

REPORT IN-008/2007

DATA SUMMARY

LOCATION

Date and time	Thursday, 8 February 2007; 2:30 h UTC
Site	At FL410 over the Atlantic Ocean, 130 NM from the Canadian coast (approximate coordinates 48N 50W)

AIRCRAFT

Registration	EC-KBC
Type and model	GULFSTREAM G-200; S/N 145
Operator	TAG Aviation España (TAG Aviation E.)

Engines

Type and model	PRATT & WHITNEY PW-306A (LH S/N CC0299; RH S/N CCC0298)
Number	2

CREW

	Pilot in command	Copilot
Age	34 years	30 years
Licence	ATPL(A)	CPL(A)
Total flight hours	4,700 h	1,900 h
Flight hours on the type	55 h	30 h

INJURIES

	Fatal	Serious	Minor/None
Crew			2
Passengers			2
Third persons			

DAMAGE

Aircraft	None
Third parties	None

FLIGHT DATA

Operation	Commercial air transport – Non revenue services – Ferry flight
Phase of flight	En route

REPORT

Date of approval	26 September 2007
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1. FACTUAL INFORMATION

1.1. History of the flight

1.1.1. *First intended flight Dallas-St. John's on 7 February 2007*

On 7 February 2007, a Gulfstream G-200 aircraft, registration EC-KBC, was to be flown from Dallas Love (KDAL), Texas, to St. John's (CYYT) in Canada, as the first leg of a delivery flight with final destination Valencia Airport (LEVC), in Spain.

This aircraft was the first Gulfstream G-200 being delivered to the operator, which already had other high performance corporate and business aircraft. The operator was a part of a large international corporate, business and charter commercial air transport group.

The aircraft had the "increased operating weight" MOD 10082, i.e. the MTOW according to the type certificate data sheet was 35,650 lb.

The operator assigned the only type-rated pilot and the only type-rated copilot they had for the delivery flight. Both crew members had obtained the G-200 type rating in October 2006.

The manufacturer usually assigned one of its own pilots to be on board during delivery flights, to provide additional assistance to the company pilots. In this case, no manufacturer pilot was available, so a mechanic was appointed to be on board during the delivery flight. This mechanic was also going to conduct training with the operator's maintenance personnel after his arrival in Spain.

The aircraft started the take-off run with the pilot in command (PIC or CM-1), the copilot (CM-2), a mechanic from the operator and a mechanic from the manufacturer on board. When the aircraft was accelerating at around 70 kt, an L FADEC FAULTY caution appeared in the cockpit. The CM-1 continued the take off and the caution angle of attack heat (AOA HEAT (L/R)) was displayed during the climb. The mechanic recommended returning to the airport, which they did.

During the landing the AOA probe heat fail message went out and the L FADEC FAULTY message remained lit.

They parked the aircraft and, after some discussion, started the engines again and carried out ground engine run tests with satisfactory results. Then they took off again for the intended flight to CYYT and during the climb the message "AOA HEAT (L/R)" appeared again. They returned to the airport and waited for the manufacturer's maintenance personnel to carry out the corresponding corrective actions. No discrepancy was found.

1.1.2. *Flight Dallas-St. John's on 8 February 2007*

Next day, with the same people on board, they took off again from Dallas without further incident or messages. The weight of the aircraft was approximately 31,600 lb.

On approach to St. John's, the amber "R AOA HEAT", "L AOA HEAT" and "TAT PROBE HEAT" indicators appeared and the circuit breakers for both pitot heaters tripped. The flight crew selected OVERRIDE on the probe switch, as required by operational procedures. After landing, the switch was put in auto and then in override again, as part of the troubleshooting activities. The mechanic from the manufacturer checked the pitot heaters and other systems. During the refueling of the aircraft, the L FADEC and R FADEC MAJOR messages appeared. The mechanic checked the Maintenance Data Computer (MDC) for faults. No fault codes were present. Both A channel and B channel circuit breakers were cycled for each engine. This extinguished the FADEC MAJOR indications for both engines.

Since the messages were no longer present, the aircraft was dispatched for flight again.

1.1.3. *Incident flight, St. John's-Madrid on 8 February 2007*

The flight crew had the following two documents for load and balance computation (weight in pounds):

Operational flight plan (prepared by dispatchers and approved by the PIC)		Load and balance sheet
Basic operating weight (BOW)	19,000	
Basic empty weight		19,844
Crew, documents, etc. (weight of mechanics not included)		624
Payload	400	
Dry operating weight		20,468
Fuel	10,500 (actual at take-off)	10,000 (at take-off)
Take-off weight	29,900	30,468
Cg		36.6% of mean aerodynamic chord (MAC)

None of the documents was correct. The manufacturer's actual airplane weighing record dated 6 December 2006 showed an empty weight of 19,773 lb.

The Operational flight plan form had an error in the BOW, which was considered equivalent to the dry operating weight and therefore should have been 20,468 lb. The load and balance sheet did not include the weight of the mechanics and their baggage (around 400 lb) and missed 500 lb of fuel actually loaded (10,500 was the real value of fuel on board at the time taxiing was initiated).

The actual take-off weight was probably around 31,368 lb (adding 500 lb of fuel and 400 lb of the mechanics and baggage and documents) to the load and balance sheet. This compares with the MTOW of 35,650 lb.

The aircraft had spent approximately 1 h parked. The engines were started at around 1:56:16 h and they took off 10 min later.

The co-pilot was the pilot flying, the CM-1 was handling ATC communications and monitoring the flight. The mechanics were seated in the passenger cabin.

Air traffic control (ATC) cleared them to climb and to be established in 48N 50W (which is located 140 NM away from St. John's) at FL330 or FL440. The CM-1 used a rule of thumb and, thinking that their weight was approximately 29.9 thousand pounds, calculated they could climb to 40,700 ft and therefore he asked ATC for clearance to climb to FL410.

However, the crew later thought they would not reach the geographical point at the assigned altitude. The CM-2 asked whether to reduce climb rate or speed and the CM-1 instructed him to do whatever he wanted but not to drop below Mach 0.66, based on the performance chart, Page IV-70, of the Operational Planning Manual (see Figure 4).

The pilots recalled that the climb was made with the autopilot with the thrust levers at the maximum climb detent at a Mach number of around 0.7 or 0.69. When they were approximately 200 ft below FL410, at a static air temperature (SAT) of -55°C , both crew members noticed a lateral shaking of the rear part of the aircraft (as if the left engine "dragged behind" in a sort of Dutch roll), and shortly afterwards the stall warning sounded. The autopilot disengaged and the disconnection warning started sounding. This warning continued sounding for more than 4 minutes during the incident sequence until it was silenced by the crew. The pilot stated that he tried to mute the warning earlier but he did not succeed.

They pushed the control column forward to reduce the pitch angle and the CM-1 said "Mine, mine," meaning "I have control." He advanced the thrust levers to the take off detent and was surprised because he did not see any increase in thrust. He then retarded the levers towards idle and moved them forward in a series of quick movements before leaving the levers in idle.

The flight crew did not apply standard stall-correcting procedures since there were inadequate pitch changes.

He told the CM-2 that the engines were not working and instructed him to declare an emergency through the radio.

The CM-2 started handling communications and 24 s after the start of the stall warning (this is the time reference used from now on in the following paragraphs of this section) he said on the radio: "We have had a flame out. We declare emergency." ATC instructed them to descend.

The conversations between the pilots recorded on the cockpit voice recorder (CVR) showed that the crew was confused about the possible cause of the situation.

The CM-2 asked whether to read off any checklist. The CM-1 thought the engines were not running. He then pushed the engine cutoff switches of both engines at the same time for one second. He did not advise the CM-2 of this action.

These switches cut the fuel flow to each engine and are intended to be used on the ground only. Their use in flight is not included in any of the aircraft's operational procedures.

The LH engine fuel flow (see Figure 2 below) went to zero and that of the RH engine dropped, though it did not reach zero. The core engine RPM (N2) also dropped for both engines but recovered shortly afterwards and the CM-1 said "Ok they are restarting," but around 20 s afterwards he said, "They are not working, they are not working." He thought they might have ice and switched on the engine anti-ice.

They turned towards St. John's and the CM-1 requested the CM-2 to enter that destination in the FMS.

At second 102 after the first stall warning, the CM-1 said they were going to restart one engine only to think once again that it was working, though he did not have control over the engine.

At second 145 he pushed the LH cutoff switch for 3 s, without advising the CM-2. The LH engine fuel flow went to zero at 2:30:11 h. The N2 of this engine reached a minimum of 41.59% at 2:30:54 h. After the LH engine cutoff switch was released its fuel flow and N2 recovered.

The RH engine continued operating normally during that sequence because its cutoff switch was not pressed.

The CM-2 again asked what checklist he could read off. The mechanic from the manufacturer went to the cockpit at that time and was asked by the flight crew about

the possible causes of the engine behavior they were noticing. He said he did not know.

The aircraft continued its descent and return to St. John's. There were two further stall warning activations (at seconds 237 and 248, with the aircraft at 31,954 ft and 31,481 ft).

At second 285 the autopilot aural disconnect warning went out. At second 319, the CM-2 informed ATC that they had "the engine working, a little bit but working".

The aircraft approached St. John's Airport with the autopilot engaged until it was around 200 ft AGL. It finally landed normally 2,024 s (33 min and 44 s) after the initial stall warning appeared.

Canadian authorities provided the radar track data of the flight, together with a graph of the trajectory followed by the aircraft compiled from these data (see Figure 1).

Over the following days, the aircraft was inspected by personnel from the aircraft and engine manufacturers. No mechanical discrepancy related to the engines or engine control was found. When the aircraft returned to Savannah, the TAT probe 102AU1AG was replaced by another supplied by the customer. An operational check did not show any defect of the probe heaters.



Figure 1. Flight path of the aircraft prepared by Canadian authorities using radar data

1.2. Personnel information

1.2.1. Pilot in command

Sex, age:	Male, 34
Nationality:	Spanish
License:	ATPL(A), obtained in 2006
Type rating:	PIC G-200 (only Spanish aircraft)
Previous type ratings:	Boeing B707, Falcon 20/200, CASA CN-235, CASA C-212
Total flight time:	4,700 h
Flight time on type:	55 h (approximately 52 h as pilot in command under supervision and 3 h as PIC)
Hours last 30 days:	9:40 h
Hours last 7 days:	6:25 h
Hours last 72 h:	6:25 h
Start of the flight duty period:	19:30 h on 7-2-2007
Previous rest:	16 h
Last course of crew resource management (CRM):	24-11-2006

The PIC had a military background and had crossed the Atlantic Ocean several times as PIC of a Boeing B-707.

He obtained his civil ATPL on 8-11-2006, and then attended the Gulfstream G-200 type rating course at Flight Safety Dallas, where he did 28 h in a flight simulator. He passed the corresponding skill test/proficiency check on 28-9-2006. He then received 1 h of actual flight training in Geneva, Switzerland, including 6 take-offs and 6 landings.

Afterwards, the PIC flew as PIC under supervision for around 25 FH and then another 30 FH as PIC without restrictions. The incident flight was the first high altitude, transatlantic flight he was to carry out with this type of aircraft.

The PIC stated he had not received any training or specific information on the behavior of the Gulfstream G-200 at high altitude. He found this behavior different from that of other turbojet aircraft flying at high altitude.

1.2.2. *First officer*

Sex, age:	Male, 30
Nationality:	Spanish
License:	CPL(A) obtained in 1999
Type rating:	Co-pilot G-200 (only Spanish aircraft); Class rating instructor (CRI(A)) Cessna single engine turbine
Previous type ratings:	Cessna 208 Caravan
Last medical examination:	12-07-2006; valid until 29-07-2007
Total flight time:	1,900 h
Flight time on type:	30 h (as first officer under supervision)
Hours last 30 days:	6:25 h
Hours last 7 days:	6:25 h
Hours last 72 h:	6:25 h
Start of the flight duty period:	19:30 h on 7-2-2007
Previous rest:	16 h
Last course of crew resource management (CRM):	24-11-2006

The copilot had received his training on the G-200 on the same dates as the PIC. He attended initial training at Flight Safety Dallas, where he passed the skill test/proficiency check on 30 September 2006 and then received 1:15 h of flight training in Geneva on 18 October 2006. Then he flew approximately 30 FH as copilot under supervision.

The copilot was used to flying the Cessna Caravan turboprop, and this was the first time he was to cross the Atlantic Ocean as the copilot of an actual flight.

1.3. **Aircraft description**

The engines of the G-200 aircraft have a Full Authority Digital Engine Control (FADEC) system. This system regulates the high pressure rotor speed (N2) and low rotor (fan) speed (N1) to apply a certain level of thrust to the engine depending on several factors like phase of flight, ambient conditions, aircraft discrete inputs, and thrust lever angle (TLA) position (i.e., the input from the pilot). The FADEC filters or

dampens quick TLA movements to make the engine respond slowly to avoid surges at altitude.

The AFM contains a specific abnormal procedure for ENGINE SLOW RESPONSE (page. III-22, 8-3-2006) that states:

"Possible ice contamination to engine sensor probes. FADEC has reverted to conservative acceleration/deceleration schedule to mitigate the risk of engine surge/stall and potential associated engine damage.

1. ENGINE ANTI-ICE pushbutton - ON
2. ENGINE SYNC switch - OFF
3. Thrust levers - OPERATE INDIVIDUALLY"

However, there are no instructions on when to apply this procedure.

The thrust levers have detents for certain flight conditions like flight idle, maximum cruise, maximum climb, take-off, automatic power reserve and reverse. According to Gulfstream, above an altitude of 20,000 ft, the amount of thrust provided with the TLA in the take-off detent is the same as that provided with the lever placed in the max climb position. Therefore, above 20,000 ft, moving the thrust lever from max climb position to take-off position will not produce any increase in thrust and therefore there will be no change in the engine parameters N1, N2 and fuel flow displayed to the crew.

The aircraft has a centralized system to display warnings and cautions (EICAS). One of those cautions is FADEC MAJOR (L/R), which means that the Full Authority Digital Engine Control computer has a malfunction. According to page III-19 of the Aircraft Flight Manual (AFM) dated 8 March 2006, this is a "failure in engine control that may have minor effect on engine operation. This message appears on ground only." There is a note that says that in this case, "Dispatch is not authorized." Another caution affecting the FADEC is the "FADEC FAULTY" message, which means "Failure in engine control that affects engine operation." The thrust levers must be operated gently and the engine indications must be monitored. The engine's back-up capability is reduced when this caution message appears and dispatch is not authorized.

The angle of attack (AOA), total air temperature (TAT) and pitot probes are heated to protect them against ice build-up. All heaters are controlled by a single PROBES HEAT switch on the overhead panel. This switch has two positions: AUTO and OVERRIDE. The nose gear oleo switch interrupts power to the heaters when the switch is in AUTO and the aircraft is on the ground. In OVERRIDE, the probes' heaters are powered in flight and on the ground.

The caution messages associated with the probe heaters are:

AOA HEAT (L/R). In flight. Discontinuity in power line. Corrective action: PROBES HEAT switch - OVERRIDE, as applicable.

PITOT HEAT (L/R). In flight. Power supply failure. Corrective action: PROBES HEAT switch - OVERRIDE, as applicable.

TAT PROBE HEAT. In flight. Power supply failure. Corrective action: PROBES HEAT switch - OVERRIDE, as applicable.

If the override position has been selected for the PROBES HEAT SWITCH, it has to be placed back to auto on the ground, and this is an item in the normal cockpit preflight checklist (reference AFM Normal Procedures, Page IV-10, 8 March 2006).

If this action is not carried out, heat is applied on the ground to the probes and during aircraft power up on the ground a FADEC MAJOR (L/R) message could be displayed. This was the subject of a Customer Support article published by Gulfstream on 13 October 2006. However, the display of the FADEC MAJOR message due to this reason would normally generate a fault code to be recorded on the MDC.

NOTE: As stated in 1.1.2 above, after the FADEC MAJOR messages appeared on the ground in St. John's, no fault code was recorded in the MDC. The engine manufacturer mentioned that this absence of recorded fault codes could be due to the EICAS switch being in the maintenance position or a power interruption to the FADECs after engine shutdown.

1.4. Flight recorders

1.4.1. Cockpit voice recorder (CVR)

The aircraft had a solid state cockpit voice recorder (CVR) P/N 1603-02-12, S/N 1656. It records 30 minutes of digital sound on four channels (CM-1, CM-2, CM-3 and cockpit area microphone) and two hours of digital sound in two additional files. One of those files ("mixer") jointly records the last two hours of the CM-1, CM-2 and CM-3 channels, and the other file ("area") records the last two hours of sounds from the cockpit area microphone.

The CVR was downloaded and found to have recorded the moments when the incident happened. The sound of the stall warning was recorded after 11 min and 36 sec of recording.

The relevant information of the CVR is as follows:

CVR recording elapsed time (hh:mm:ss)	Seconds after the start of the stall warning	DFDR UTC time (hh:mm:ss)	DFDR comment	Station talking	Text (not literal, only a summary of the conversations, when relevant or applicable, is included)
00:11:36	0	02:27:42		Sound	Clicker, stall warning.
00:11:38	2			CM-1	It is the stall.
00:11:47	11			CM-1	Ok, Ok.
00:11:50	14			CM-1	Mine, mine (meaning "I have control").
00:11:51	15			CM-1	What's happening with the engines?
00:11:53				CM-1	[Exclamation]. They are not working!
00:11:56				CM-1	Tell ATC we have an emergency.
00:12:00	24		CM-2 (radio)		We have had a flame out. We declare emergency
00:12:14	38			CM-1	I am already descending.
00:12:16	40			CM-2	What do I do (name of the CM-1)?
00:12:25	49			CM-1	We do not have the engines running
00:12:35	59			CM-1	Ok, they are restarting.
00:12:48	72			CM-1	Tell him we are descending to level 330.
00:12:58	82			CM-1	They are not working, they are not working.
00:13:45	89			CM-1	Put me direct to Saint John's.
00:13:58	102			CM-1	We are going to try to restart one engine.
			CM-1		No, wait, it's working.
00:14:06	110			CM-1	What I don't have is control.
00:14:45	149		CM-2		What do I read off to you, (name of the CM-1)?
00:14:50	154			CM-2	What can it be?
00:14:52	156			Mechanic	I do not know
00:15:24	188			Mechanic	They are running
00:17:15	299		CM-2 (radio)		We have four people on board
00:17:35	319			CM-2 (radio)	We have the engine working, I little bit but working
00:18:00	344			CM-2	Engine working again

1.4.2. Digital flight data recorder (DFDR)

The aircraft had a solid state DFDR. The data was downloaded and the relevant information is as follows:

DFDR UTC time on 8 Feb 2007 (hh:mm:ss)	Seconds after the first stall warning		Airspeed (KIAS)	Altitude (ft)	Comentario
00:44:05	N/A	Master warning active	169	2.570	While on approach on the flight Dallas-St. John's. Master warning active for three seconds.
00:46:22	N/A	Weight on wheels on	118	903	Touchdown at St. John's after the flight from Dallas.
00:54:53	N/A	Engines shutdown after landing and taxi			
01:56:16	N/A	Engines started again			
02:06:52		Weight on wheels off	139	952	Lift-off during take off from St. John's.
02:27:42	0	Stall warning and shaker active	199	40.875	Master warning active. Autopilot disengages at the same time. Autopilot disengage warning sounds.
02:27:47	5	Stick pusher active for 1 s	198	40.874	Autopilot disengage warning continues sounding. It remains active until 02:32:27 h.
02:27:52	10	Stick pusher active for 1 s	200	40.776	
02:28:17	35	Stick shaker and stall warning disappear	200,5	36.698	
02:28:25	43	Stick shaker and stall warning active again for 4 s	218,5	38.869	
02:28:38	56	Engine cut off LH and RH active for 1 s	230,5	37.444	LH engine fuel flow goes to zero at 2:28:41 h. RH fuel flow engine reaches a minimum of 208 at 2:28:47 h. LH engine N2 reaches a minimum of 64.9% at 2:28:38 h. RH engine N2 reaches a minimum of 66.75% at 2:28:39 h.
02:30:07	145	Engine cut off LH active for 3 s	221,5	34.473	LH engine fuel flow goes to zero at 2:30:11 h. LH engine N2 reaches a minimum of 41.59% at 2:30:54 h.
02:31:31	229	LH thrust lever advanced in two seconds to 10° of TLA and then immediately returned to 0° (flight idle)	205	31.970	
02:31:37	237	Stall warning active for 2 s	203	31.945	

DFDR UTC time on 8 Feb 2007 (hh:mm:ss)	Seconds after the first stall warning		Airspeed (KIAS)	Altitude (ft)	Comentario
02:31:50	248	Stall warning active for 1 s	202	31.481	
02:32:09	267	Thrust levers advanced to around 17°	208	30.665	
02:32:27	285	Autopilot disengage warning disappears	228	29.654	
02:33:36	354	Autopilot is engaged again	237	28.500	Thrust levers at around 9° of TLA.
03:01:02	2.000	Autopilot disengages	146	1.188	The autopilot is disconnected during final approach at 160 ft AGL.
03:01:26	2.024	Weight on wheels on	133	920	Landed again at St. John's.

Regarding the moments when the actual incident happened during the flight from St. John's, the DFDR data showed that after the stall warning sounded at 02:27:42 h (at which time the autopilot automatically disconnected upon activation of the stick shaker), the flight crew advanced the thrust levers to the take-off detent (33° of thrust lever angle (TLA)) and maintained them in this position for about 7 s. The N2 and fuel flow for both engines did not vary, because (see Section 1.3) above an altitude of 20,000 ft the thrust delivered by the engines with the thrust levers located in the take-off detent is the same as when the levers are in the maximum climb detent.

After approximately 7 s, there was a series of quick movements of the thrust levers back and forward until they were left close to idle (0° of TLA) 21 s following the stall warning. When the levers were retarded, the N2 and the fuel flow of the engines fell after a lag of several seconds as per design.

At second 42, coincident with a new triggering of the stall warning, the levers were advanced slightly (TLA of 1.9°) for 5 s and retarded again to 0°. The fuel flows stopped decreasing and the values of N2 for both engines suffered a less noticeable variation (due to a higher lag) as a result of these inputs.

At second 56 the engine cut-off switches for both engines were pushed for 1 s. This caused the LH engine fuel flow to go to zero and the RH engine fuel flow to decrease noticeably also. Both N2 also fell. The manufacturer interpreted those values as meaning both engines were shut-down.

After a few seconds the engines recovered fuel flow and N2 and afterwards there were three movements of the thrust levers forward and backwards in what seemed to be a check of the status of the engines.

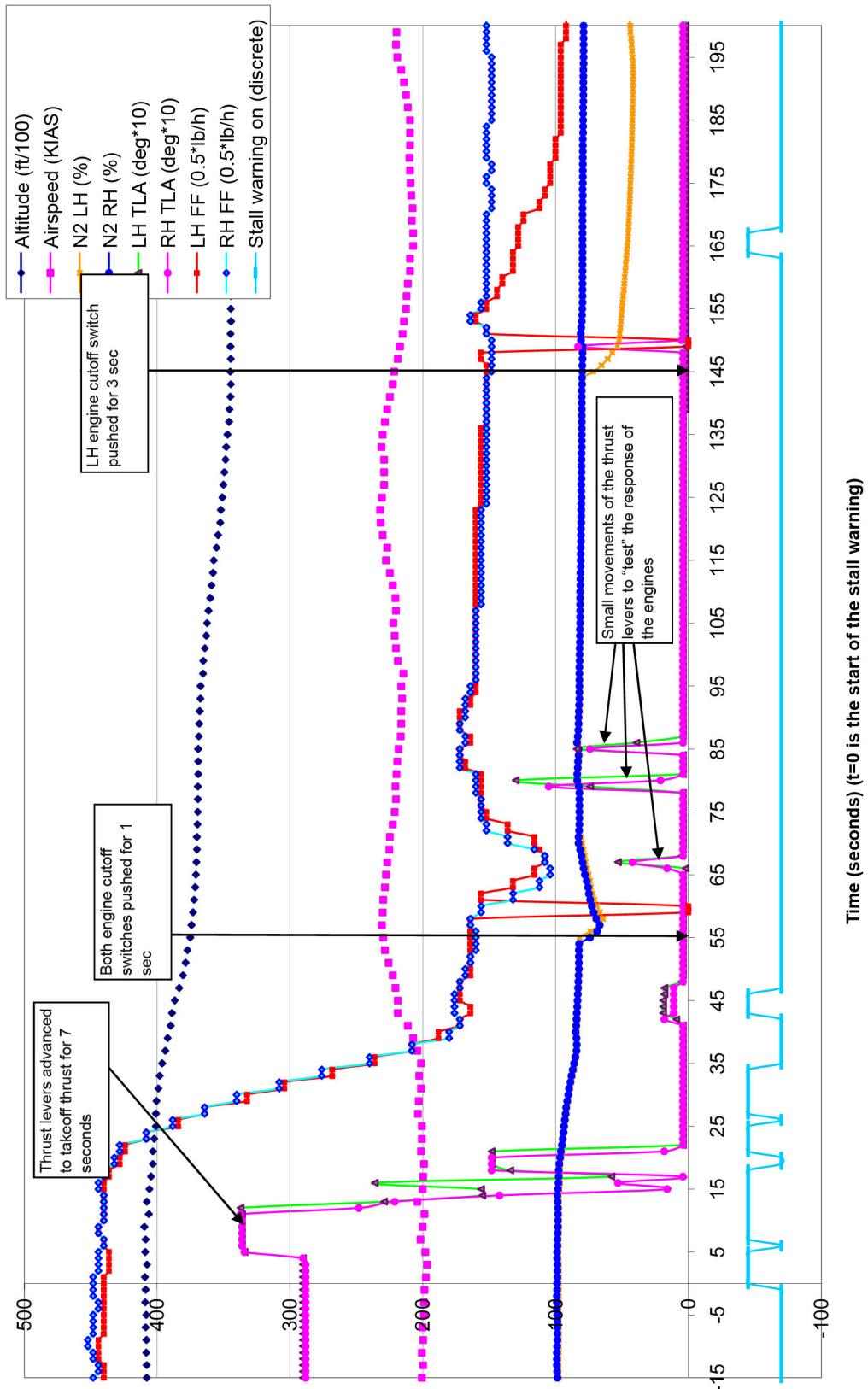


Figure 2. Qualitative variation of various DFDR parameters after the start of the stall warning. The scale of the curves has been adjusted to have all the data on the same graph

At second 145, with both thrust levers still at idle, the LH engine cut-off switch was pressed for 3 s, which caused the LH fuel flow to go to zero and the LH N2 to drop down to 41.7% in what was considered a complete shut-down of the engine. After several seconds, the fuel flow and N2 recovered and the engine re-started again.

There were no further manipulations of any engine cut-off switches. The stall warning sounded twice more. At 2:32:09 h the thrust levers were advanced to around 17° and the N2 of both engines returned to approximately 90%.

The autopilot disconnection warning remained active until 02:32:27 h (i.e. it had been sounding in the cockpit for almost 5 minutes while the flight crew was dealing with the stall warning situation). The pilot stated he tried to disconnect it earlier but he did not succeed. The reason for this could not be determined.

The aircraft continued descending back towards St. John's. Sixty nine seconds after the autopilot warning was muted, the autopilot was connected again and remained engaged until the aircraft was close to the runway during the final approach to the airport. No relevant incidents were recorded on the flight back to St. John's. The thrust levers were moved within the 4°-12° range as needed during the descent and approach. After touchdown the TLA reached -13.7° when reverse thrust was applied.

1.5. Operational procedures

The new model was included in the operator's "Manual de Operaciones" (Operations Manual) dated 6 November 2006. Part B of this manual had some G-200 aircraft information translated into Spanish but the reader was directed to the original AFM issued by the manufacturer for most of the procedures and performance information.

Part A (General) of the Operations Manual contained information and procedures for preparing the weight and balance of the aircraft and assigning flight crews to each flight. The procedures contained enough information to appropriately carry out these tasks. The operational flight plan was normally prepared by the operator's dispatchers and approved by the pilot in command.

The operator had also prepared a document of "Standard Operating Procedures" for their only G-200 aircraft. This document was based on the manual of the parent operating company, and was in a draft format effective 9 January 2007 (i.e. approximately one month in advance of the airplane delivery date). These procedures assigned detailed tasks to the PF and the PNF, as well to the pilot in command and copilot.

The procedures and aircraft information, contained in the different manuals issued by the manufacturer or by the operator, reviewed after the incident, did not include the information that, above 20,000 ft, the thrust delivered by the engines with the TLA in

the max climb detent was the same as that delivered with the TLA located in the takeoff detent.

They also did not include signs to identify an "engine slow response."

2. ANALYSIS

2.1. General

The analysis of the factual information available shows that the St. John's-Madrid flight was initiated with an aircraft weight above the value calculated by the flight crew, and planned at an excessive cruise altitude for the actual weight. The climb schedule was not optimum in terms of speed but was within limits. As a result, the aircraft stalled upon reaching the planned cruise altitude and the flight crew could not adequately identify the response of the engines to the situation. They misinterpreted the available information and the CM-1 traced the inputs they were receiving to an engine problem, believing they had no control over the engines, and in order to solve this incorrect assessment, he took actions outside the approved operational procedures of the aircraft without advising the CM-2 or the mechanic that was on board of those actions, which led both engines to lose thrust simultaneously. Later on he took the same action (to push the engine cutoff switch) for the left engine.

The following paragraphs try to assess the influence of different factors on the actions carried out by the flight crew that put the operation at risk.

2.2. Previous flights

The information gathered shows that several cautions had appeared in the cockpit of this new aircraft during three flights carried out on the day of the incident and on the previous day. These cautions had included L FADEC FAULTY, L and R AOA HEAT and TAT PROBE messages. The Dallas-St. John's flight was cancelled twice as a result. When the flight was finally conducted, the AOA HEAT (L and R) and TAT PROBE messages appeared again on the approach to St. John's. During the three flights there was a mechanic from the manufacturer on board.

Finally, before the take-off of the incident flight, an L and R FADEC MAJOR message appeared in the cockpit while on the ground.

It was not possible to determine whether this latest appearance was due to the PROBE HEAT switch being left in the override position after the landing as a part of the troubleshooting activities.

This discrepancy had been the subject of a technical article issued by the manufacturer in one of their customer support publications. The cause of the AOA HEAT and TAT

PROBE messages could not be exactly determined. They were checked after the incident and no malfunction was detected. When the aircraft returned to Savannah, the TAT probe 102AU1AG was replaced. An operational check did not show any defects.

The analysis carried out by the aircraft and engine manufacturers shows that none of those faults was related to a malfunction of the engines or their control. However, it is probable that the different caution messages displayed led the flight crew, which was not familiar with the details of the possible malfunctions, to be prone to believe that some problem could be present when they finally took off from St. John's en route to Madrid.

2.3. Crew composition

The captain had experience in North Atlantic flights at high altitude with Boeing 707 aircraft as part of his military background. He also had experience in short haul "business type" flights in Falcon 20s, but his experience with the G-200 was very limited. He had around 30 FH as CM-1 without restrictions on this type.

The copilot had no experience in high performance, high altitude jet aircraft, or on long haul or North Atlantic flights.

According to their statements, the type rating training of the flight crew did not include extensive training on engine-related emergencies. They had not received specific training related to the high-altitude performance of the aircraft. They did not know that the thrust delivered by the engines with the thrust levers at maximum climb was the same as that delivered with the levers at take-off detent when the aircraft was above 20000 ft. For this reason, a safety recommendation is issued to Gulfstream to include this information in the G-200 training programs.

It is considered that the composition of the crew was not adequate for the type of flight being conducted. Although the Operations Manual had procedures in place to assure that the assignment of flight crews was studied and prepared in advance, this did not happen in this case. These were the only pilots type rated for the G-200 that the operator had at that time, and therefore there was no option for another crew composition, unless pilots outside the company were considered. They tried to locate pilots from the operator's parent company, but none were available.

On other delivery flights, the manufacturer usually assigned one of their own company pilots to be on board, but in this case none were available and a mechanic was assigned instead. In any case, this should be considered as an additional safety measure provided for that kind of flight, not to replace the need for a suitable and balanced flight crew being provided by the operator. Therefore, a safety recommendation is issued in this regard. Because it is considered that the coordination in the cockpit was not optimum during the management of the emergency, even though the crew attended a course of CRM on 24-11-2006, the recommendation includes the need to improve CRM training.

2.4. Flight planning

The flight planning was not adequate because the flight crew used the wrong load sheet data. The load sheet take-off weight was 30,468 lb, which did not reflect the payload (passengers' weight plus baggage) and also did not reflect the final actual fuel on board (500 lb of additional fuel). The estimated error of the load sheet was at least 900 lb below the actual weight.

The operational flight plan (29,900 lb) had an estimated error of 1,468 lb below the actual weight (31,368 lb). The empty weight values for the aircraft were not correct. A safety recommendation is issued to the operator to review their weight and balance dispatch procedures in order to assure that correct and updated information is being used every time.

On the other hand, the crew used the take-off weight from the flight plan (29,900 lb, which had the biggest error) to calculate the optimum flight level.

The CM-1 used a rule of thumb (that was inadequate in this case because of its inaccuracy) and the result was that the aircraft could climb to 40,700 ft. When ATC requested them to be established at FL330 or FL410 by waypoint 48N50W, he chose FL410.

The CM-1 assigned the copilot the role of pilot flying during the takeoff and climb, which was initially a good decision because the copilot was not familiar with North Atlantic communication and navigation procedures, which were going to be handled directly by the pilot in command.

However, he did not provide appropriate monitoring of the climb carried out by the copilot. ATC had requested them to be at FL330 or FL410 before reaching the waypoint at 48N50W (located around 140 NM away from St. John's). The climb speed was around 0.7 M, instead of the optimum value of 0.75 M (or 290 kt). The copilot said at the time that at that speed they would not reach the assigned flight level at the requested position, and asked what to do, whether to reduce the speed or increase the climb rate. The CM-1 answered "do what you want, but do not go below Mach 0.66," which was in accordance with the manufacturer's performance chart.

The flight crew did not have an adequate means to accurately check the capability of the aircraft to reach FL410 at the waypoint requested by ATC, especially given the SAT in the area. The operational flight plan, considering a take-off weight almost 2,000 lb below the actual weight of the aircraft, called for reaching FL410 after 02:37 h and 1,415 NM of flight.

The DFDR data show that the flight profile differed significantly from the best profile after leaving FL250. From FL350 to FL370, the Mach number was maintained steady at 0.72 M, below the optimum 0.75. This Mach value was a significant departure from Cruise mode for Long Range Settings (0.76) and from the flight plan computed cruise speed of 0.80 M.

From FL370 to FL400, it was 0.70, significantly below the optimum of 0.75. Finally, the last 1,000 ft were more critical. The speed progressively decreased down to 199 KIAS in a short period of time given the high altitude at which they were flying. As a consequence, the aircraft experienced low speed buffet onset.

2.5. Management of the stall warning situation

The first sign that the aircraft was too high was a sort of asymmetric Dutch roll experienced at around 40,700 ft. When the aircraft was at 40,900 ft the stall warning sounded. The crew correctly recognized the warning and the CM-1 took the flight controls. The actions to recover the stall were not ideal. Pitch oscillations went from $+5.4^\circ$ to -0.4° in 3 s and from -4.9 to $+7.4^\circ$ in 2 s. AOA oscillated from -7.7° to $+14.4^\circ$ in 3 s and from $+14.4^\circ$ down to 1.9° in 3 s.

The master warning was active intermittently for 6 s. The stick pusher was active for 2 s. The stall warning lit up to 7 times. Speed recovery was very slow (from 196.5 kt up to 211 kt in 37 s). Altitude loss was 2,530 ft in 48 s before stabilizing the descent.

In an attempt to regain control, the CM-1 advanced the thrust levers to the take-off detent. Because there was no change in engine parameters, he thought there was an erroneous interface between both FADEC and the thrust levers or some sort of engine control failure. The levers were put at idle, then shortly moved forward, and finally left at idle. This produced quick changes in fuel flow and slower RPM variations in the engines.

The CM-1 probably had in mind the previous FADEC MAJOR messages seen in the cockpit before the start of the flight.

However, at the time of the stall warning, no Master Caution was activated and no FADEC EICAS message was shown.

The CM-1 probably misinterpreted the following two engine behavior conditions as being caused by a faulty FADEC or a malfunction of another part of the engine control system:

- lack of increase in thrust when the TLA was increased to the take-off detent,
- slow response of the engines to thrust lever rapid movements.

The first condition was because the aircraft was above 20,000 ft, in which case the thrust delivered by the engines at maximum climb is the same as when the levers are at take-off. It seems the pilots were not aware of this fact, and had never been instructed about this important characteristic of the power plant system. The manufacturer manuals reviewed as a result of this investigation did not contain any reference to this condition. Therefore, a safety recommendation is issued to Gulfstream to include this information in the corresponding parts of the manuals.

The second condition was due to the design of the FADECs, which prevents the engines from surging in response to rapid throttle movements. It seems from the recorded data that the engine response was normal and in accordance with their design. In any case, the AFM contains a specific procedure for "Engine slow response" that was never resorted to or mentioned by the crew. However, the procedure does not include signs for identifying slow engine response, and a safety recommendation is issued to Gulfstream in this regard.

In these conditions, the activation of the engine anti-ice, with no external visible moisture conditions, was an isolated action and not a part of any procedure. The engine anti-ice reduces both maximum and optimum altitudes, and therefore its activation at that time could have made the situation worse.

Later on, both engine cutoff switches were pushed simultaneously, which reduced both fuel flows to near zero. This action was against the approved operational procedures and was taken without advising the copilot (PNF at those moments). At this time the aircraft was in descent, passing through 37,450 ft at 230 KIAS. This altitude is beyond the Air Start Envelope (Windmilling and Starter-Assist) (Figure 3-2, Section III, Abnormal Procedures, page III-24 of the AFM). Nevertheless, the engines restarted without any problem once the fuel flow was re-established.

After the accident, the CM-1 acknowledged that he should not have taken this action, but did so in the belief that the engines were not responding and as the only action he could think of at the time that could make the engines react.

The crew was worried and under great pressure at the time. They coped with the situation and the CM-1 decided to declare an emergency and return to St. John's shortly after the stall warning was activated.

Almost two minutes later, the CM-1 activated the "L FUEL ENGINE CUT OFF" for 3 seconds. The aircraft was still descending, passing through 34,473 ft at 221 KIAS, which is at the limit of the envelope for a wind milling air start, but it was not yet in good conditions for an air start, due to a slow speed deceleration and an excessive pitch angle (+4.2°). However, the engine restarted without any problems.

2.6 High altitude flights

One conclusion of the whole event is that the flight crew was not very familiar with low speed buffet onset and high altitude stalls and associated recovery actions, or with the conditions under which engine response may be slow. They also had a lack of information concerning high altitude aircraft performance. It is necessary that the operator assure that their crews are provided with enough training in high altitude flights with high performance aircraft. The operator has informed that they send their

crews to approved flight training centers that teach the complete airplane course in flight simulators. Nevertheless, they will take it into account in the future to further reinforce this kind of training.

The performance information of the G-200 provided by the manufacturer was reviewed. The buffet boundaries are provided in Figure 7-19 of the AFM. However, the curves on this graph are closely spaced and are very difficult to read. The graph does not show bank angle (only load factor, which is less intuitive to the flight crews) (see Figure 3). Additionally, it would be useful for operational purposes if this graph were also included in the Quick Reference Handbook. A recommendation is issued in this regard.

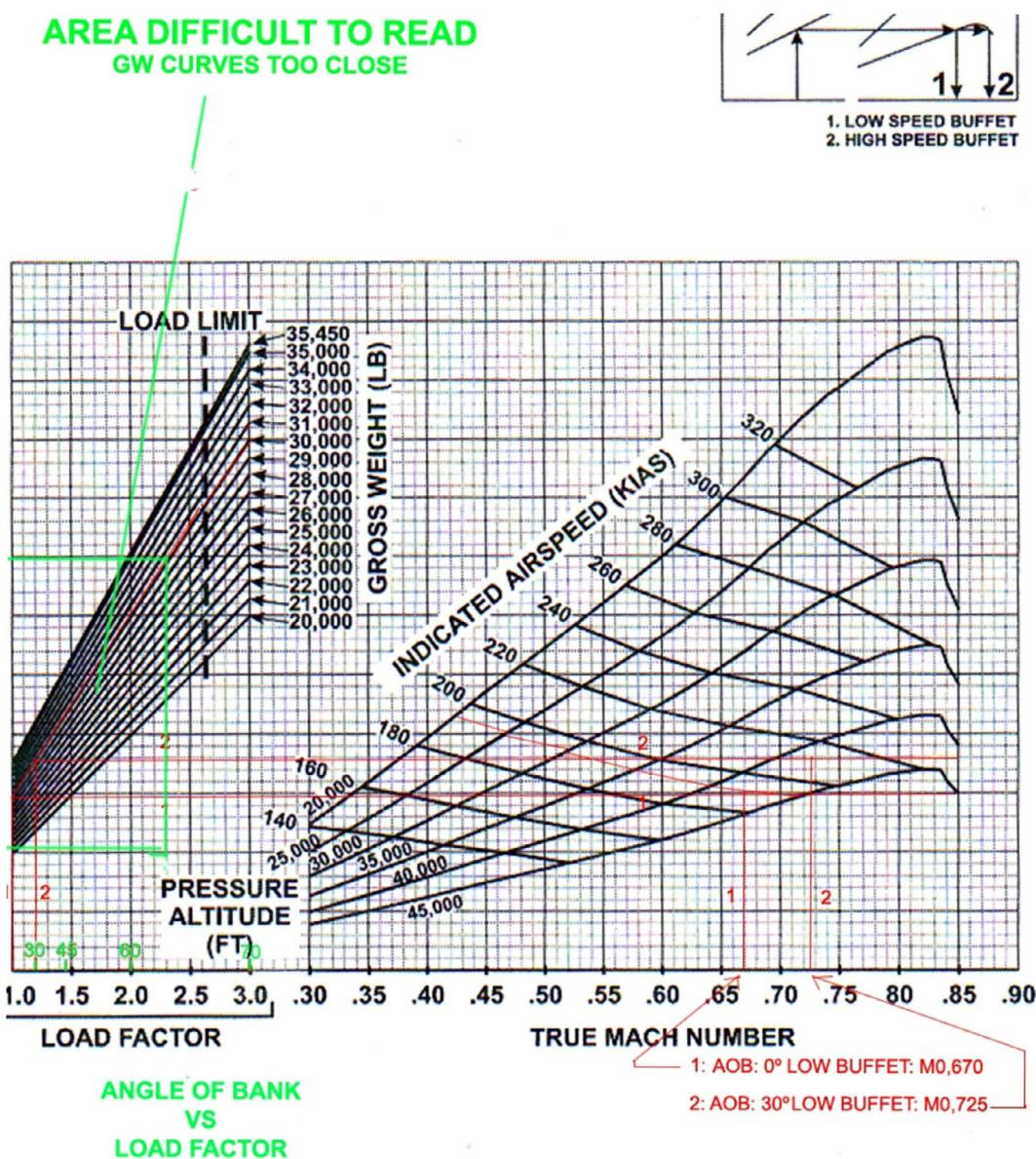


Figure 7-19. Buffet Boundary; Clean Configuration

Figure 3. Modified composition of the buffet onset graph from the G-200 AFM

According to the Operational Planning Manual, page IV-70 (18 September 2004, see Figure 4 attached) at 30,000 lb the aircraft could theoretically fly at FL410 with constant speed cruise parameters at Mach 0.66 and N1 101.4%. However, this value is lower than the low speed buffet value shown in figure 3 (0.67 Mach with 0° of bank angle). Therefore, this table should be reviewed by the manufacturer and a safety recommendation is issued in this regard.

Section IV

Constant Speed Cruise

TOC Local

41,000 FT PRESSURE ALTITUDE

0.66 M						0.68 M					
-76	-66	-56	-46	-36	OAT (°C)	-76	-66	-56	-46	-36	
-20	-10	0	10	20	ISA DEV	-20	-10	0	10	20	

30,000	97.0	99.3	101.4			%N1	97.4	99.6			
1577	1628	1678				LB/HR	1601	1652			
0.228	0.227	0.225				NM/LB	0.228	0.227			
31,000	99.2	101.4				%N1	99.7				
1681	1735					LB/HR	1714				
0.214	0.213					NM/LB	0.213				
32,000						%N1					
						LB/HR					
						NM/LB					
											30,000
											31,000
											32,000

Figure 4. Extract of page IV-70 of the Operational Planning Manual. Flight at FL410 is permitted at Mach 0.66 with 30,000 kg of gross weight

3. CONCLUSION

It is considered that the incident probably happened because, after the aircraft entered a high altitude stall due to inadequate flight planning in terms of aircraft weight and to the wrong acceptance of the ATC altitude restriction, the pilot in command simultaneously pushed the left and right engine fuel cut-off switches, which momentarily shut down both engines.

Contributing factors were:

- Execution of the final climb that resulted in a quick loss of airspeed.
- Lack of detailed knowledge of aircraft and engine behavior at critical high altitude, because this information was not a part of the manuals or the type rating training programs. This precluded the detailed checking of the capability of the aircraft to comply with the ATC altitude restriction (FL410 at 48N50W).
- Appearance in previous flights of several caution messages of undetermined origin involving the FADECs and the probe heaters, which probably misled the crew into thinking that there could be a latent problem with the engine control.

4. SAFETY RECOMMENDATIONS

REC 36/07. It is recommended that TAG AVIATION E. establish suitable practical procedures to assure that adequate flight crews are assigned for every planned flight, as described in their Operations Manual. These flight crews should have adequate training in crew resource management (CRM).

REC 37/07. It is recommended that TAG AVIATION E. review their weight and balance dispatch procedures in order to assure that the correct and updated information is being used every time.

REC 38/07. It is recommended that Gulfstream include in the appropriate parts of the aircraft manuals information regarding the variation with altitude of the maximum thrust delivered by the engines depending on the position of the thrust levers. This information should also be a part of the type rating training program.

REC 39/07. It is recommended that Gulfstream revise the engine slow response abnormal procedure of the airplane flight manual to provide flight crews with information to determine when they need to apply this procedure.

REC 40/07. It is recommended that Gulfstream revise the buffet boundaries graph provided in Figure 7-19 of the AFM in order to improve readability of the gross weight curves and to include the bank angle in addition to load factor. Additionally, it is recommended that this graph also be included in the Quick Reference Handbook.

REC 41/07. It is recommended that Gulfstream revise the table on page IV-70 (18 September 2004) of the Operational Planning Manual to assure that the Mach, gross weight and flight level values provided are consistent with the buffet boundary margins of the aircraft.