude, may occur even when the FBW system is functioning normally, especially at high AoA.

(4) Besides, the FCOM recommends a pitch angle of 7 to 8 degrees for touchdown. It results in a significant increase in the risk of the thrust reverser door strikes due to the pronounced pitch up effect caused by the application of maximum reverse thrust if a high pitch attitude is maintained.

(5) The available flight data regarding the incident aircraft reveals a consistent high pitch angle achieved through a specific landing technique. However, it also raises the possibility of other pilots encountering a similar situation due to variations in individual landing technique. Some pilots may inadvertently induce and maintain a high pitch angle thereby leading to a low speed/high AoA landing situation.

(6) It is vital to effectively manage the pitch up effect resulting from the thrust reverser deployment in a low speed/high AoA landing situation to ensure that the aircraft's operational limits are not exceeded.

(7) In order to ensure that the prescribed handling techniques do not inadvertently result in a high pitch angle situation, a thorough review of the guidance and procedures outlined in the ROPAT is essential to providing a clear and comprehensive guidance regarding these techniques, and how to apply them appropriately. This should be reinforced by the appropriate training and dissemination of flight/handling characteristics through appropriate means and channels for pilot awareness[12].

2.6. Aircraft's Envelope Protection

(1) In the current FBW regime, the flight control laws do not prevent the pilot from commanding excessive aft sidestick input in a low speed/high AoA situation when deploying the thrust reverser during mainwheel touchdown.

(2) The aircraft does not provide any warnings or cues to alert the pilot of the undesirable AoA in relation to the thrust reverser deployment.

(3) In addition to addressing landing techniques as both a preventive measure and a last line of defence for recovery, there is potential for improvement in

[12] Refer to Safety Recommendation SR-2023-08

the aircraft's envelope protection to effectively prevent such incidents. Considerations should also be given to implementing an appropriate measure(s) to alert the crew of the undesirable aircraft AoA at touchdown in relation to the thrust reverser deployment[13].

2.7. Aircraft Maintenance

The investigation team did not identify any maintenance related issue, or inherent defect that might have led to the incident. Aircraft maintenance was not a factor in this incident.

[13] Refer to Safety Recommendation SR-2024-02

3. Conclusions

3.1. Findings

(1) The flight crew were licensed and qualified for the flight in accordance with licensing requirements of the United States of America. (2.2.1)

(2) The prevailing weather conditions were generally fine for the flight and were not a factor in this incident. (2.2.2)

(3) No evidence was found that the use of HUD had any material effect on this incident. (2.2.3)

(4) The data confirmed that the aircraft was in the correct landing configuration. [2.3 (1)]

(5) The initial touchdown was generally smooth, with both the left and right main gears touching down simultaneously. Aircraft pitch angle was approximately 7.5 degrees when the thrust reverser was selected. [2.3 (2)]

(6) After the mainwheel touchdown, back pressure was applied to the PF's sidestick, moving it to approximately 10 degrees and then aircraft pitch angle rapidly increased from 6-7 degrees to approximately 14 degrees. In response to the sudden pitch up, the PF pushed the sidestick forward to lower the aircraft's nose. [2.3 (3)]

(7) From a handling perspective, the PF maintained a high nose angle after touchdown. Examination of the flight recorder readouts from the previous flights confirmed this technique. This handling technique delayed the aircraft from de-rotating as it decelerated and created a precursor to the subsequent event when combined with the pronounced pitch up effect associated with a low speed/high AoA situation after the maximum reverse thrust was applied. [2.3 (4), 2.3 (5)]

(8) The contact between the thrust reverser doors and the runway occurred before the nose-up pitch angle of the aircraft reached the pitch angle limits specified in FCOM. [2.4.1 (3)]

(9) There was no pitch angle limit prescribed for aircraft configuration with the thrust reverser door deployed. [2.4.1 (4)]

(10) Without specifying the geometry limit related to the lower thrust reverser door, the flight crew may not be aware of this hazard, especially if this limit is more restrictive (i.e. lower) than the tail strike limits. Given that this is an inherent characteristic of the flight handling, it is crucial for the

manufacturer to explicitly communicate this information to the pilot community [2.4.1 (5)].

(11) There is the possibility of confusion due to differing advice for the FBW nosewheel de-rotation as outlined in both the FCOM and the ROPAT, combining with the absence of a consistent training curricula. [2.4.2 (4)]

(12) According to the Bombardier's computer simulation, the pitch effect due to deploying the thrust reverser primarily resulted in a downward pitch when the AoA was close to zero. However, it transitioned into an upward pitch when the AoA reached higher values. This pitch up effect intensified rapidly as the AoA exceeded 7 degrees after touchdown. [2.5 (1)]

(13) From the incident landing and computer simulations, it has been observed that the pitch up phenomenon, caused by application of maximum reverse thrust while maintaining a high pitch attitude, may occur even when the FBW system is functioning normally, especially at high AoA. [2.5 (3)]

(14) The available flight data regarding the incident aircraft reveals a consistent high pitch angle achieved through a specific landing technique. However, it also raises the possibility of other pilots encountering a similar situation due to variations in individual landing techniques. Some pilots may inadvertently induce and maintain a high pitch angle, thereby leading to a low speed/high AoA landing situation. [2.5 (5)]

(15) In order to ensure that the prescribed handling techniques do not inadvertently result in a high AoA situation, a thorough review of the guidance and procedures outlined in the ROPAT is essential to providing a clear and comprehensive guidance regarding these techniques, and how to apply them appropriately. This should be reinforced by the appropriate training and dissemination of flight/handling characteristics through appropriate means and channels for pilot awareness. [2.5 (7)]

(16) In the current FBW regime, the flight control laws do not prevent the pilot from commanding excessive aft sidestick input in a low speed/high AoA situation when deploying the thrust reverser during mainwheel touchdown. [2.6 (1)]

(17) The aircraft does not provide any warnings or cues to alert the pilot of the undesirable AoA in relation to the thrust reverser deployment. [2.6 (2)]

(18) In addition to addressing landing techniques as both a preventive measure and a last line of defence for recovery, there is potential for improvement in the aircraft's envelope protection to effectively prevent such incidents. Considerations should also be given to implementing an appropriate measure(s) to alert the crew of the undesirable AoA at touchdown in relation to the thrust reverser deployment. [2.6 (3)]

(19) The investigation team did not identify any maintenance related issue, or inherent defect that might have led to the incident. Aircraft maintenance was not a factor in this incident. (2.7)

3.2. Cause

Following the mainwheel touchdown, the aircraft's de-rotation was delayed by the pilot's continued aft sidestick input. The aircraft then entered a low speed/high AoA situation which, when combined with the selection of maximum reverse thrust, induced an upward pitching moment. Consequently, the aircraft pitched up, causing both lower thrust reverser doors to contact the runway. [3.1 (6), 3.1 (12)]

4. AAIA Safety Recommendation Report

(1) When a safety issue is identified at any stage of the investigation, the AAIA issues Safety Recommendation Report to the relevant organisation(s) to recommend preventative action that has to be taken promptly to enhance aviation safety.

(2) During the investigation, the AAIA identified safety issues regarding pitch up effect when deploying the thrust reverser during mainwheel touchdown in a low speed/high AoA situation, as well as the touchdown guidance and procedures outlined in the FCOM/ROPAT. It was crucial to address both issues promptly. Consequently, the AAIA issued Safety Recommendation Report 02-2023 on 10 November 2023, which included Safety Recommendation SR-2023-07[14] and SR-2023-08 to Bombardier Inc. On 7 March 2024, the AAIA issued the 2nd Safety Recommendation Report SRR-2024-02, which included Safety Recommendation SR-2024-02 to Bombardier Inc.

4.1. Safety Recommendation SR-2023-07

It is recommended that the manufacturer takes proactive measures to communicate the flight/handling characteristics observed in this incident, along with any pertinent lessons learned, to a broader pilot community. This dissemination of information should be carried out through appropriate means and channels, in order to effectively raise awareness among pilots [3.1 (10)].

Safety Recommendation Owner: Bombardier Inc.

4.2. Safety Recommendation SR-2023-08

It is recommended that the manufacturer conducts a thorough review of the guidance and procedures outlined in the ROPAT to ensure that the prescribed handling techniques do not inadvertently result in a high nose attitude situation [3.1 (15)]. This review should focus on the following aspects:

(1) Ensure that the ROPAT provides clear and comprehensive guidance regarding these techniques, and how to apply them appropriately.

(2) Ensure that both training manuals and training vendors provide operational guidance in the appropriate techniques.

Safety Recommendation Owner: Bombardier Inc.

[14] Due to the change of the AAIA's internal file reference numbers associated with the introduction of the new Investigation Management System (IMS), Safety Recommendation 07-2023 and 08-2023 were retitled to SR-2023-07 and SR-2023-08 respectively.

4.3. Safety Recommendation SR-2024-02

It is recommended that the manufacturer conducts a thorough technical evaluation of the aircraft’s envelope protection to determine if any suitable measure(s) can be implemented in safeguarding the aircraft against the pitch up effect resulting from the thrust reverser deployment in a low speed/high angle-of-attack regime after landing [3.1 (18)].

Safety Recommendation Owner: Bombardier Inc.

5. Implementation of the AAIA Safety Recommendations

5.1. Safety Actions Taken in Response to the Safety Recommendations

5.1.1. Safety Actions Taken by Bombardier

(1) Regarding Safety Recommendation SR-2023-08, Bombardier initiated an internal review by the relevant Subject Matter Experts (SMEs) of the guidance and procedures outlined in the ROPAT, as per the recommendation. Changes have been made to the FCOM, clarifying the correct landing technique to prevent abrupt pitch up and subsequent thrust reverser doors contact with the runway. These changes would be incorporated into Revision 25 of the FCOM, which was scheduled to be released on 3 April 2025. Concerning part (b) of recommendation SR-2023-08, Bombardier would advise training vendors of any revised guidance in the ROPAT and recommend incorporating these changes into their training curricula. They would also evaluate the best methods to disseminate awareness of the appropriate landing technique, in accordance with recommendation SR-2023-07.

(2) In response to Safety Recommendation SR-2024-02, Bombardier stated that the recommendation was submitted to their Continuing Airworthiness assessment process to evaluate reported potential safety issues in terms of fleet risk and mandate corrective action if required, to achieve a formal and complete determination. The assessment concluded that the level of risk to the fleet was low, and no potential regulatory design compliance issue was identified. Additionally, the risk of implementing a design change in envelope protection for this scenario might be higher than the perceived risk. Consequently, Bombardier concluded that the best course of action was not to modify the control laws but to rely on the training initiatives and procedural enhancements to address the identified risks.

6. General Details

6.1. Occurrence Details

Date and time:	27 October 2022, 2122 hours (local time)	
Occurrence category:	Incident	
Primary occurrence type:	Abnormal Runway Contact (ARC)	
Location:	Runway 07R, Hong Kong International Airport, Hong Kong	
	Latitude: 22°18'41.14"N	Longitude: 113°53'58.32"E

6.2. Pilot Information

6.2.1. Pilot Flying

Age:	66 years
Licence:	Airline Transport Pilot Licence (ATPL), FAA
Aircraft ratings:	BD700, G7500
Date of first issue of aircraft rating on type:	5 August 2021
Instrument rating:	Group 1 (ATPL)
Medical certificate:	Class 1, valid to 30 November 2022
Date of last proficiency check on type:	22 August 2022
Date of last line check on type:	22 August 2022
Date of last emergency drills check:	22 August 2022
ICAO Language Proficiency:	Level 6

Limitation:	Corrective lenses are required
Flying Experience	
Total all types:	15,465 hours
Total on type (G7500) :	285 hours
Total in last 90 days:	54.4 hours
Total in last 30 days :	15.7 hours
Total in last 7 days:	6.7 hours
Total in last 24 hours:	2.2 hours
Duty Time	
Day up to the incident flight (Hours:Mins) :	6 hours
Day prior to incident (Hours:Mins) :	5 hours

6.2.2. Pilot Monitoring

Age:	54 years
Licence:	ATPL, FAA
Aircraft ratings:	BD700, CL604, DA50, G7500
Date of first issue of aircraft rating on type:	6 August 2021
Instrument rating:	Group 1 (ATPL)
Medical certificate:	Class 1, valid to 7 June 2024
Date of last proficiency check on type:	22 September 2022
Date of last line check on type:	22 September 2022
Date of last emergency drills check:	22 September 2022

ICAO Language Proficiency:	Level 6
Limitation:	Nil
Flying Experience	
Total all types:	13,840 hours
Total on type (G7500) :	290 hours
Total in last 90 days:	47.2 hours
Total in last 30 days :	15.7 hours
Total in last 7 days:	6.7 hours
Total in last 24 hours:	2.2 hours
Duty Time	
Day up to the incident flight (Hours:Mins) :	6 hours
Day prior to incident (Hours:Mins) :	5 hours

6.3. Aircraft Details

Manufacturer and model:	Bombardier BD-700-2A12
Registration:	N899ST
Aircraft Serial number:	70078
Year of Manufacture	2021
Engine	Two General Electric Passport 20-19 turbo fan
Engine Serial Number	LH: 904273 RH: 904272
Owner:	Bank of Utah Trustee

Type of Operation:	Private	
Certificate of Airworthiness	Standard Airworthiness Certificate in Transport Category Issued on 16 September 2021	
Departure:	Nanjing Lukou International Airport (ZSNJ)	
Destination:	VHHH	
Persons on board:	Crew – 3	Passengers – 2
Injuries:	Crew – 0	Passengers – 0
Aircraft damage:	Minor Damage	

6.4. Aerodrome Information

6.4.1. Aerodrome of Destination

Aerodrome Code	VHHH
Airport Name	Hong Kong International Airport
Airport Address	Chek Lap Kok, Lantau Island
Airport Authority	Airport Authority Hong Kong
Air Navigation Services	Approach Control, Aerodrome Control, Ground Movement Control, Zone Control, Flight Information Service, Clearance Delivery Control, Automatic Terminal Information Service
Type of Traffic Permitted	Instrument Flight Rules (IFR) / Visual Flight Rules (VFR)
Coordinates	22° 18' 32" N, 113° 54' 53" E
Elevation	28 feet
Runway Length	3,800 metres

Runway Width	60 metres
Stopway	Nil
Runway End Safety Area	240 metres x 150 metres
Azimuth	07L / 25R, 07R/ 25L[15]
Category for Rescue and Fire Fighting Services	CAT 10

[15] Hong Kong International Airport initially had two runways, the North Runway and the South Runway. With the introduction of a third runway, which commenced operations in July 2022, the original North Runway was re-designated as the Centre Runway (07/C/25C), while the new third runway was designated as the North Runway (07L/25R). The South Runway remains as 07R/25L. At the time of this incident, the Centre Runway was closed to facilitate construction works, expansion, and upgrades.

7. Abbreviations

AAIA	Air Accident Investigation Authority of Hong Kong
AoA	Angle of attack
ARC	Abnormal runway contact
ATC	Air Traffic Control
ATPL	Airline Transport Pilot Licence
CAT	Category
CLAWS	Control laws
CVR	Cockpit Voice Recorder
DFDR	Digital Flight Data Recorder
FAA	Federal Aviation Administration of the United States of America
FADEC	Full Authority Digital Engine Control
FCOM	Flight Crew Operating Manual
FBW	Fly-by-Wire
GLD	Ground lift dumping
GSs	Ground spoilers
HKBAC	Hong Kong Business Aviation Centre
HSTAB	Horizontal stabilizer
HUD	Head Up Display
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMS	Investigation Management System
MFS	Multifunction spoiler

NTSB	National Transportation Safety Board of the United States of America
PIC	Pilot-in-command
PF	Pilot Flying
PM	Pilot Monitoring
ROPAT	Recommended Operational Procedures and Techniques
RTO	Rejected takeoff
RWY	Runway
TSB	Transportation Safety Board of Canada
TSIB	Transportation Safety Investigation Bureau of Singapore
UTC	Coordinated Universal Time
VHF	Very High Frequency
VFR	Visual Flight Rules
VHHH	Hong Kong International Airport
ZSNJ	Nanjing Lukou International Airport

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8. Table of Figures, Photos, Tables