Gulfstream Aerospace Corporation (GAC) Document No.: GIV-GER-0017, GIV Gust Lock & Autothrottle Systems Ground Test Report follows this page and is included after appropriate authorization from GAC per a redacted Proprietary Notice Restriction contained on the cover page of the report.

Gulfstream

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GIV Gust Lock & Autothrottle Systems

Ground Test Report

[redacted]

DEPARTMENT: 0468

SECTION: Service Engineering

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ASO :

TECHNICAL APPROVAL:

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REV	REVISED BY	APPROVED BY	SIGNATURES	DATE
A	[redacted]			
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REVISION HISTORY

REV	PARA	DESCRIPTION OF CHANGE
-	-	Initial Release, No Change (NC)
A	-	
	1.0	Corrected typo. Additional allowable PLA due to autothrottle is 1.25, not 1.50.

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1.0 SUMMARY

The Gulfstream IV gust lock ground taxi testing was completed in accordance with the test plan GIV-GER-0016 (dated October 23, 2014). Any deviations from the original test plan are noted in this report. The following results were noted:

NOTE: Engagement or disengagement of the gust lock system was verified via standard flight controls checks for freedom of movement

- Stabilized engine data collected shows expected engine-to-engine variation but does not affect overall conclusions from the existing EPR-Temperature analysis.
- The force required to disengage the autothrottle system on this aircraft is consistent with AMM checkout requirements.
- With the gust lock handle in the up and locked position and when contacting the throttle interlock, the autothrottle system achieved an EPR that is 0.05 higher than can be achieved manually and a PLA that is 1.25 degrees higher than can be achieved manually, before it disconnects.
    - Further increasing the EPR target did not increase the achieved EPR, as the autothrottle would disconnect more quickly at approximately the same EPR value.
- When contacting the throttle interlock and when the autothrottle HOLD mode became active at 60 kts, there was no change in thrust or throttle position.
- When the gust lock handle was moved from the ON position to the unlatched position, the elevator air load did not hold the gust lock hooks in the engaged position at airspeeds up to 80 knots (highest tested speed). However, in a separate test, with rudder trim input applied, the gust lock hooks remained engaged when the gust lock handle was moved to the unlatched position.
- With the throttles contacting the throttle interlock and with the autothrottle HOLD mode activated, it was very difficult for the co-pilot position to pull the gust lock handle back and unlatch it.
- With the throttles contacting the throttle interlock and with the autothrottle HOLD mode activated, when the gust lock handle was pulled back, unlatched, and released from the up and locked position, the EPR on both engines reduced by 0.06 and the PLA reduced by 4 degrees and each remained in their new reduced state.
- With the gust lock in the intermediate/unlatched position (gust lock hooks pre-loaded with rudder trim) and a high autothrottle EPR target set (RATED EPR), the target EPR was achieved and there was no autothrottle disconnect.
- During static testing, the gust lock handle could be moved between 11-15 degrees forward before the gust lock hooks would disengage.

2.0 INTRODUCTION

This document presents the results of gathering Gulfstream IV engine data and testing of the Gulfstream IV flight control system's gust lock operations during simulated take-off, with NTSB & FAA witnesses.

The purpose of this test is to exercise GIV flight control systems in different configurations in support of the NTSB accident investigation of Gulfstream aircraft serial number 1399 (ERA14MA271). To achieve this, some of the test configurations conflict with the requirements of the GIV Airplane Flight Manual (AFM). The focus of the tests revolves around gust lock (GL) system operations and interactions with throttle movement.

The tests were conducted on Gulfstream model GIV aircraft, serial number [redacted]

2.1 Test Objective

These tests simulated abnormal operations and were intended to validate the engine EPR model, characterize the aircraft power lever angle and engine EPR response during acceleration, and, validate the presence of an aerodynamic hold on the gust lock. The test objectives were developed during team meetings to address NTSB action items as recorded in the investigation action item list.

- Engine data gathering
- Autothrottle disengage force tests
- Autothrottle/Interlock disengage test
- High speed taxi tests to characterize air load impact on elevator gust lock release
- Autothrottle hold characterization

2.2 Configuration

Testing was performed on Gulfstream GIV aircraft serial number [redacted] The aircraft had all production systems (with part numbers listed below) installed and is functionally equivalent to aircraft serial number 1399. The test aircraft had a -4 throttle control head, versus a -5 on aircraft 1399.

Flight Data Recorder Part Number
FDR – P/N S800-2000-00 S/N [redacted]

Flight Data Acquisition Unit Part Number:
FDAU - P/N 2231230-14-A-1 S/N [redacted]

Throttle Control Head Part Number:
P/N 43087-4

2.3 Test Scope

The scope of the tests was limited to investigating the test objectives listed above and as specified in the flight test plan (GIV-GER-0016). Testing was performed on 2 different days, November 13th & 14th, 2014.

TABLE 1 - SUMMARY TEST INFORMATION

A/C No.	Date	Test Cases	Personnel
[redacted]	11/12/14	5.0-8.5, 9.1	NTSB: Huray, Hauf (telecon) FAA: [redacted] GAC: [redacted], [redacted]
[redacted]	11/13/14	9.2	NTSB: Huray, Hauf (telecon) FAA: [redacted] GAC: [redacted]

2.4 System Description

See GIV-GER-0016, GIV Gust Lock & Autothrottle Systems Ground Test Plan for system descriptions.

2.5 Instrumentation and Fixturing

The following instrumentation and fixturing were required for testing as specified by the test plan. See Section 4.2 for a list of deviations:

- Video and audio recording devices to record pilot inputs and handle/lever positions
- The standard TC configuration flight data recorder
- A protractor on the pedestal to measure the throttle lever angle
- A Calibrated Force Gage

3.0 TEST RESULTS AND DISCUSSION

3.1 Methodology

- The gust lock handle shall be considered unlatched when the spring-loaded handle is rotated towards the aft position such that the entire handle is capable of being moved slightly forward, out of its detent position but not fully stowed/down.
- The gust lock system will be considered OFF and unlocked when the aileron, rudder and elevator systems are able to move freely and the gust lock handle is fully stowed/down.
- The gust lock system will be considered ON and locked when the handle is in the vertical position (in the detent, with handle latched) and the flight control systems are locked in place.
- FDR recorded data for all tests.

3.2 Deviations

Additional testing was performed that was not originally included in the test plan. These additional test points and results can be found in Sections 9.1 and 9.2 of this report. Any other minor deviations are recorded within the individual test sections.

4.0 GROUND STATIONARY TESTS

4.1 Aircraft Preparation

1. Inspect the aircraft to ensure all standard TC components are installed and functioning correctly:
   -Gust Lock System
   -Flight Data Recorder
   -Cockpit Voice Recorder
2. Install cockpit video/audio recorder (camera)
3. Install throttle lever protractor
4. Ensure sufficient fuel load: 10,000 – 14,000 Lbs.

   Results: Aircraft and instrumentation preparation complete.

5.0 ENGINE RUNS

1. Initial A/C Configuration:
   -Verify Gust Lock is OFF
   -Start both engines
   -Select both converters to ON
   -Select APU bleed air OFF and both engine bleeds to ON
   -Select both air conditioning packs to ON
   -Position aircraft heading into wind
2. Record the following information from airport weather report:
   Results: The winds were variable from 270 to 300 degrees at 6 kts with a Standard Air Temperature of 18°C.
3. Run each engine individually to a HP value of 60%, 65%, 70%, 75%, 80%, 85%, 90%, and maximum EPR value for the day, for each engine setting. Allow engine to stabilize at each setting before recording EPR and TLA data in the table below. Do not overshoot the throttle position. Repeat for opposite engine.

   Results: See Table 2
4. Bring throttles to idle and proceed to next test.

TABLE 2 – STABILIZED ENGINE/EPR DATA

ENGINE 1				Engine 2				CONDITIONS	
HP	EPR	PLA	TLA	HP	EPR	PLA	TLA	SAT	ALT
50.2	1.03	-5.8	48	49.1	1.03	-6.7	48	21	-108
59.8	1.05	-1.0	52	60.3	1.05	0.0	54	21	-108
65.1	1.06	1.1	54	64.9	1.06	2.2	56	21	-108
70.0	1.08	3.3	56	70.0	1.08	3.3	58	21	-108
75.0	1.10	5.6	59	75.0	1.11	5.6	60	21	-108
80.1	1.20	10.0	63	79.9	1.20	10.0	64	21	-108
85.0	1.32	17.5	73	84.9	1.33	15.0	71	21	-108
90.0	1.51	25.7	81	89.8	1.52	22.9	79	21	-108
94.9	1.69	31.8	91	95.1	1.69	30.0	86	21	-108
90.0	1.47	24.3	78	90.0	1.49	21.4	76	21	-108
85.0	1.29	15.0	69	84.9	1.29	13.8	67	21	-108
80.1	1.15	10.0	61	79.8	1.17	7.8	61	21	-108
75.0	1.10	5.6	57	74.8	1.09	4.4	57	21	-108
69.8	1.08	3.3	56	69.8	1.08	2.2	56	21	-108
64.9	1.06	1.1	53	64.9	1.06	1.1	53	21	-108
59.8	1.05	0.0	52	59.8	1.05	0.0	52	21	-108
51.0	1.03	-3.0	48	49.5	1.03	-4.0	48	21	-108

6.0 AUTOTHROTTLE FORCE TEST

1. Initial A/C Configuration:
   -Verify Gust Lock is OFF
   -Start both engines
   -Select both converters to ON
   -Select APU bleed air OFF and both engine bleeds to ON
   -Select both air conditioning packs to ON
2. Set manual target EPR of 1.30
3. Advance throttles to EPR of 1.20
4. Engage autothrottles
5. Allow throttles to reach stabilized position

6. Install force measuring device to throttle lever and mark location for measurement.

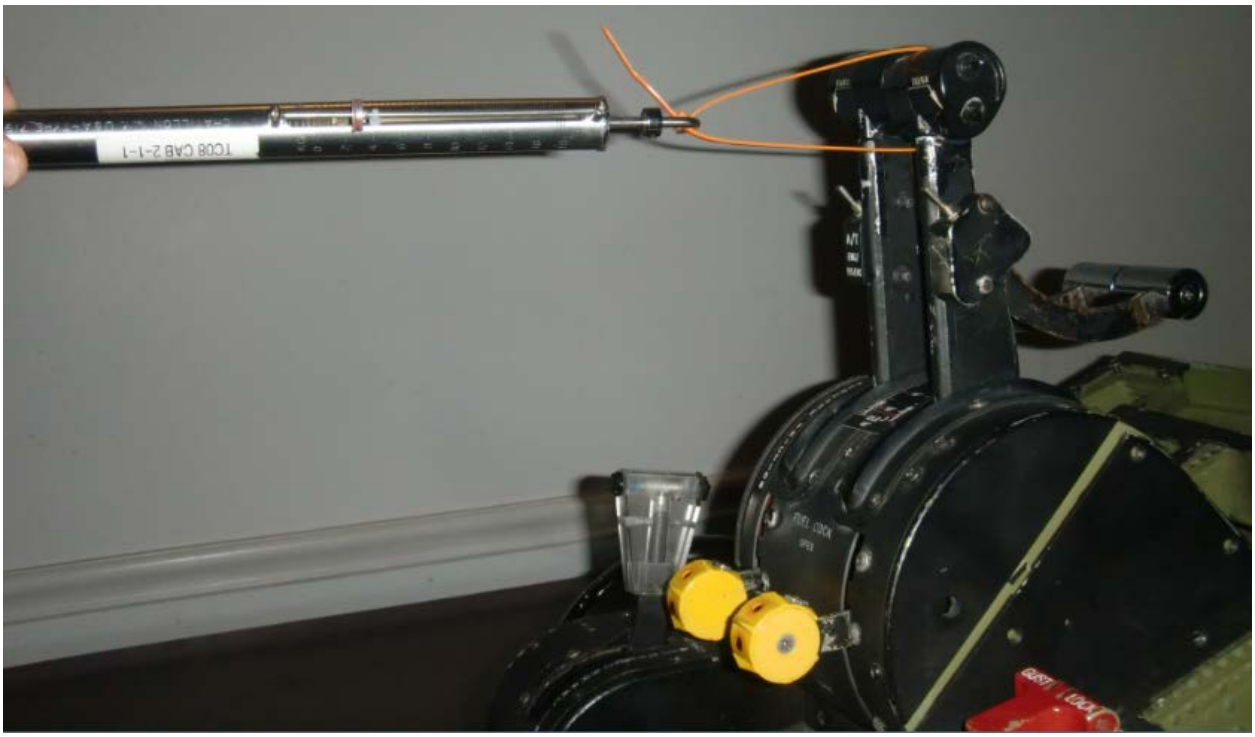

FIGURE 1 – THROTTLE HANDLE FORCE MEASURING INSTL (EXAMPLE)

7. Pull one throttle lever back until AT disengages, record max force value

   Results: LH Throttle 20 LBS RH Throttle 20 LBS

8. Repeat Steps 3 thru 7 for opposite engine.

9. Pull throttles to idle.

   Deviation: An additional test was run to measure the force as the autothrottles were being advanced towards the target position. The throttle would stop moving forward with a force of 11 LBS and the autothrottle system would disconnect after 5 seconds.

7.0 AUTOTHROTTLE/THROTTLE INTERLOCK DISENGAGE TEST

7.1 Throttle Test with Gust Lock Engaged

1. Initial A/C Configuration:
   -Verify Gust Lock is OFF
   -Start both engines
   -Select both converters to ON
   -Select APU bleed air Off and both engine bleeds to ON
   -Select both air conditioning packs to ON

Note: Standard air temperature was 21°C

Note: Idle PLA (deg) was LH -3/-4 RH -4/-5 and the TLA was LH 48 degrees and RH 48 degrees.

2. Set gust lock to ON and advance both throttles until the throttles are against the gust lock. Allow engines to stabilize.
3. Record The following:
   A) EPR readings for each engine.

      Results: LH 1.25 RH 1.26

   B) Throttle lever angle (deg)

      Results: LH 68 RH 68
4. With firm pressure (gust lock set to ON), advance the throttles as much as possible and allow engines to stabilize
5. Record the following
   A) EPR readings for each engine.

      Results: LH 1.29 RH 1.33

   B) Throttle lever angle

      Results: LH 72 RH 71

   C) FDR - PLA

      Results: LH 16.25 RH 15.00
6. Reduce throttles to idle, allow engines to stabilize

7.2 Autothrottle Test with Gust Lock Engaged

1. Initialize performance computers for autothrottle engagement.
2. Arm ground spoilers
3. Verify gust lock is ON.
4. Set manual EPR target from Section 7.1.3.A.
5. Advance both throttles to 1.18 EPR.
6. Engage autothrottle switch and verify the throttles move to the selected EPR value, allow engines to stabilize.
7. Disengage autothrottles and reduce throttles to idle
8. Repeat Steps 4-7 adding 0.01 EPR to previous target EPR each time. Repeat until autothrottle disengages. Do not exceed target EPR of 1.60.

Results: The highest EPR value for each engine was LH 1.34 RH 1.38 with a PLA of LH 17.50 RH 16.25 degrees. When a higher EPR target was selected (larger delta above the achievable target), the autothrottle system would disconnect more quickly (see Figure 2).

Note: While the autothrottles are in takeoff mode, the disconnect logic is based on current and rate vs time. As the autothrottles reach their target PLA position the servo current is reduced. At 60 Knots, the autothrottle hold mode engages. In autothrottle hold mode, the disconnect logic is based on throttle movement rate only (>8 degrees per second).

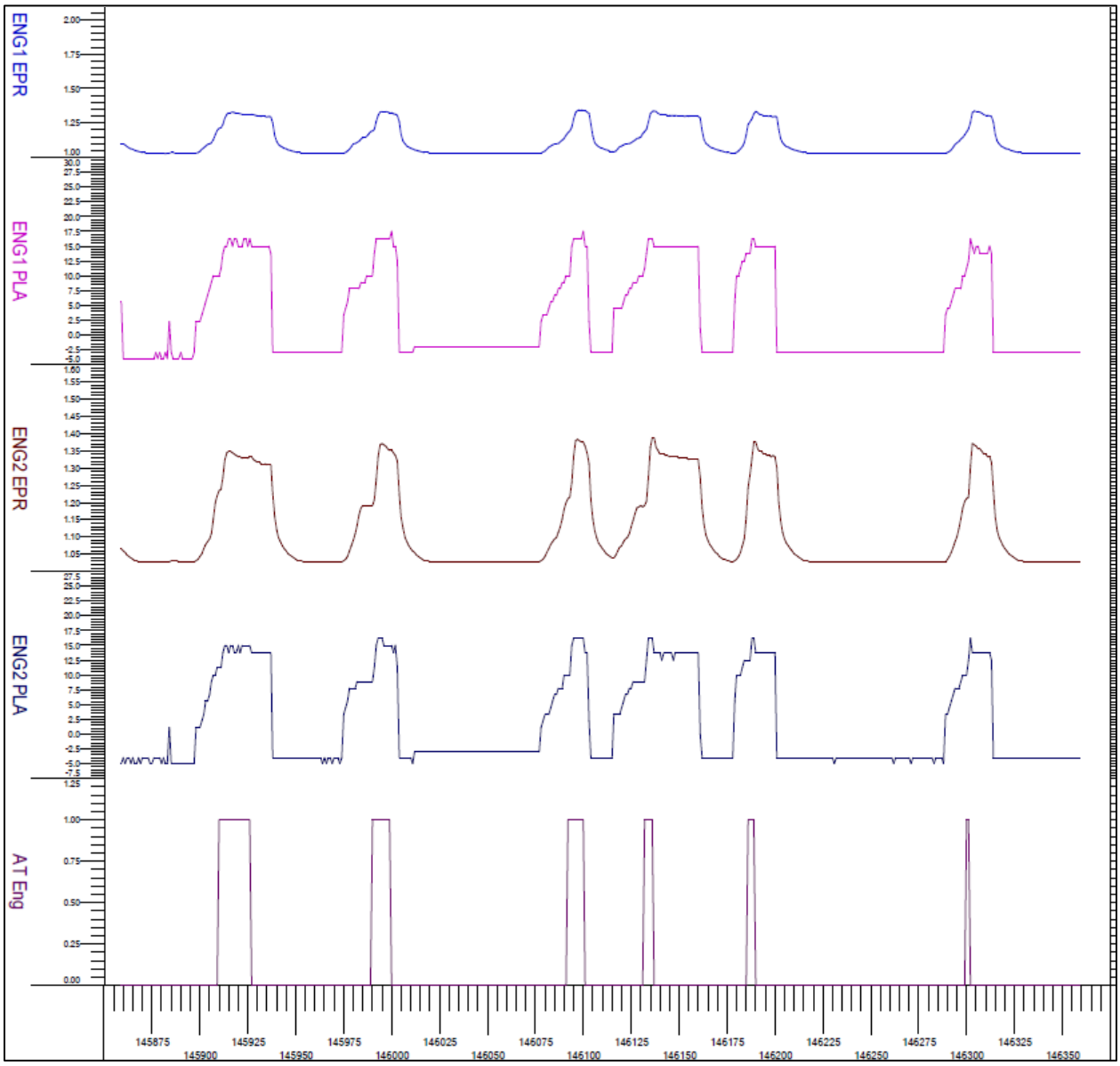

FIGURE 2 – GL ENGAGED AUTOTHROTTLE DISCONNECT TEST

8.0 HIGH SPEED TAXI TESTS

8.1 Aircraft Preparation

1. The winds must be less than 10 knots.
2. Prepare aircraft for flight.
3. Select both converters to ON
4. Select APU bleed air Off and both engine bleeds to ON
5. Verify both air conditioning packs are selected ON
6. Verify Yaw Damper is OFF
7. Verify a total fuel load of 10,000 Lbs minimum
8. Set flaps to 20 degrees
9. Verify elevator trim is set to the correct setting. Record trim setting.

   Results: 6° Nose Up

8.2 EPR Baseline Test

1. Set gust lock to ON
2. With firm pressure, advance the throttles as much as possible and hold until engines are stabilized.
3. Record the following
   A) EPR readings for each engine.

      Results: LH 1.34 RH 1.34 (No pressure: LH 1.28 RH 1.29)

   B) Throttle lever angle (deg)

      Results: LH 67 RH 67
4. Return throttles to idle
5. Release gust lock

8.3 Baseline Taxi Test with Gust Lock Off

1. Prior to starting this test run, verify brake temperatures are below 200 degrees C.

   Results: 20 degrees C
2. Using the EPR value from step 8.2.3.A, set a manual EPR target of this value.
3. On the active runway with both engines running, verify gust lock is OFF.
4. Verify Yaw Damper is OFF
5. Arm the ground spoilers
6. Advance throttles to an EPR value of 1.20.

7. Release brakes and let the aircraft accelerate to 40 knots.
8. At 40 Knots, engage autothrottle system and verify the throttles move to the selected EPR value.
9. Record speed at which the control column starts to move aft.

   Results: At approximately 60 Knots, column starts to move aft. At 80 Knots, column has moved 4 to 5 inches aft and can be moved to forward stop with very little force.

10. At 60 knots, verify AT HOLD illuminates on the PFD

    Results: Verified

11. At 80 Knots, abort the take-off and decelerate to 40 knots without using brakes or thrust reversers (unless required). Do not use the rudder for directional control.

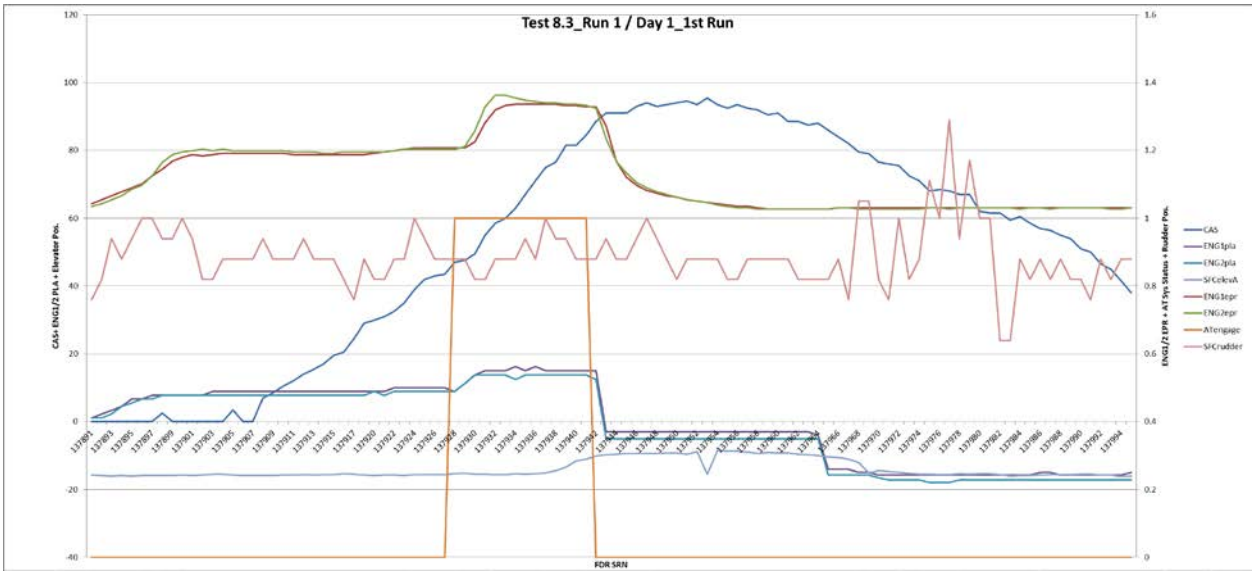

FIGURE 3 – BASELINE TAXI TEST W/ GL OFF

8.4 Taxi Test with Gust Lock Engaged

1. Prior to starting this test run, verify brake temperatures are below 200 degrees C.
2. Using the EPR value from step 8.2.3.A, set a manual EPR target of this value. If a different EPR value is used, record value.

   Results: LH 1.34 RH 1.34.

3. On the active runway with both engines running, set gust lock to ON.
4. Verify Yaw Damper is OFF
5. Verify ground spoilers are armed
6. Advance both throttles until they are restricted by the gust lock. Do not force throttles forward.
7. Release brakes and let the aircraft accelerate to 40 knots.

8. At 40 Knots, engage autothrottle system and verify the throttles move to the selected EPR value.
9. At 70 knots, release gust lock and note gust lock handle position

   Results:

   1st Run: Gust lock handle could not be unlocked by the co-pilot. Forces were much higher than expected.

   2nd Run: Gust lock handle was unlocked from the flight engineer position and the gust lock went to the off/down position. The EPR on both engines dropped 0.06 and the PLA dropped 4 degrees after the gust lock handle was pulled aft and then released.

   3rd Run: Gust lock handle was pulled back and released at 80 kts. The handle went to the off/down position (see FDR & video data for the 5th run on Day 1).

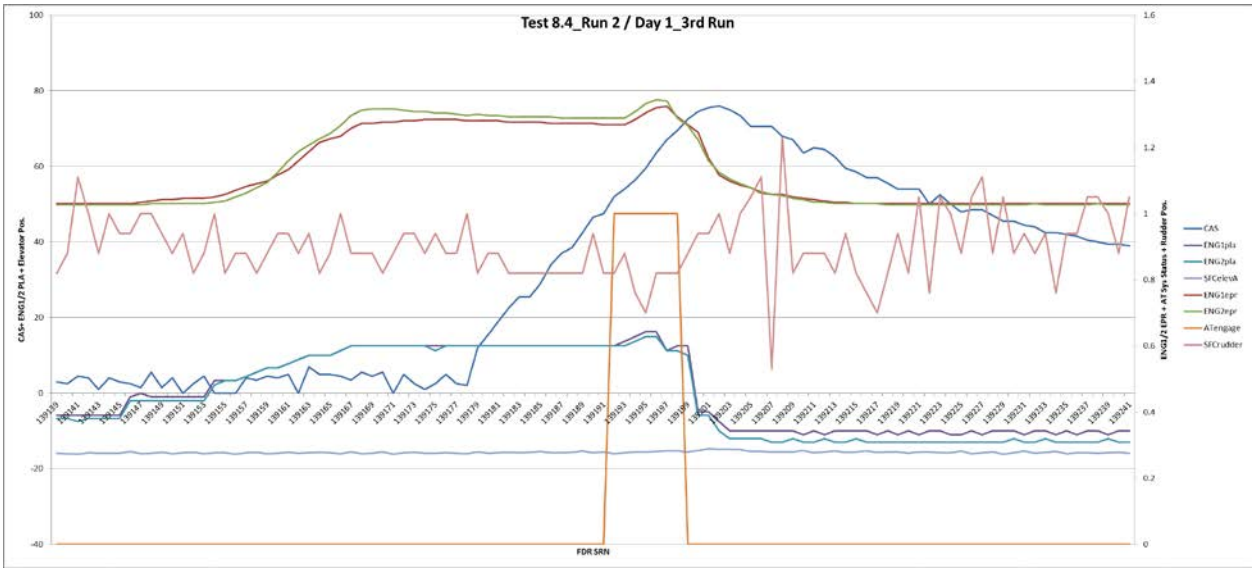

FIGURE 4 – TAXI TEST W/ GL ON

10. At 80 Knots, abort the take-off and decelerate until the gust lock handle goes to the OFF position without using brakes or TR's . Do not use the rudder or brakes for directional control.
11. During deceleration, record the airspeed at which the gust lock handle goes from the unlatched position to the down and locked position (OFF). Use normal brakes and TR's after this occurs

    Results:

    1st run: Gust lock handle remained in the up and locked position. Gust lock handle could not be unlocked by the co-pilot. Forces were much higher than expected.

    2nd Run: Gust lock handle moved to the down and OFF position.

    3rd Run: The elevator air load would not hold the gust lock hook in the locked position at any speed during testing, which was limited to 80 knots.

8.5 Taxi Test with Gust Lock Handle in the Unlatched Position

1. Prior to starting this test run, verify brake temperatures are below 200 degrees C.
2. Set the performance computer for a flex EPR take-off of 1.59.
3. Verify Yaw Damper is ON
4. Verify ground spoilers are armed
5. On the active runway with both engines running, set gust lock to ON.
6. Apply right rudder until the rudder limit CAS message comes on, reduce rudder pressure slowly until the rudder limit CAS message goes out, and hold this pressure until the AT system is engaged at 40 Knots during the test run.
7. Release the gust lock handle. Gust lock handle should go to the unlatched position. If the gust lock handle goes to the OFF position, engage gust lock and try again.

   Note: Rudder pedal input was attempted on 2 runs to hold the gust lock handle in the unlatched position for the duration of the test, but was unsuccessful.. Rudder trim input (1.0 units to the left) was used on a 3rd attempt (see FDR & video data for the 6th run on Day 1) and successfully held the gust lock handle in the unlatched position. .
8. Advance both throttles to an EPR target of 1.40.
9. Release brakes and let the aircraft accelerate to 40 knots. It is acceptable for the rudder limit light to come on during this test run.
10. At 40 Knots, engage autothrottle system and remove pressure from the rudder pedals. Verify the gust lock handle remains in unlatched intermediate position.
11. At not less than 60 knots, pull the gust lock handle towards the locked position once and release back to the unlatched position. Do not latch the gust lock handle.

    Results: On the 3rd run, the gust lock handle was pulled back at 70kts and released. It returned to the unlatched intermediate position.
12. At 80 Knots, abort the take-off and decelerate until the gust lock handle goes to the OFF position without using brakes or TR's. Do not use the rudder or brakes for directional control.
13. During deceleration, record the airspeed at which the gust lock handle goes from the unlatched position to the down and locked position (OFF). Use normal brakes and TR's after this occurs.

    Results: Rudder trim was never removed and the gust lock handle remained in the unlatched intermediate position.
14. End of test.

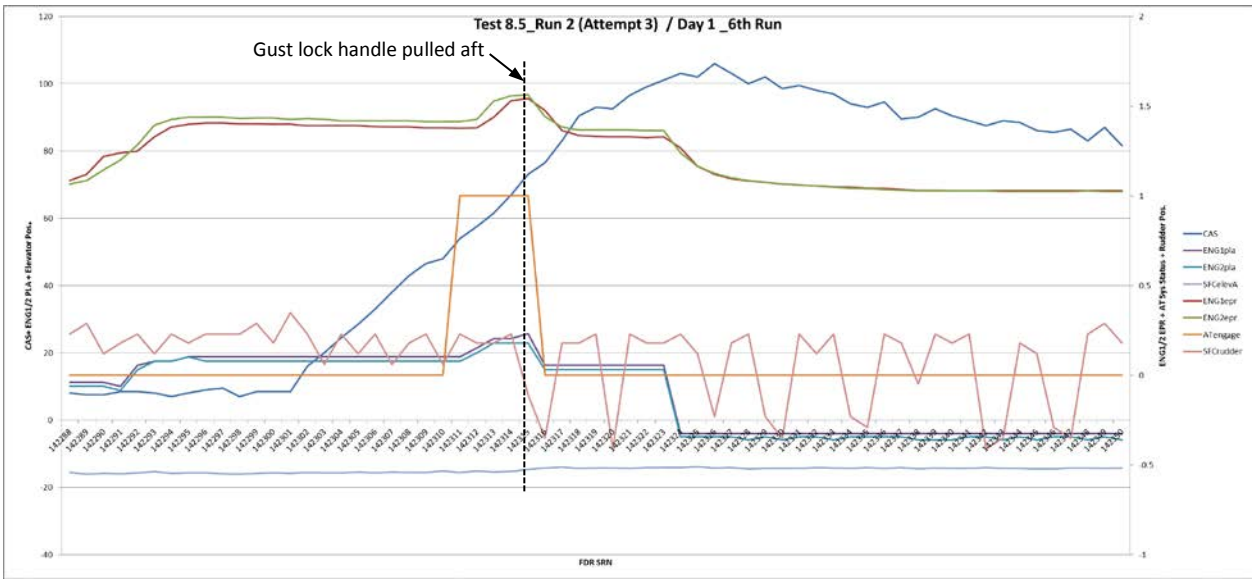

FIGURE 5 – TAXI TEST W/ GL UNLATCHED (FLEX EPR)

9.0 ADDITIONAL TESTING

The following tests were not included in the original test plan. All additional testing was discussed for relevancy and for potential impacts to safety prior to conducting the test.

9.1 Static Gust Lock Handle/Hook Displacement

Under static conditions, the gust lock system was operated to determine how far the GL handle could be moved before the hooks would disengage from the flight control surface.

1. Ensure hydraulics are OFF.
2. Set gust lock to ON.
3. Perform flight control check to ensure surfaces are locked. Continue to apply light pressure to the wheel, control column and pedals.
4. Unlatch gust lock handle and slowly allow the handle to move forward.
5. Record angle of the gust lock handle at which point the wheel, control column and pedals become free.

   Results: During multiple test runs, the gust lock hooks disengaged when the gust lock handle reached positions between approximately 11-15 degrees forward from the UP and locked position.

   Note: With the gust lock handle in the unlatched position (preloaded with rudder trim), the handle was 14 degrees forward from the UP and locked position.

9.2 Taxi Test with Gust Lock Handle in the Unlatched Position (RATED EPR[1])

1. Prior to starting this test run, verify brake temperatures are below 200 degrees C.
2. Set the performance computer for a RATED EPR take-off. Record the EPR value.

   Results: 1.67 LH, 1.68 RH
3. Verify Yaw Damper is ON

   Deviation: This test was run 3 times. On the third test run, the yaw damper was turned OFF.
4. Verify ground spoilers are armed
5. On the active runway with both engines running, set gust lock to ON.
6. Apply rudder trim until the rudder limit CAS message illuminates and then reduce rudder trim slowly until the rudder limit CAS message extinguishes. Record rudder trim position.

[1] The terms “RATED EPR” and “MIN EPR” are used interchangeably in Gulfstream’s GIV manuals and are synonymous. These terms refer to the minimum EPR required to perform a maximum thrust takeoff.

1st Run Results: 0.125 units left rudder trim input.

2nd Run Results: 7.5 units right rudder trim input.

3rd Run Results: 3.0 units left rudder trim input.

7. Release the gust lock handle. Gust lock handle should go to the unlatched position.

   Results: For all test points, the gust lock handle remained in the unlatched intermediate position prior to brake release.

8. Release brakes and engage autothrottle system. It is acceptable for the rudder limit light to come on during this test run. Verify the gust lock handle remains in unlatched intermediate position.

   Results:

   1st Run Results: Gust lock handle goes to OFF position at 72 kts.

   2nd Run Results: Gust lock handle goes to OFF position at 53 kts.

   3rd Run Results: Gust lock handle remains in the unlatched intermediate position for duration of test until aircraft turns off the runway.

   Note: It is believed that the gust lock handle fell to the OFF position in the first two tests due to the gusting crosswinds and resulting yaw damper motion.

At 80 Knots, abort the take-off with normal braking, etc.

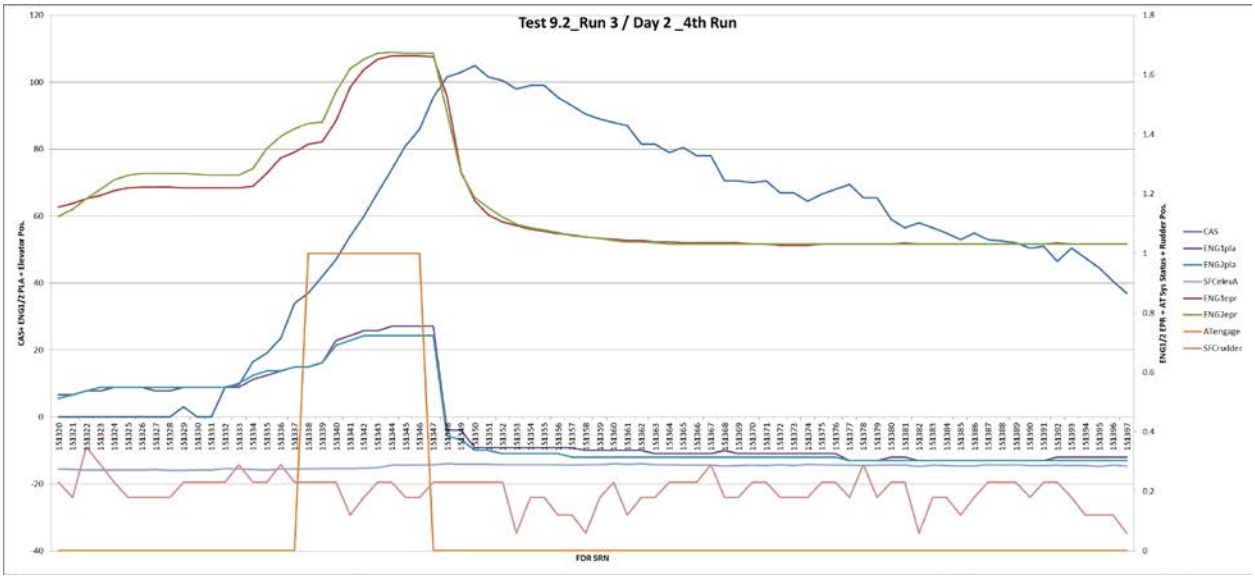

FIGURE 6 – TAXI TEST W/ GL UNLATCHED (RATED EPR)

End of test.

10.0 REFERENCES

GIV-GER-0016 GIV Gust Lock and Autothrottle Systems Ground Test Plan

FDR & video data from tests