AIRCRAFT SERIOUS INCIDENT INVESTIGATION REPORT

MULTIPLE MALFUNCTIONS
IMPEDING THE SAFE FLIGHT OF AIRCRAFT,
GULFSTREAM AEROSPACE G-IV, N146BG
PRIME JET, LLC
AT AN ALTITUDE OF ABOUT 13,200 m
ABOUT 300 km SOUTHWEST OF
TOKYO INTERNATIONAL AIRPORT
AT AROUND 19:58 JST, MAY 22, 2020

August 2, 2024

Adopted by the Japan Transport Safety Board

Chairperson	TAKEDA Nobuo
Member	SHIMAMURA Atsushi
Member	MARUI Yuichi
Member	SODA Hisako
Member	NAKANISHI Miwa
Member	TSUDA Hiroka

1. PROCESS AND PROGRESS OF THE AIRCRAFT SERIOUS INCIDENT INVESTIGATION

1.1 Summary of the Serious Incident	On Friday May 22, 2020, at around 19:58 Japan Standard Time (JST: UTC + 9 hours: all times are indicated in JST on a 24-hour clock), a Gulfstream G-IV N146BG, operated as a positioning flight by Prime Jet, LLC became the airspeed indications unreliable on both primary flight displays *1 (PFDs) receiving the air-data from a remaining Digital Air Data Computer *2 (DADC) when commencing the descent for landing while the flight crew members had deactivated one of the two DADCs, which the flight crew members decided that it had failure during the cruise for the Tokyo International Airport after the take-off to position the Aircraft from Phnom Penh International Airport. After that, the Aircraft landed at Tokyo International Airport. There were three people on board, including two crew members other than the captain in the Aircraft, no one was injured, and the aircraft had no damage.

*1 “Primary Flight Display” is an integrated instrument that displays information necessary for flight, such as attitude, altitude, and speed.
*2 “Digital Air Data Computer” is a device that processes outside air information and digitally outputs such as altitude, speed, temperature, and others.

1.2 Outline of the Serious Incident Investigation

The occurrence covered by this report falls under the category of "Multiple malfunctions in one or more systems equipped on aircraft impeding the safe flight of aircraft" as stipulated in Article 166-4, item (ix), the Regulation for Enforcement of Civil Aeronautics Act of Japan (Order of Ministry of Transport No. 56 of 1952) prior to revision by the Ministerial Order on Partial Revision of the Regulation for Enforcement of Civil Aeronautics Act of Japan (Order of Ministry of Land, Infrastructure, Transport and Tourism No. 88 of 2020), and is classified as a serious incident.

On May 24, 2020, upon receiving the report of this serious incident, the Japan Transport Safety Board (JTSB) designated an investigator-in-charge and two investigators to investigate this serious incident.

An accredited representative of the United States of America, as the State of Design and Manufacture, Registry and the Operator of the aircraft involved in this serious incident, participated in the investigation.

Although it was found during this investigation that the serious incident occurred on the high seas, the entire investigation was delegated by the State of Registry of the aircraft in accordance with the provisions of Annex 13 of the Convention on International Civil Aviation.

Comments on the draft Final Report from parties relevant to the cause of the serious incident and the Relevant State were invited.

2. FACTUAL INFORMATION

2.1 History of the Flight

According to the statements of the captain and the co-pilot (CO) as well as the records of the digital flight data recorder (DFDR), the history of the flight up to the serious incident is summarized below:

Figure1 The aircraft

On May 22, 2020, at 14:46 Japan Standard Time (JSTT; UTC + 9hrs, unless otherwise stated all times are indicated in JST on a 24-hour clock), a Gulfstream Aerospace G-IV, N146BG, operated by Prime Jet, LLC, took off from Phnom Penh International Airport (Kingdom of Cambodia) for a positioning flight with three people on board consisting of the captain and two crew members. The aircraft started its cruise at FL450 at around 17:23 climbing step by step after cruising at an altitude of 41,000 ft (flight level (FL[*3]) 410). The air current was generally smooth on the cruise. In the

*3 "FL" is the altitude expressed as a numerical value obtained by dividing the altimeter instruction (unit: ft) when the altimeter setting value is set to 29.92 inHg at the pressure altitude of the standard atmosphere by 100. Flight levels are usually used in flight altitudes above 14,000 ft in Japan. As an example, FL 410 represents altitude 41,000 ft.

cockpit of the aircraft, the captain sat in the left seat as PF*4 and the CO in the right seat as PM*4

Approximately one hour before landing at Tokyo International Airport, the message "DADC MISCOMPARE" indicating a mismatch between two DADCs was displayed on the Engine Indication and Crew Alerting System (EICAS). At this time, the PFD in the left seat displayed the data calculated by No. 1 DADC and the PFD in the right seat by No. 2 DADC (until (a) in Figure 4), and each PFD did not display a flag (Red X mark) indicating a DADC failure.

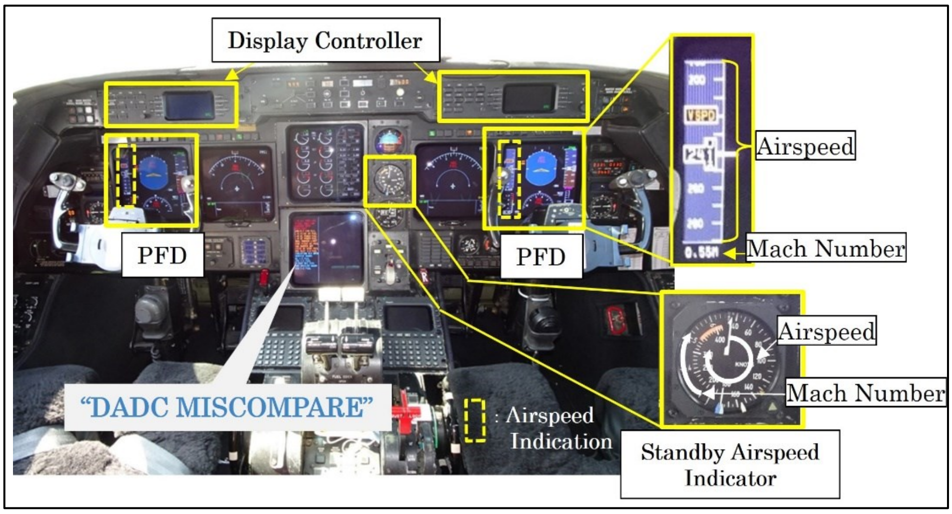


Figure 2 Cockpit

The flight crew members followed the QRH*5 DADC MISCOMPARE procedure, then determined that No.2 DADC which was providing data on the right seat side PFD closer to the standby airspeed indicator was correct because the standby airspeed indicator indicated a Mach number of 0.81 while the Mach number on the PFD indicated 0.79 for the left seat and 0.82 for the right seat. At 19:29:14, the captain selected No.2 DADC by the display controller*6 on the left seat

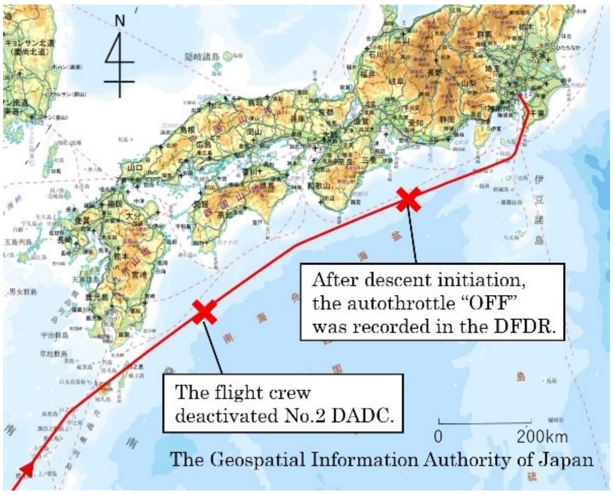


Figure 3 Estimated Flight Route

*4 "PF" and "PM" is a term for identifying a pilot from role sharing in an Aircraft controlled by two people, PF stands for Pilot Flying, mainly manipulates the Aircraft and PM stands for Pilot Monitoring, mainly performs monitoring of flight condition of the Aircraft, and makes cross check of operation of PF and operations other than maneuvering.

*5 "QRH" stands for Quick Reference Handbook, which describes the contents of the Airplane Flight Manual regarding emergency operations and performance for quick retrieval and viewing in actual flight operations.

*6 "Display controller" is a device that switches the data (navigation data, sensors, and others) displayed on the PFD by means of push buttons installed in front of each pilot seat.

side((a)~(b) in Figure4). The flight crew members deactivated No.1 DADC by pulling its circuit breaker to shut off the power.

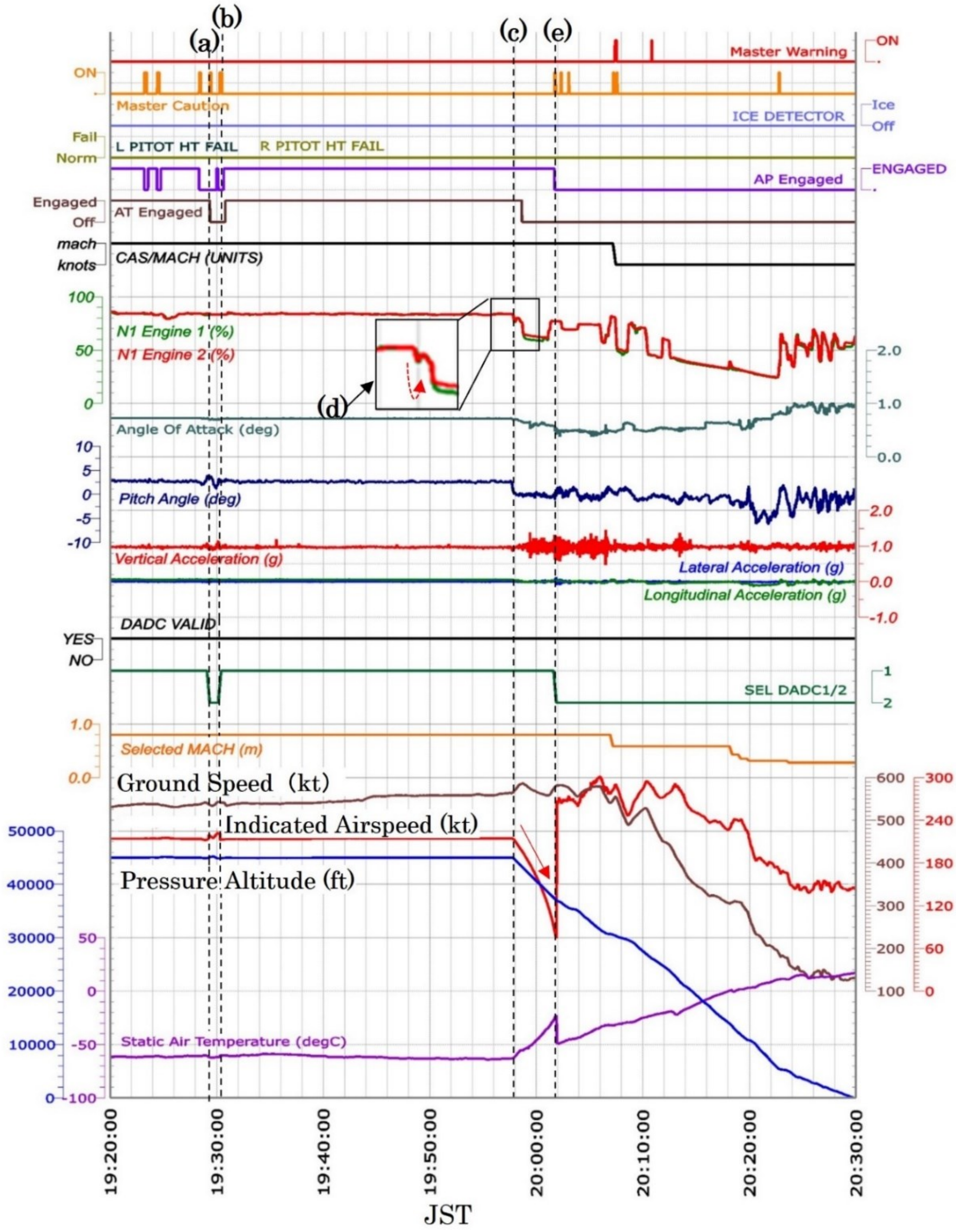
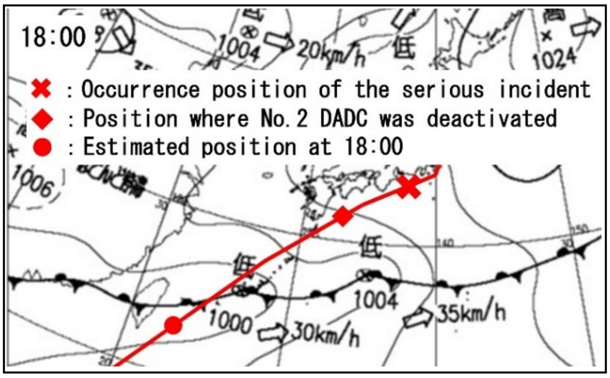


Figure 4　DFDR Records

(Note) DFDR records only the DADC data selected by the left seat display controller.

At 19:30:00, the flight crew members suspected the No.2 DADC failure because when they attempted use the autopilot, part of its function did not work, then activated No.1 DADC by pushing in its circuit breaker and deactivated No.2 DADC by pulling its circuit breaker to shut off the power. At 19:30:39, the flight crew members attempted to use the autopilot again, and it operated normally. The captain and the CO selected No. 1 DADC on

	their respective display controllers and continued the flight((b) to (e) in Figure 4). At 19:57, the aircraft began the descent maintaining a constant Mach number from FL450 for Tokyo International Airport. Shortly after the aircraft began the descent, the indicated airspeed on the standby airspeed indicator increased while the airspeed on the left and right PFDs decreased (see (c) in Figure 4). At around 19:58, the flight crew members disconnected the autothrottle because the airspeed on the standby airspeed indicator further increased when the autothrottle which had reduced the engine thrust increased the engine thrust (see (d) in Figure 4). The flight crew members determined that the airspeed indications on the left and the right PFDs were unreliable and continued the flight controlling the attitude and the engine thrust while monitoring the standby airspeed indicator and the standby altitude indicator according to the procedure of QRH Suspected Erroneous/Unreliable Airspeed Indications (hereinafter referred to as "Unreliable Airspeed Indications") which was used when an erroneous indication on an airspeed indicator was suspected. In addition, the flight crew members re-activated No.2 DADC and selected it by the display controller on the left seat in response to the situation where the airspeed indications became unreliable (after (e) in Figure 4). At around 20:08, the flight crew members followed the Unreliable Airspeed Indications procedure, requested priority handling of air traffic control, and the aircraft landed at Tokyo International Airport at 20:30. The serious incident occurred at about 19:58 on May 22, 2020, at an altitude of about FL 446 over about 300 km southwest of Tokyo International Airport (near 33° 36 '42" N, 137° 37' 12" E).
2.2 Injuries to Persons	None
2.3 Damage to the Aircraft	None
2.4 Personnel Information	(1) Captain, Age 33 Airline Transport Pilot Certificate (Airplane) December 20, 2017 Type rating for Gulfstream Aerospace G-IV December 20,2017 Class 1 Aviation Medical Certificate Validity June 30, 2021 Total flight time 4,981 hours 54 minutes Flight time in the last 30 days 30hours 12 minutes Total flight time on the type of aircraft 412 hours 18 minutes Flight time in the last 30 days 30 hours 12 minutes (2) Co-pilot, Age 34 Airline Transport Pilot Certificate (Airplane) March 23, 2020 Type rating for Gulfstream Aerospace G-IV June 13, 2019 Class 1 Aviation Medical Certificate

	Validity November 20, 2020 Total flight time 5,730 hours 18 minute Flight time in the last 30 days 78 hours 24 minutes Total flight time on the type of aircraft 1,850 hours 00 minute Flight time in the last 30 days 47 hours 12 minutes
2.5 Aircraft Information	Aircraft type: Gulfstream Aerospace G-IV Serial number: 1146 Date of manufacture: September 11, 1990 Certificate of airworthiness: Issue date: September 11,1990 Category of airworthiness: Airplane, Transport T Total flight time 16,783 hours 03 minutes When the serious incident occurred, the weight and the position of the center of gravity of the aircraft were within the allowable range.
2.6 Meteorological Information	(1) Surface Analysis Chart  Figure 5 Analysis chart at 18:00 (Excerpt) According to the analysis chart issued at 18:00 on May 22, over the Pacific Ocean in the south of Japan, the stationary front (seasonal rain front) extending from the east to the west, extended more westerly from the Okinawa region, and two low pressures on the front whose were 1,000 hPa and 1,004 hPa of center pressure were moving to the east-northeast with the speed of 30 km/h and 35 km/h, respectively. (2) Weather Satellite Imagery (Water vapor and Infrared) According to the water vapor imagery, it was indicated in white around the aircraft's flight route and the condition including a lot of water vapor quantity.

In addition, according to the infrared image, the area around the flight route of the aircraft during the time of the serious incident was shown in white, and high cloud top height clouds were observed.

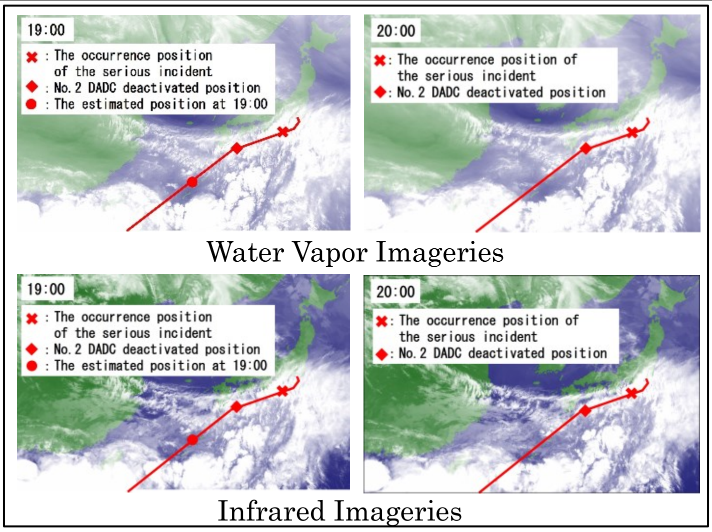


Figure 6 Weather Satellite Imageries (Excerpt)

(3) Radar Composite Chart (Echo*7 top height and Echo intensity)

In the period related to the serious incident, the radar echoes with a cloud top height of 9 to 10 km were observed over the sea south of Kyushu and those with a cloud top height of 7 to 8 km over the sea southeast of the Kii Peninsula.

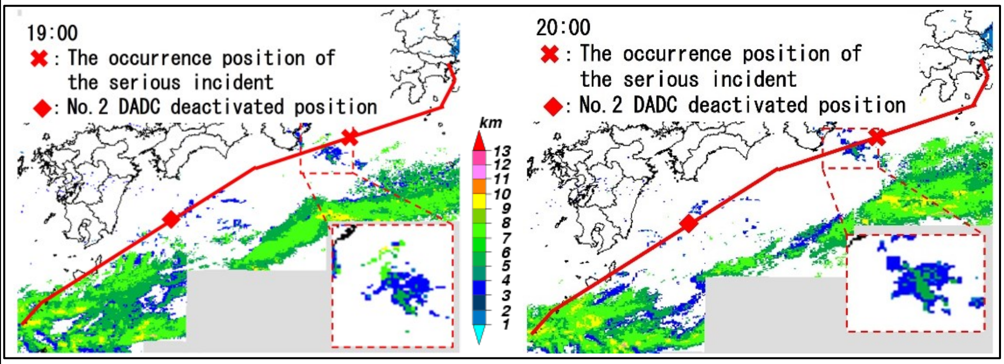


Figure7 Radar Composite Chart (Echo Top Height) (Excerpt)

In addition, it was analyzed that the maximum echo intensity in the echo area at each cloud top height was 4 to 8 mm/h and 40 to 48 mm/h, respectively.

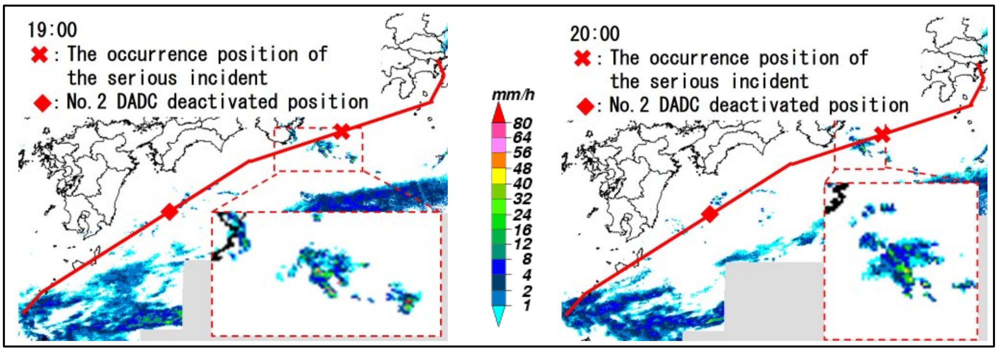


Figure 8 Radar Composite Chart (Echo Intensity) (Excerpt)

*7 "Echo" is a reflected wave received by a radar system when a radio wave emitted from a weather radar system is reflected by raindrops or ice particles. The distribution and intensity of precipitation areas can be observed from these reflected waves, and these precipitation areas are sometimes referred to as echoes.

(4) Wide-Area Cloud Imagery Information

According to the wide-area satellite imagery information analyzed automatically based on the information from the weather satellite every hour, it was analyzed as of 18:00 that the cumulonimbus cloud area with the maximum cloud top height of 54,000 ft south of Taiwan, the isolated cumulonimbus cloud with the cloud top height of 47,000 ft and the cumulonimbus cloud area with the maximum cloud top height of 53,000 ft south of Okinawa.

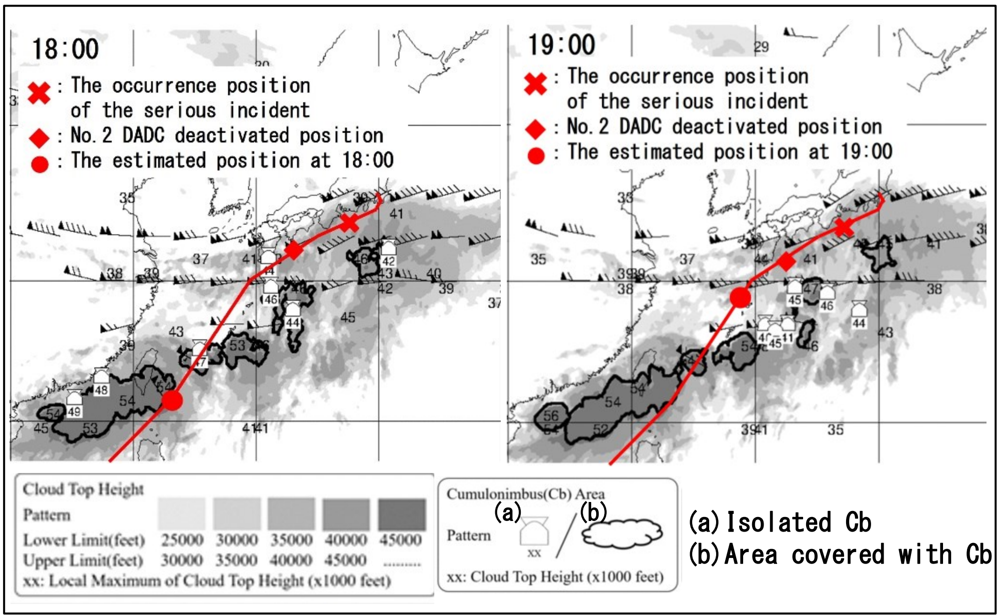


Figure 9　Wide area cloud imagery information（TSAS1 Excerpt）

(5) Hourly Analysis Chart

According to the Hourly Analysis (Cross-section: Kagoshima-Tokyo) at 19:00, there was no remarkable change in wind direction between FL 450 and FL 430 around the estimated commencing descent point, and the wind direction was analyzed at 110 kt at each altitude.

In addition, the temperature was analyzed -65˚C and below at FL 410 and above.

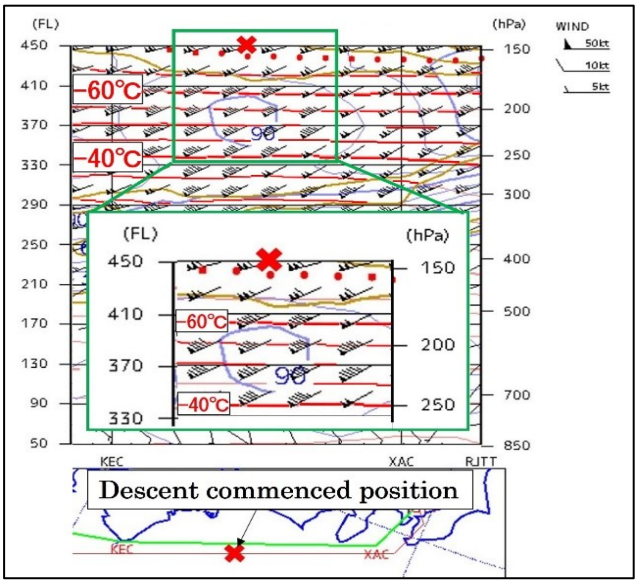


Figure 10　Hourly Analysis at 19:00 (Excerpt)
（Cross section：Kagoshima－Tokyo ）

2.7 Additional Information

(1) Pitot Static System

The Aircraft measures the air pressure (total air pressure) by two pitot tube installed on the upper forward fuselage, the left one is for No.1 DADC and the right one is for No.2 DADC and supplies the measured total air pressure value, respectively. In addition, a pitot tube is also equipped in the forward of the entrance door to supply the total air pressure value to the standby airspeed indicator.

Four static pressure ports are equipped on the left and right sides of the fuselage to measure atmospheric pressure (static pressure) and supply static pressure values to No.1 DADC, No.2 DADC, the standby altimeter, and the pressurization system.

Each DADC calculates the velocity from the difference between total and static pressure (dynamic pressure) measured by the corresponding pitot tube and static port, and altitude from static pressure. The standby airspeed indicator and the standby altimeter display the velocity and altitude from the corresponding pitot tube and static port measurements without going through the DADC.

The left and right PFDs display the speed and altitude calculated by the DADC that the flight crew members select by a display controller installed in front of the left and right pilot seats, respectively.

Furthermore, each pitot tube is anti-iced by an electric heater operated by a pilot switch, and when the switch is in the OFF position, the switch illuminates "OFF" in amber. In addition, when the switch is set to ON, the CAS message[*8] "L/R/STBY PITOT HT FAIL" will be displayed if the current to the heater falls below the specified value. According to the statements of the flight crew members, each pitot heater switch was set to ON and the message was not displayed. In addition, there is no record regarding the standby pitot tube, but the DFDR did not also record that the message was displayed concerning the left and right pitot tubes.

On the other hand, the four static pressure ports are not equipped with heaters.

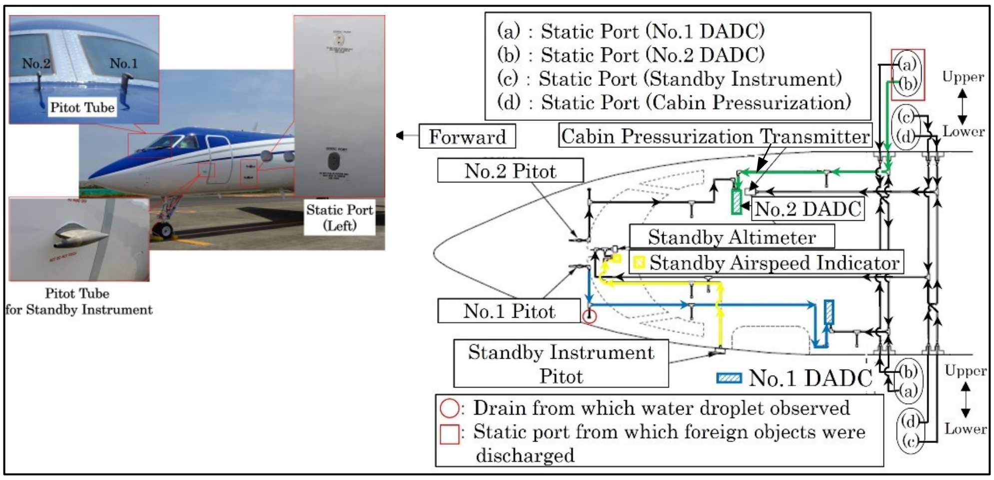


Figure 11 Pitot Static System

*8 "CAS message" is a message displayed by EICAS, which shows the operating status of the engine and each system and monitors the operation condition of each system, when an abnormal condition occurs in systems.

During a detailed investigation of a pitot-static system using high-pressure air, several drops of water were discharged from the drain of the No. 1 pitot system and the foreign objects were discharged from the static port on the right side of the fuselage that supplies static pressure to No.1 DADC and/or No. 2 DADC, however, it is not clear that the foreign objects were discharged from which static port. The leaf veins were observed when the discharged foreign objects were observed using a scanning electron microscope.

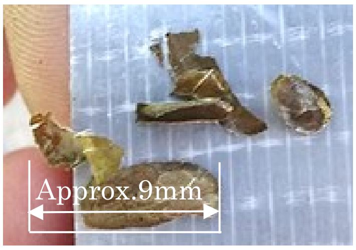


Figure 12 Foreign Objects from Static Port

(2) Corrective Action for CAS message "DADC MISCOMPARE"

This message is one of the advisory messages that indicates a non-hazardous failure of the aircraft and is displayed when the flight guidance computer detects a difference between No. 1 and No. 2 DADC outputs (dynamic pressure, true airspeed, indicated airspeed, barometric altitude, Mach number) that exceeds a reference value. Regarding a Mach number, the message is displayed when a difference of 0.02 or more is detected when the Mach number indication of both pilot seats exceeds 0.7.

Quick Reference Handbook **GULFSTREAM IV**

Advisory (Blue) Messages and Annunciations Index

Message	Page
AC EXT POWER .... (DC EXT POWER Also)	MC-4
AP CTLR SW STUCK	MC-4

(Omitted)

Message	Page
CPL DATA INVALID	MC-8
DADC 1-2 FAIL	MC-8
DADC MISCOMPARE	MC-9

(Omitted)

REVISION 24 (RE-ISSUE) MESSAGES AND ANNUNCIATIONS
Mar 17/10 Page MC - 1

Figure 13 QRH Message Index (Excerpt)

Quick Reference Handbook **GULFSTREAM IV**

Advisory (Blue) Messages and Annunciations, ctd... AFM 3B

Message:	Cause(s):	Corrective Action:
DADC MISCOMPARE	Priority FGC has detected an unflagged miscompare between DADC 1 and DADC 2.	1. Identify faulty DADC by reference to PFD, ND, standby flight instruments, guidance panel, pressure control and transponder panel. 2. Select good DADC to those panels. 3. Isolate faulty DADC with CB: (DADC #1: CP, F-3; DADC #2: CP, G-3.) 4. Check message clear. 5. Re-engage yaw damper and autopilot if desired. See DADC Failures, page EA-36.

(Omitted)

REVISION 24 (RE-ISSUE) MESSAGES AND ANNUNCIATIONS
Mar 17/10 Page MC - 9

Figure 14 QRH DADC MISCOMPARE

When the message appears, the flight crew members consult the QRH message index (Figure 13) and takes the Corrective Action of the QRH (Figure 14) for the DADC MISCOMPARE message. The corresponding procedure for QRH (Figure 14) is outlined as follows:

1. Identify the faulty DADC by reference to the PFD, navigation display (ND), standby flight instruments, guidance panel, pressurization control, and transponder panel.
2. Select a good DADC as the data source for the instruments shown in 1.
3. Isolate the faulty DADC by pulling its circuit breaker.
4. Check the message is cleared.
5. Re-engage the yaw damper and the autopilot if desired.

See "DADC failures."

In the reference, DADC failures are divided into two categories, and the QRH description is summarized as follows:

(a) Flagged DADC failure

It is easy to identify a failure because the CAS message "DADC1 (or 2) FAIL" is displayed, and red “X” marks are shown on the scale for all four air data (airspeed, altitude, AOA[*9], and rate of ascent) in the PFD that is using the failed DADC air data selected by the display controller.

(b) Unflagged DADC failure

The CAS message “DADC MISCOMPARE” is displayed. The failure may not be readily apparent, but the following can be expected to occur.

a. The autopilot and yaw damper will disconnect and will not re-engage until the faulty DADC has been identified and isolated by pulling its circuit breaker.

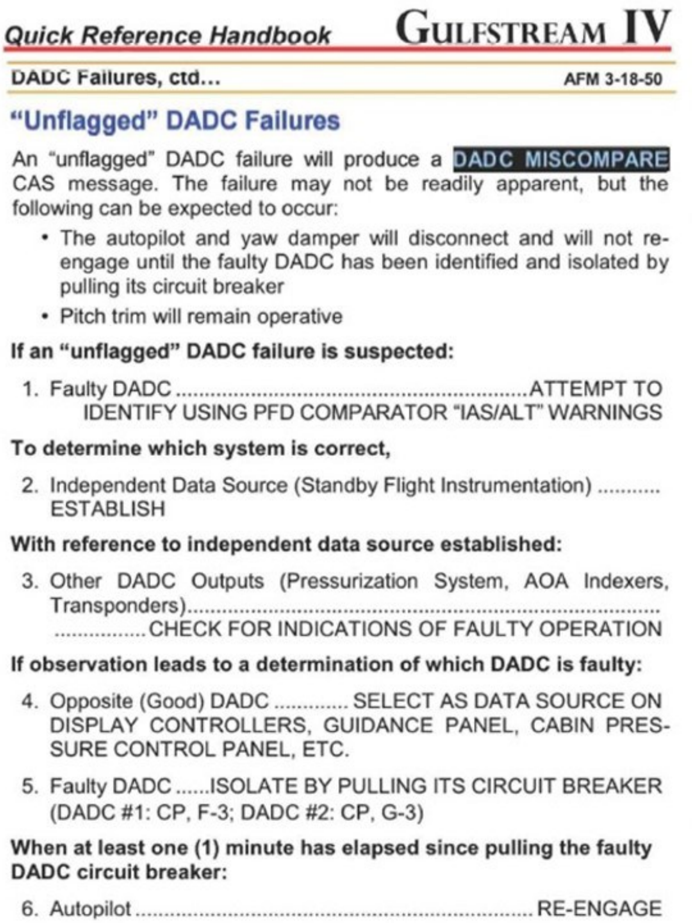
b. Pitch trim will remain operative.

The flight crew members take the Unflagged DADC failures procedure (Figure 15) in response to the CAS message “DADC MISCOMPARE”.

The description contents in Figure 15 are summarized as follows.

If an unflagged DADC failure is suspected:

1. Attempt to identify the faulty DADC by using “IAS/ALT”[*10] warning displayed on the PFD.
2. Establish the independent data source (Standby flight instrumentation) to determine which system is correct.
3. Check for indications of faulty operation using other DADC outputs (Pressurization System, AOA indexers, Transponders) with reference to the established independent data source.
4. If the faulty DADC can be determined, select the good DADC as the data source for the display controller, cabin pressure control panel, and others.
5. Isolate the faulty DADC by pulling its circuit breaker.
6. Re-engage the autopilot when at least one minute has elapsed since pulling the faulty DADC circuit breaker.



Quick Reference Handbook GULFSTREAM IV

DADC Failures, ctd... AFM 3-18-50

“Unflagged” DADC Failures

An “unflagged” DADC failure will produce a DADC MISCOMPARE CAS message. The failure may not be readily apparent, but the following can be expected to occur:

- The autopilot and yaw damper will disconnect and will not re-engage until the faulty DADC has been identified and isolated by pulling its circuit breaker
- Pitch trim will remain operative

If an “unflagged” DADC failure is suspected:

1. Faulty DADC ....ATTEMPT TO IDENTIFY USING PFD COMPARATOR “IAS/ALT” WARNINGS

To determine which system is correct,

2. Independent Data Source (Standby Flight Instrumentation) .... ESTABLISH

With reference to independent data source established:

3. Other DADC Outputs (Pressurization System, AOA Indexers, Transponders)................ ....CHECK FOR INDICATIONS OF FAULTY OPERATION

If observation leads to a determination of which DADC is faulty:

4. Opposite (Good) DADC .... SELECT AS DATA SOURCE ON DISPLAY CONTROLLERS, GUIDANCE PANEL, CABIN PRESSURE CONTROL PANEL, ETC.
5. Faulty DADC ......ISOLATE BY PULLING ITS CIRCUIT BREAKER (DADC #1: CP, F-3; DADC #2: CP, G-3)

When at least one (1) minute has elapsed since pulling the faulty DADC circuit breaker:

6. Autopilot .... RE-ENGAGE

Figure 15 QRH DADC Failures (Excerpt)

*9 “AOA" stands for Angle of Attack and is the angle between the direction of the airflow and the chord (a straight line connecting the leading and trailing edges of the wing) when the wing is placed in a uniform airflow.

*10 “IAS/ALT” is a warning regarding speed and altitude, and each input data selected for the left seat and right seat were compared, IAS/ALT in the PFD is displayed if a difference of more than 20 kt in speed and more than 200 ft in altitude is detected.

	The designer/manufacturer expresses its opinion that regarding the reason for waiting at least one minute after pulling a faulty DADC circuit breaker before re-engaging the autopilot is the generally recommended time to reset the system. Besides, the designer/manufacturer expresses the opinion that it is not appropriate to determine that the DADC in use has failed at that time, even if the autopilot does not operate normally when re-engaged after the flight crew has deactivated the DADC determined to be faulty. Furthermore, the design/manufacturer expresses the opinion that when the DADC MISCOMPARE message is displayed during a cruise with slight changes in altitude and speed, as was the case during the serious incident, the situation should be analyzed over time, and the Unreliable Airspeed Indications procedure may be one of the ways in this case. (3) Unreliable Airspeed Indications The description of the procedures during cruise for the QRH Unreliable Airspeed Indications is summarized as follows: If one or more airspeed indications including standby airspeed is erroneous or unreliable with or without DADC failures, stabilize pitch, power setting (fuel flow), and normalized angle of attack on the AOA indicator, as appropriate to the phase of flight. In the event of an overspeed condition, the pitch, power setting and AOA shall be checked, and the AOA shall be maintained between 0.30 and 0.50. If the overspeed condition persists, reduce the power setting, and increase AOA in the range not exceeding 0.50 to maintain level flight. Disconnect the autopilot and the autothrottle. Check that the pitot and standby pitot heaters are operational and that the respective circuit breakers are pushed in, and if the flight is in icing conditions, immediately depart the icing conditions. Notify the air traffic control authority, proceed to the nearest suitable airport, and land. Maintain current attitude, power setting (fuel flow), and normalized AOA if encountered while cruising. Determine the source of suitable airspeed to continue the flight by comparing the indicated airspeed with the predicted airspeed based on the manual, or by using the IRS*11 and GPS ground speeds and the predicted ground speed of the computerized flight plan. Continue to monitor pitch, power setting (fuel flow), and AOA. The conditions and causes of icing/blockage of pitot-static are as follows: · Airspeed and altitude information is not consistent with pitch attitude and thrust setting · Airspeed/Mach failure-flags are visible · Airspeed is fluctuating

*11 "IRS" stands for Inertial Reference System, a device to obtain the information required for navigation by measuring the inertial forces on the aircraft without navigation assistance such as radio waves from outside.

	· A variation exists between pilot and co-pilot airspeed indications · Overspeed indications exist · Simultaneous overspeed indications and stall warnings exist · The radome*12 has been lost or damaged (4) Federal Aviation Administration (FAA) Information The AC*13 (AC91-74B Pilot Guide: Flight in Icing Conditions) issued by FAA states on convective weather and icing as follows: *2-4 CONVECTIVE WEATHER AND ICE CRYSTALS* *a.* ***Convective Weather Systems.*** *Convective weather systems, especially those associated with tropical weather fronts, can pump large quantities of moisture to high altitudes that freezes into ice crystals that can remain aloft. These ice crystals can remain as a cloud well after the convective system has decayed. Clouds and temperatures less than 10 ℃ are better indicators of the possible presence of ice crystals when near convective weather.* *b.* ***Hazards.*** *Above flight level (FL) 250, clouds contain little liquid water and mostly contain ice particles. These clouds with no liquid water have about 20 times less radar reflectivity than rain drops, and therefore are difficult to detect. Airborne weather radar will receive little to no returns at these altitudes unless it is tilted down to lower altitudes near or below the freezing level. Strong returns from the lower altitudes indicate the possibility of hail, severe turbulence, or large quantities of ice crystals that could be encountered above and accrete inside turbine engines when overflying these areas. Large deposits may ultimately result in engine upset, engine damage from ice shedding, power loss, or engine shutdown.* *3-11 EFFECTS OF ICING ON CRITICAL SYSTEMS.* *a. Pitot Tube.* *The pitot tube is particularly vulnerable to icing because even light icing can block the entry hole of the pitot tube where ram air enters the system. This will affect the airspeed indicator and is the reason most airplanes are equipped with a pitot heating system. The pitot heater usually consists of coiled wire heating elements wrapped around the air entry tube. If the pitot tube becomes blocked, and its associated drain hole remains clear, ram air no longer is able to enter the pitot system. Air already in the system will vent through the drain hole, and the remaining will drop to ambient (i.e., outside) pressure.* *Under these circumstances, the airspeed indicator reading decreases to zero because the airspeed indicator senses no difference*

*12 "Radome" is a cover that houses the radar antenna and protects it from wind, rain, and sunlight.
*13 "AC" stands for Advisory Circular, which is published by the FAA to provide professionals in the aviation industry with useful information.

	between ram and static air pressure. If the pitot tube, drain hole, and static system all become blocked in flight, changes in airspeed will not be indicated, due to the trapped pressures. However, if the static system remains clear, the airspeed indicator would display a higher-than-actual airspeed as the altitude increased. As altitude is decreased, the airspeed indicator would display a lower-than-actual airspeed.

3. ANALYSIS

(1) Regarding Foreign Objects from Static Port

The JTSB concludes that because leaf veins were observed in the foreign objects discharged from the static port on the right side of the fuselage, they were more likely part of a plant leaf.

Except when the No.1 DADC was deactivated in response to the CAS message "DADC MISCOMPARE", data from the No.1 DADC was recorded in the DFDR, and no abnormalities were found in the pressure altitude calculated by the No.1 DADC during climb, cruise, or descent until data from the No.2 DADC was recorded in the DFDR. Furthermore, even after data from the No.2 DADC began to be recorded in the DFDR during descent (Figure 4(e)), no abnormalities were found in the pressure altitude calculated by the DADC. Based on the above, it is most likely that the foreign objects discharged from the static port during the detailed investigation using high-pressure air did not affect the flight of the aircraft.

(2) Weather Conditions along Estimated Flight Route

The JTSB concludes as follows:

Isolated cumulonimbus and cumulonimbus cloud areas with the maximum cloud top height exceeding 45,000 ft were analyzed along the aircraft's estimated flight route from about 18:00 to 19:00. In addition, since there was a large amount of water vapor over the Pacific Ocean in the south of Japan and the radar echoes were observed over the sea southeast of the Kii Peninsula, the aircraft was likely flying through airspace where ice crystals were formed by convective weather systems from before the DADC MISCOMPARE message was displayed to the point when the aircraft began the descent.

(3) Multiple Malfunctions impeding the Safe Flight of Aircraft

The JTSB concludes as follows:

The aircraft was displaying data from No. 1 DADC on the PFD for the left seat and No. 2 DADC on the PFD for the right seat, however, in response to the DADC MISCOMPARE message displayed during the cruise, the flight crew members deactivated No. 2 DADC determined to be faulty. As a result, in the situation where the PFDs for both seats became to use the data from No. 1 DADC, it is certainly classified as a serious incident falling under the category of “multiple malfunctions impeding the safe flight of aircraft” because when the aircraft began its descent, the airspeed indications on the PFDs for both seats became unreliable.

a. No.1 DADC

When the aircraft began its descent using the autopilot from FL450 with only No.1 DADC operating, the flight crew members recognized a decline in the airspeed indications on both PFDs, an increase in the standby airspeed indication, and the movement of the autothrottle in the direction to increase the engine thrust when it was decreasing the uengine thrust. At this time, the DFDR recorded the increase in the ground speed calculated by the IRS while recording the decrease in the indicated airspeed calculated by No.1 DADC. According to Figure 10, because there was probably no remarkable change in wind direction between FL 450 and FL 430 near the point where the aircraft began its descent, it is more likely that the change in the groundspeed recorded on the DFDR was caused by an actual increase in the airspeed. Accordingly, the standby airspeed indicator probably indicated normal values. On the other hand, it is probable that because the No. 1 pitot Line, which supplied the total pressure to No.1 DADC, was blocked, the decrease in the indicated airspeed calculated by the DADC which was recorded on the DFDR was caused by the increase in the static pressure as the aircraft descended while the total pressure at the time of the blockage in the pitot line was maintained.

Regarding the blockage of the No.1 pitot line, it is possible that because the aircraft flew in the area where ice crystals existed from the fact which water droplets were discharged from its drain hole and cumulonimbus and cumulonimbus area were analyzed along the aircraft's route, ice crystals froze again in the non-temperature controlled portion of the pitot line after the ice crystals were changed to a liquid state by the pitot heater when they had entered the pitot line. Regarding the time when ice crystals infiltrated the Pitot tube, it is likely in the cruise before the aircraft started the descent because very little change in speed during the cruise and the decrease in speed with the rise of static pressure just after starting descent were recorded on the DFDR.

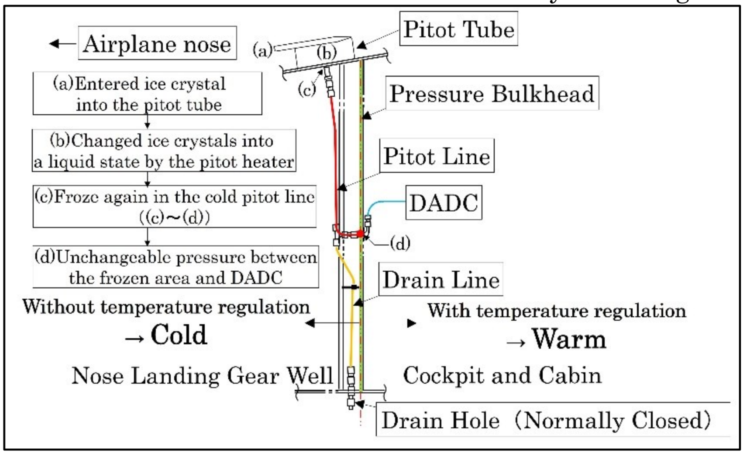


Figure 16 Image of Pitot Line Blockage

b. No.2 DADC

When the DADC MISCOMPARE message was displayed, the flight crew members followed the procedure for the message of the QRH and determined that No.1 DADC supplying air data to both PFDs for the left and right seats was faulty based on those airspeed indications of the PFDs for both left/right seats and the standby airspeed indicator and then deactivated the DADC by pulling its circuit breaker. However, when the flight crew members attempted to use the autopilot with only No.2 DADC operating, part of its function did not work, the flight crew members reassessed that it was not No.1 DADC but No.2 DADC that had failed, reactivated No.1 DADC and deactivated No. 2 DADC.

After that, the flight crew members selected No.2 DADC by using the display controller for the left seat as the response to whom the airspeed indications for both the left and right seat became unreliable during the descent, thereafter, the airspeed and altitude with the data from No.2 DADC became recorded on the DFDR.

After No.2 DADC was selected by using the left display controller and the DADC information was recorded on the DFDR, there were no abnormal values in the altitude records which the DADC with the static port where discharged the foreign objects calculated, moreover, there were also no abnormal values in the airspeed records, therefore, it is highly probable that there was no effect to the DADC by infiltration of the foreign objects and the DADC was working normally. However, it was unable to determine the operating status of

No.2 DADC before its information was recorded during the descent because there is almost no record and there is little objective information to verify its operating status.

(4) Actions by Flight Crew Members

The JTSB concludes as follows:

(a) Identify the Failed DADC

The flight crew members more likely determined that No.1 DADC was faulty based on the standby airspeed when following the Corrective Action of the QRH (Figure 14) after referring to the message index of the QRH(Figure 13) in response to the message of DADC MISCOMPARE. However, the flight crew members more likely reassessed that No.2 DADC was faulty because, after that, part of the autopilot function did not work when engaged. This judgment is more likely to be the sole judgment of the flight crew members because the autopilot operating status is not included as information to assess DADC faulty in the QRH(Figure 14).

(b) Autopilot Partial Inoperative

The DFDR did not record the time when the No.1 DADC circuit breaker was pulled out, but it recorded that No.2 DADC was selected at 19:29:14 as the data source of the PFD for the left seat which had been selected No.1 DADC until then and the autopilot was engaged at 19:30:00. According to the corrective action of the QRH (Figure 14), after identifying the faulty DADC, the flight crew members are to select the DADC (in this case, No. 2 DADC) that they have determined to be a good data source for the instrumentation. In addition, because the flight crew members are to pull the faulty DADC (in this case No. 1 DADC) circuit breaker after checking the DADC MISCOMPARE message was cleared the flight crew members more likely pulled the No. 1 DADC circuit breaker and deactivated the DADC after 19:29:14. As a result, the time since pulling the No. 1 DADC circuit breaker before reengaging the autopilot did not meet the one minute, design and manufacturing company's recommended time to reset the system, which likely resulted in the faulty part of the autopilot function.

(c) QRH (Quick Reference Handbook)

Although QRH (Figure 14) describes the entire series of procedures for the DADC MISOMPARE message, it is probably structured in such a way that it is not necessarily organized as a procedure for promptly responding to defects, as some procedures are described in duplicate in the QRH (Figure 15) to which the QRH (Figure 14) advises to refer. In addition, the QRH (Figure 15) states to re-engage the autopilot when at least one minute has elapsed since pulling the faulty DADC circuit breaker, however, the QRH (Figure 14) had no descriptions such as waiting for one-minute despite its description about re-engaging the autopilot. The flight crew members were probably unable to read the necessity to wait for one minute from it because the flight crew members probably performed the QRH(Figure 14) first in response to the DADC MISCOMPARE message.

In addition, the flight crew members more likely determined the DADC failure based on the fact that part of the function of autopilot did not work, but the designer/manufacturer expressed the opinion that it is not appropriate to determine that the DADC in use failed at that point, even if the autopilot does not operate normally when re-engaged after the flight crew members deactivated the DADC

	determined to be faulty. However, there are no descriptions expressing this designer/manufacturer's opinion in the QRH (Figure 14) and the QRH (Figure 15), and the QRH (Figure 15) stated that the autopilot may not re-engage until the faulty DADC has been isolated. Besides, the designer/manufacturer stated that when a DADC MISCOMPARE message is displayed during a cruise with small changes in altitude and airspeed where as in this serious incident, performing the procedure for the Unreliable Airspeed Indications may also be one way to do, however, since this is also not described in the QRH, it is possible that the flight crew members did not select as a procedure when identifying the faulty DADC. It is more likely necessary for the designer/manufacturer to clarify the corrective actions as well as to reorganize the descriptions in these QRHs in order to provide the flight crew members with the information necessary to take the actions. (d) Actions for Multiple DADC Failures After No. 2 DADC was deactivated, the aircraft certainly continued flying with the autopilot engaged until the flight crew members recognized that the airspeed indications on the PFDs became unreliable. It is certain that after the airspeed indications on the PFDs for both seats became unreliable shortly not long after starting the descent, the flight crew members controlled the attitude and engine thrust to the flight situation while monitoring the standby airspeed indicator according to the procedure of Unreliable Airspeed Indications of the QRH and landed the aircraft safely at Tokyo International Airport.

4. PROBABLE CAUSES

The JTSB concludes that the probable cause of this serious incident is certainly to be determined as falling under the category of multiple malfunctions in one or more systems installed on aircraft impeding the safe flight of aircraft because both airspeed indications became unreliable when the aircraft began the descent in the situation where the flight crew members deactivated No. 2 DADC determined to be faulty as the action for the DADC MISCOMPARE message and the PFDs for both seats use the data from No. 1 DADC.

It is possible that the reason that the airspeed indications on the PFDs for both seats, which had been using the data from No. 1 DADC became unreliable was because the aircraft was flying through airspace where ice crystals existed and the No. 1 pitot line was blocked.

Regarding the operating status of No. 2 DADC determined to be faulty by the flight crew members, it could not be determined with almost no records on the DFDR except the one during the descent and few objective factual information.

5. SAFETY ACTIONS

5.1 Safety Actions Required	As described in ANALYSIS, the design and manufacturing company probably needs to reorganize the descriptions in the QRHs related to DADC MISCOMPARE message.
5.2 Safety Actions Taken after the Serious Incident	The designer/manufacturer decided to revise the descriptions related to DADC MISCOMPARE and the DADC failures in the Gulfstream Aerospace G-IV Airplane Flight Manual and the QRH.

	(a) DADC MISCOMPARE Delete part of the corrective action for the message described in the QRH, remains only a reference to the DADC failures and clarifies the corrective action and precautions for DADC MISCOMPARE message. (b) DADC failures Add the description that identifying the failed system becomes easy by increasing the difference of the air data by changing the airspeed, and the altitude because it is difficult to determine the occurrence of failure in which DADC. In addition, add the description that recommends referring to Unreliable Airspeed Indications if unable to identify the faulty DADC.