AI2020-7

AIRCRAFT SERIOUS INCIDENT INVESTIGATION REPORT

ALL NIPPON AIRWAYS CO., LTD.
J A 8 2 8 A

November 26, 2020

Japan Transport Safety Board

The objective of the investigation conducted by the Japan Transport Safety Board in accordance with the Act for Establishment of the Japan Transport Safety Board (and with Annex 13 to the Convention on International Civil Aviation) is to prevent future accidents and incidents. It is not the purpose of the investigation to apportion blame or liability.

TAKEDA Nobuo
Chairman
Japan Transport Safety Board

Note:

This report is a translation of the Japanese original investigation report. The text in Japanese shall prevail in the interpretation of the report.

AIRCRAFT SERIOUS INCIDENT INVESTIGATION REPORT

CASE EQUIVALENT TO MULTIPLE MALFUNCTIONS IN ONE OR MORE SYSTEMS EQUIPPED ON AIRCRAFT IMPEDING THE SAFE FLIGHT OF AIRCRAFT ALL NIPPON AIRWAYS CO., LTD. BOEING 787-8, JA828A, AT FL 430 ABOUT 280 NM NORTHEAST OF NARITA INTERNATIONAL AIRPORT, JAPAN AT ABOUT 14:02 JST, JUNE 1, 2019

November 6, 2020

Adopted by the Japan Transport Safety Board

Chairman	TAKEDA Nobuo
Member	MIYASHITA Toru
Member	KAKISHIMA Yoshiko
Member	MARUI Yuichi
Member	NAKANISHI Miwa
Member	TSUDA Hiroka

1. PROCESS AND PROGRESS OF THE INVESTIGATION

1.1 Summary of the Serious Incident	On Saturday, June 1, 2019, a Boeing 787-8, registered JA828A, operated by All Nippon Airways Co., Ltd., took off from San Jose International Airport, USA bound for Narita International Airport. When it was flying over at FL 430*[1] over the Pacific Ocean about 280 nm northeast of Narita International Airport, both of the two air conditioning systems became inoperative.
1.2 Outline of the Serious Incident Investigation	The occurrence covered by this report falls under the category of Article 166-4, Item (xvii) of the Ordinance for Enforcement of Civil Aeronautics Act (Ordinance of Ministry of Transport No. 56 of 1952) prior to revision by the Ministerial Ordinance on Partial Revision of the Ordinance for Enforcement of Civil Aeronautics Act (Ordinance of Ministry of Land, Infrastructure, Transport and Tourism No. 88 of 2020), as the case equivalent to “Multiple malfunctions in one or more systems equipped on aircraft impeding the safe flight of aircraft” as stipulated in Item (ix) of the same Article, and is classified as a serious incident. On June 4, 2019, upon receiving the notification of the serious incident, the Japan Transport Safety Board (JTSB) designated an investigator-in-charge and three other investigators to investigate this serious incident.

*[1] “Flight Level (FL)” refers to the pressure altitude of the standard atmosphere. It is the altitude indicated by value divided by 100 of the index of the altitude indicator (unit: ft) when QNH is set to 29.92 inHG. FL is usually applied when flight altitude is 14,000 ft or above in Japan. E.g., FL 200 indicates an altitude of 20,000 ft.

	An accredited representative and their advisors of the United States of America, as the State of Design and Manufacture of the aircraft involved in the serious incident, participated in the investigation. Comments were invited from parties relevant to the cause of the serious incident and the Relevant States.

2. FACTUAL INFORMATION

2.1 History of the Flight	According to the statements of the flight crewmembers (Pilot in Command (PIC), Deputy Captain*2 and First Officer (FO)), and the cabin attendant (Chief purser), as well as the air traffic control (ATC) communications records, the radar track records and the records of flight data recorder and others (EAFR*3 and CPL*4), the history of the flight is as outlined below. At 04:32 Japan Standard Time (JST: UTC+9 hours, all times are indicated in JST on a 24 hour clock) on June 1, 2019, a Boeing 787-8, registered JA828A, operated by All Nippon Airways Co., Ltd. (hereinafter referred to as "the Company"), took off from San Jose International Airport (the United States of America) as scheduled flight 171 bound for Narita International Airport with a total of 163 people, consisting of the PIC, other 11 crewmembers and 151 passengers. According to the PIC, there was no discrepancies during preflight check at San Jose International Airport, it was continuing to fly normally after take-off. The PIC sat as the PF*5 in the left seat and the Deputy Captain sat as the PM*5 in the right seat in the cockpit. While flying at FL 430 bound for Narita International Airport, when the Aircraft gradually decelerated the flight speed from M 0.84 to M 0.78 in order to adjust the arriving time at the Airport, EICAS*6 displayed "PACK L" indicating that the PACK on the left side had become inoperative (Figure 2 ①) at 13:56:49. The PIC checked the operating status of the air conditioning systems with the MFDU*7 and found that among Cabin Air Compressors (hereinafter referred to as "CACs") that compress air from an outside source and deliver the compressed air to the PACK, both of the two CACs (L1 CAC and L2 CAC) for the Left PACK shut down and the air conditioning system on the left side had been inoperative.

*2 "Deputy Captain" shall assume the duties of the captain when the captain leaves the cockpit for the purpose of taking rest. When abnormal or emergency conditions arise, he/she shall take appropriate actions and notify the captain as soon as possible, and comply with the directions of the captain.
*3 "EAFR" stands for Enhanced Airborne Flight Recorder. This is an integrated flight recorder with the functions of flight data recorder (FDR), Cockpit Voice Recorder (CVR) and data link recorders.
*4 "CPL (ACMF CPL)" stands for Airplane Condition Monitoring Function Continuous Parameter Logging, a device that monitors aircraft conditions and continuously records predetermined parameters.
*5 "PF" (Pilot Flying) and "PM" (Pilot Monitoring) are terms used to identify pilots with their roles in aircraft operated by two persons. The PF is mainly responsible for maneuvering the aircraft. The PM mainly monitors the flight status of the aircraft, cross checks operations of the PF, and undertakes other non-operational works.
*6 "EICAS" stands for the Engine Indicating and Crew Alerting System, a device that displays the operational conditions of the engine, air conditioning and other systems, and notify the pilot of the occurrence of abnormalities in each system by visual and auditory means.
*7 "MFDU" stands for Multi-Function Display Unit, a device that can display a variety of aircraft information such as operational conditions of each system on a large LCD screen.

After that, at 14:00:17, according to the procedure to be followed when the PACK is inoperative, which is stipulated in the Company's aircraft operations manual, the PIC attempted to reset the air conditioning systems by pushing its reset switch (See Figure 2 ②).

This enabled to restart the air conditioning systems of the Aircraft, but at 14:02:13, EICAS displayed the "PACK L+R" message indicating that both of PACKs had become inoperative (See Figure 2 ③). The PIC checked the operating condition of the air conditioning systems with the MFDU and found that all of four CACs (L1 CAC, L2 CAC, R1 CAC and R2 CAC) shut down and the air conditioning systems on both left and right sides had been inoperative.

Therefore, at 14:02:52, the Aircraft started to descend from FL 430 (See Figure 2 ④), continued to descend while watching the climb rate of cabin altitude.

And then, at 14:08:00, at FL 277, EICAS displayed the "CABIN ALTITUDE" message indicating that the cabin altitude had reached at an altitude of about 10,000 ft (See Figure 2 ⑤), thus the PIC declared an emergency, made an emergency descent until an altitude of about 10,000 ft, continued to fly (See Figure 2 ⑦), and the Aircraft landed at Narita International Airport at 14:56.

At 14:12:55, when the Aircraft reached at an altitude of about 11,300 ft during the emergency descent, the cabin altitude hit the highest, about 11,400 ft (See Figure 2 ⑥).

In the detailed inspection after arrival at Narita International Airport, any damages and others were not found in the airframe structure of the Aircraft.

The serious incident occurred at about 14:02 on June 1, 2019, at FL 430 about 280 nm northeast of Narita International Airport (approximately 38°54'19" N, 144°45'50" E).

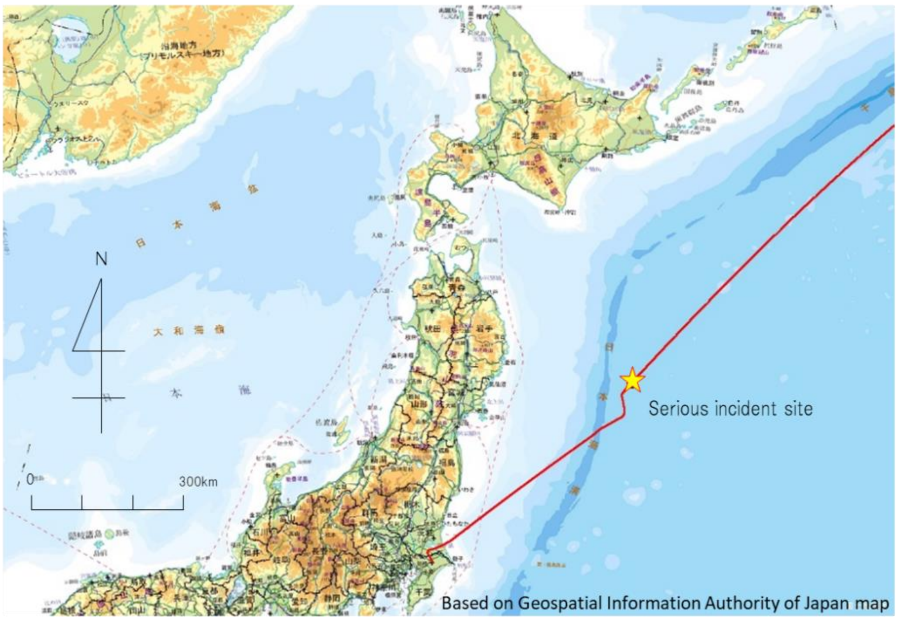

Figure 1: Serious incident site and estimated flight route

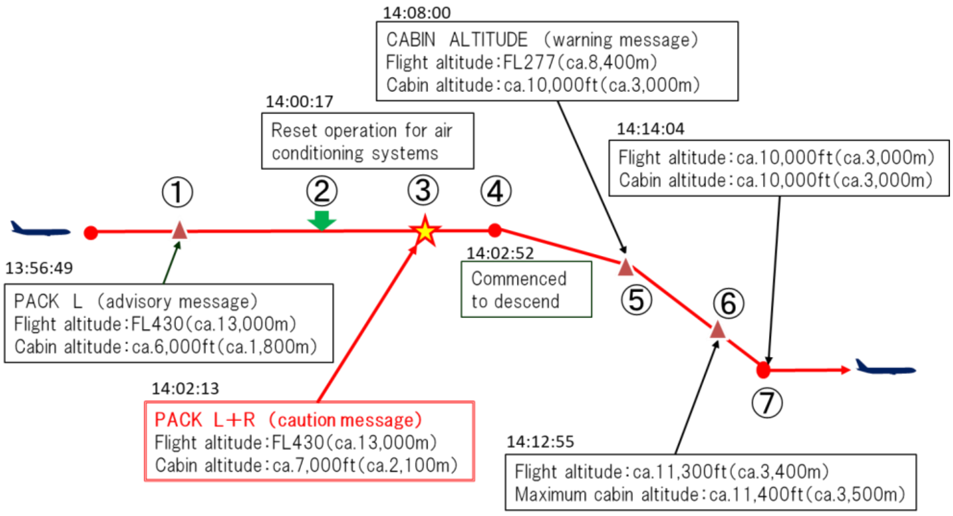

Figure 2: History of the flight

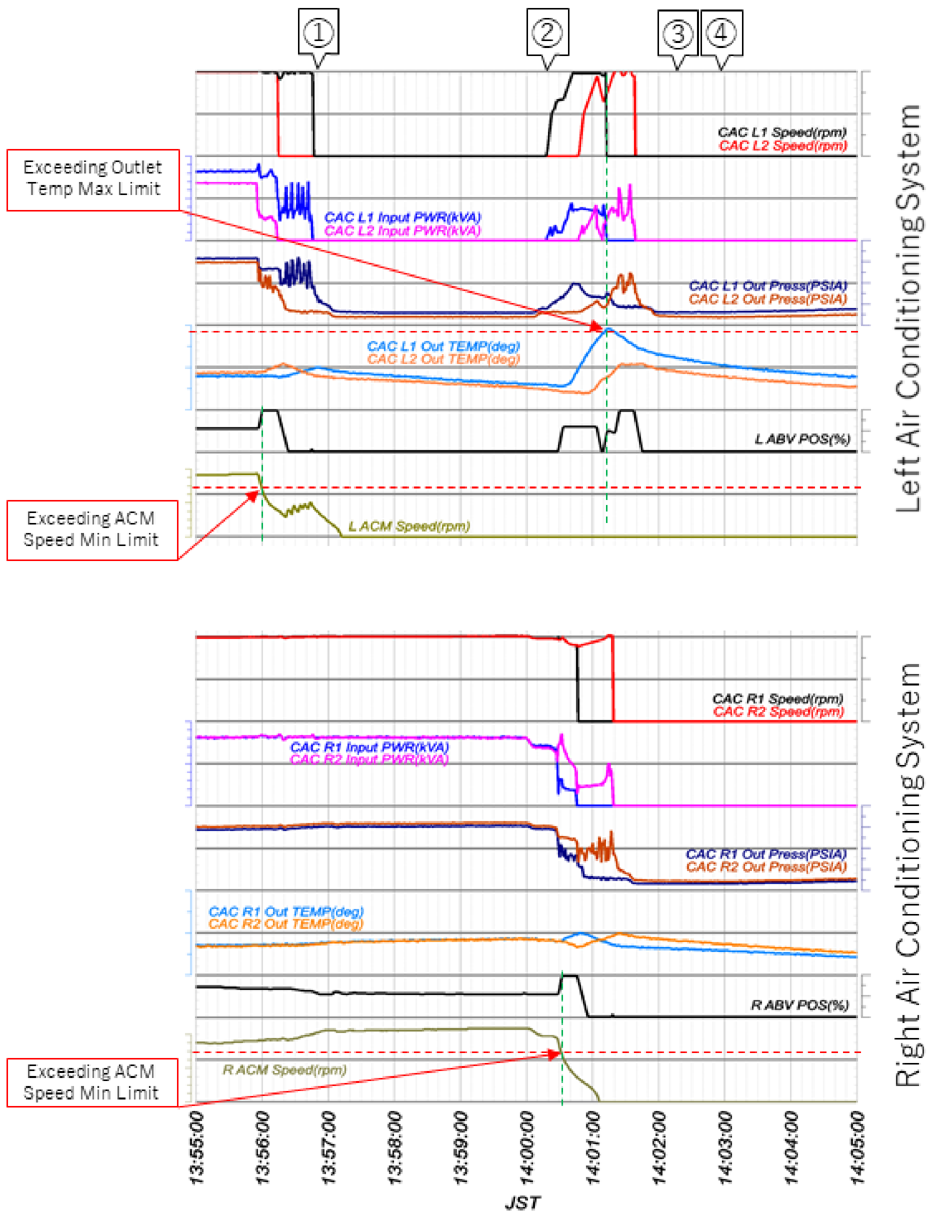

Figure 3: Records of the digital flight data recorder

2.2 Injuries to Persons	None
2.3 Damage to the Aircraft	None
2.4 Personnel Information	(1) Pilot in Command Male, Age 50 Airline Transport Pilot Certificate (Airplane) February 27, 2008 Type rating for Boeing 787 October 6, 2016 Class 1 Aviation Medical Certificate Validity date: April 19, 2020 Total flight time 13,368 hours 31 minutes Flight time in the last 30 days 71 hours 45 minutes Flight time on the same type of aircraft 2,004 hours 45 minutes Flight time in the last 30 days 71 hours 45 minutes (2) Deputy Captain Male, Age 48 Airline Transport Pilot Certificate (Airplane) January 20, 2010 Type rating for Boeing 787 February 8, 2017 Class 1 Aviation Medical Certificate Validity date: October 1, 2019 Total flight time 10,545 hours 05 minutes Flight time in the last 30 days 75 hours 02 minutes Flight time on the same type of aircraft 1,472 hours 37 minutes Flight time in the last 30 days 75 hours 02 minutes
2.5 Aircraft Information	Type: Boeing 787-8 Serial number: 42248 Date of manufacture: January 16, 2014 Certificate of Airworthiness: No. 2014-008 Category of airworthiness Airplane, Transport Category Total flight time 24,417 hours 12 minutes Total cycles 2,795 cycles Flight time since last periodical check (A13C inspection performed on April 17, 2019) 549 hours 46 minutes
2.6 Meteorological Information	In the vicinity of the serious incident site, the weather was fine. The airspace around 43,000 ft was in an area of jet stream winds at 90 kt, but there was no turbulence.
2.7 Additional Information	(1) Summary of air conditioning systems The air conditioning systems of the Aircraft comprise components shown in Figure 4. The CACs draw the air from outside and release it at a hot temperature and high pressure, use the PACKs that bring the compressed air to a more comfortable temperature and pressure, and then deliver the air to the cabin. This allows a cabin air to be compressed at FL 430, providing an environment of a cabin altitude of about 6,000 ft. Besides, the airflow from the CACs can go not through the Air Cycle Machine (hereinafter referred to as "ACM") but directly to the cabin by controlling the ACM Bypass Valve (hereinafter referred to as "ABV"), resulting in conditioning the ACM outlet temperature of the air flowing into the cabin. As shown in Figure 5, the CAC comprises the main unit of electric compressor that compresses air by rotating blades with an electric motor and

components. According to the change in flight environment, the Pack Control Unit (hereinafter referred to as "PCU") monitors the operation status of air conditioning systems including CACs and controls them so that they could operate in optimum efficiency. For this reason, with the Smarter ECS Mode*8 can be utilized to adjust the airflow based on occupant count of the Aircraft at altitudes exceeding 35,000 ft.

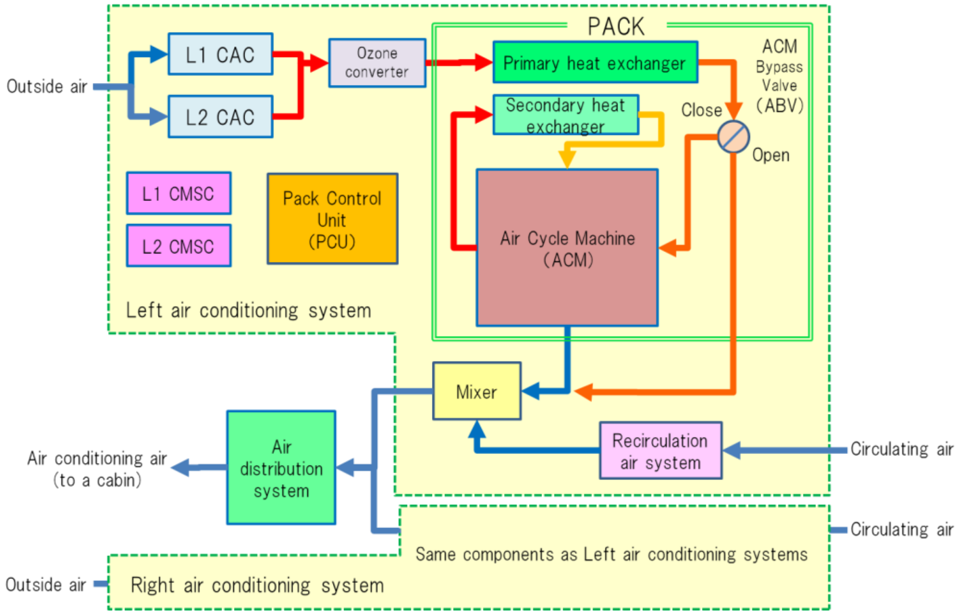

Figure 4: Air conditioning systems

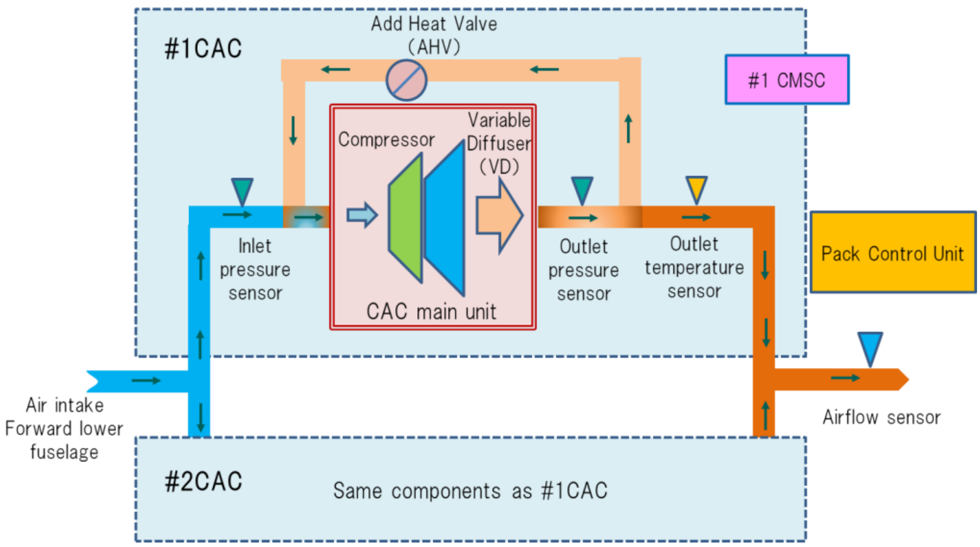

Figure 5: Cabin Air Compressor (CAC)

(2) Function to control CAC surging

In the case of the compressor like Aircraft's CACs that compresses air

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*8 "Smarter ECS Mode" is an operation mode to ensure that airflow across the CAC can be reduced by lowering the CAC rpm so that the PCU can generate minimal Pack Flow required for cabin air according to the number of persons on board input in the Cabin Attendant Panel (CAP).

by rotating blades in flow tube, in general, more easily occurs a phenomenon called the surging in which extreme disturbance of airflow around the blades and air delivery pressure pulsation are caused when the airflow from the intake is excessively reduced.

The CAC systems of the Aircraft is equipped with the following devices to avoid the occurrence of surging according to the operational status of the CAC; one is the Variable Diffuser (hereinafter referred to as "VD") that controls the airflow which is compressed mechanically at the air intake to pass through the CAC, and the other is the Add Heat Valve (hereinafter referred to as "AHV") that controls the temperature of the airflow to pass through the CAC.

(3) Status of the maintenance of air conditioning systems

The Company prescribed the implementation method for the maintenance of air conditioning systems based on the technical information issued by the design and manufacturing company and appropriately performed maintenance work. Besides, the Company also performed all the repair and alterations works of air conditioning systems, which were instructed by the design and manufacturing company in writing such as service bulletins and others.

(4) Occurrence of similar incidents

After collecting the failure information related to the air conditioning systems from operators, if required, the design and manufacturing company provides instructions on how to perform repair and alterations works and apply limitations on the operations, etc.

In May 2019, both of two air conditioning systems of the aircraft in the other company temporarily stopped at the same time, but the aircraft was able to continue flying normally because a reset of the air conditioning systems was made successfully during descent.

(5) Detailed investigation of components

The components of air conditioning systems were dismounted and detailed inspection was performed for them at the laboratory of the design and manufacturing company. As a result, it was found that rotational resistance of the L1 CAC motor exceeded the specified value. Because of this, a teardown inspection and a performance test of motor rotor were conducted, but it could not identify the cause of the rotational resistance exceeding the specified value.

(6) The Company's operation procedure in case of failure of air conditioning systems

According to procedures to be followed when the PACK is inoperative, which is stipulated in the Company's Aircraft Operations Manual at the time of the serious incident, the following is the outline for procedures when the "PACK L" or "PACK R" message indicating that the PACK on either the left or right side becomes inoperative are displayed.

	i Wait two minutes after confirming the PACK message showing the PACK is inoperative. ii Push and hold the AIR COND RESET switch for one second. Note: Attempt only one reset for this condition per flight. iii Wait two minutes. iv The procedure shall be completed if PACK message blanks. v Leave the PACK switch in AUTO for the rest of the flight if PACK message shows. (7) Additional operation procedure instructed by the design and manufacturing company in case of failure of air conditioning systems On April 5, 2019, the design and manufacturing company had already issued the Flight Crew Operations Manual Bulletin on the additional operation procedure when EICAS displays the messages ("PACK L" or "PACK R") that indicate the PACK on either the left or right side becomes inoperative. The general outline is as follows. When the airplane altitude is above 35,000 ft, if one pack becomes inoperative, descend to 35,000 ft or lower before attempting a pack reset with the AIR COND RESET switch. Moreover, in the Bulletin, the background information on the issuance is provided as follows. *The CACs can shut down due to surging. One of the four CACs can surge during normal low pack flow operation in cruise. It is not typical for more than one CAC to surge per flight. The low flow condition occurs when the pack is in "smarter ECS mode". CAC surge can be noticed in the flight deck or cabin as short-duration, low rumbling nose.* *When the airplane altitude is above 35,000 feet, the CACs operate close to the surge margin. If one pack becomes inoperative, one reset attempt using the AIR COND RESET switch is allowed per flight for this condition. A pack may not reset above 35,000 feet due to the decreased surge margin.* *The design and manufacturing company plans to add a step into PACK L and PACK R checklists to descend to 35,000 feet or lower before attempting a pack reset, providing this Bulletin as an interim measure.* (8)The Company's obtaining technical information issued by the design and manufacturing company and subsequent procedures The Company's department in charge obtained the technical information (Airplane Flight Manual, Flight Crew Operations Manual and others) issued by the design and manufacturing company, and after conducting the technical consideration, the result was included in the Company's manual such as the Aircraft Operations Manual. On April 5, 2019, before the serious incident occurred, the Company had obtained the additional operation procedure to be followed when air conditioning systems failure occurs, which was instructed by the design and manufacturing company, but the Company did not yet reflect the content in the

	Aircraft Operations Manual at the time of the serious incident, because the content had been under consideration in the Company.

3. ANALYSIS

3.1 Involvement of Weather	None
3.2 Involvement of Pilots	None
3.3 Involvement of Aircraft	Yes
3.4 Analysis of Findings	(1) Situation up to the occurrence of the serious incident It is highly probable that in this serious incident both of the two air conditioning systems shut down at the same time because the following events occurred one after another over the Pacific Ocean about 280 nm northeast of Narita International Airport. i) Shut-down of Left air conditioning system When the Aircraft was flying at FL 430, the airflow generated by the CACs was restricted because the Smarter ECS Mode was activated. Therefore, it is probable that the CACs of the Aircraft were working in a state that surging could easily occur. After that, it is probable that surging avoidance functions of the VD and the AHV of the L1 and L2 CACs reached performance limits due to the flight environment change by a reduction in airspeed and others, resulting in surging in both CACs. For this reason, the ABV completely opened in order to smooth airflow to pass through the CACs by reducing the CACs downstream load, which permitted the airflow from the CACs to flow not through the ACM but directly to the cabin, but there was no effect from that, and the L2 CAC could not be recovered from surging and shut down. Because the ACM rpm continued to slow as the ABV opened completely, and after L2 CAC shut downed, the ACM protection function*9 was active and ABV was fully closed, which, however, further worsened airflow to pass through the L1 CAC, and it is probable that the L1 CAC also shut down without recovering from surging. As a result, it is highly probable that the Left air conditioning system shut down because all the airflow supply to the PACK L stopped. ii) Reset operation by the flight crew It is highly probable that according to the Company's Aircraft Operations Manual the PIC performed a reset of the air conditioning systems at FL 430 after confirming the L1 and L2 CACs shut down and the Left air conditioning system was not working. On the other hand, the design and manufacturing company of the

*9 "ACM protection function" is a function to prevent the ACM rpm from falling below a certain level in order to protect the air-bearing of the ACM.

Aircraft provided instructions issued on April 5, 2019 to inform operators to descend to 35,000 ft or lower before attempting a reset of air conditioning systems since an air conditioning system may not reset at altitudes exceeding 35,000 ft. It is certain that before the serious incident occurred, the Company had obtained this instruction, but the Company did not yet reflect the content in the Aircraft Operations Manual at the time of the serious incident, because the content had been under consideration in the Company, and this information had not been made known to their flight crews.

iii) Left air conditioning system not recovered by reset

It is probable that at FL 430, the L1 and L2 CACs were restarted, but they were not able to generate enough airflow because of the high altitude exceeding 35,000 ft or higher where the environmental conditions were harsh.

For this reason, it is probable that the ABV completely opened in order to smooth airflow across the CACs by reducing the CACs downstream load, but there was no sustained system effect. The L1 CAC shut down again because the CAC outlet temperature exceeded the limit value and the L2 CAC was not recovered due to a detected surge condition.

As a result, it is highly probable that the Left air conditioning system shut down again because all the airflow supply to the PACK L stopped.

iv) Shut-down of Right air conditioning system

During the reset of air conditioning systems, the function controlling the airflow generated by normally operating R1 and R2 CACs worked to prevent the total airflow of the Left and Right air conditioning systems from surging; it is probable, however, that this allowed those CACs to be easily surging and the surging avoidance functions of the VD and the AHV reached performance limits, resulting in both CACs surging.

After that, it is probable that the R1 and R2 CACs shut down one after another in the same phenomenon as the L1 and L2 CACs described in 3.4 (1) i).

Consequently, it is highly probable that both of the two air conditioning systems shut down at the same time because all the airflow supply to the PACK R stopped and the Right air conditioning system shut down.

(2) PACK reset procedure

i) PACK reset procedure added by the design and manufacturing company

It is probable that as the CACs tend to become more sensitive to surge at high altitudes, according to the procedure added by the design and manufacturing company, a recovery can be made by attempting a PACK reset after descending to 35,000 ft or lower, when one PACK becomes inoperative. Moreover, by doing so, the simultaneous shut-down of both of Packs can be avoided. Therefore, the Company should include the

	additional operation procedure provided by the design and manufacturing company in the Company's Aircraft Operations Manual. ii) Notification to flight crews. It is desirable that among those of the technical information issued by the design and manufacturing company, the changes, which are related to the procedures to be followed when a PACK is inoperative, should be made known to flight crews promptly upon receipt.

4. PROBABLE CAUSES

In this serious incident, it is highly probable that both of the two air conditioning systems shut down at the same time because the Left air conditioning system was unable to restart and the normally having been working Right air conditioning system also shut down during the reset of air conditioning systems of the Aircraft after the Left air conditioning system shut down.

It is highly probable that the Left air conditioning system was unable to restart and the normally having been working Right air conditioning system also shut down because the reset of air conditioning systems was performed at high altitude and under environmental conditions where the CACs tend to more sensitive to surge.

5. SAFETY ACTIONS

(1) The Company included the additional operation procedure instructed by the design and manufacturing company in the Company's Aircraft Operations Manual in order to prevent the simultaneous shut-down of both of the two air conditioning systems.

(2) In the process of including the technical information issued by the design and manufacturing company in the Company's Aircraft Operations Manual, the Company amended the Company's manual so that those changes in the related matters that could have a significant impact on safe operation of aircraft such as the non-normal procedures should be made known promptly upon receipt.

(3) By means of issuing the technical information, the design and manufacturing company notified the operator of the operation method to restrict functions of the Smarter ECS Mode that controls the airflow generated by the cabin air compressors (CACs) in order to prevent the CACs from surging. The Company included this operation method in the Company's Aircraft Operations Manual according to the technical information.

(4) By means of issuing the technical information, the design and manufacturing company will notified the operator of the revise the software for controlling the ACM Bypass Valve in order to mitigate the adverse effects of a surging CAC on the remaining operating CACs. This change is expected to reduce the likehood of both systems shut down at the same time. The Company will revise this software of the Company's aircraft according to the technical information.