NATIONAL TRANSPORTATION SAFETY BOARD
Vehicle Recorder Division
Washington, DC 20594

December 18, 2014

Flight Data Recorder - Addendum

Specialist's Factual Report Addendum
By Christopher Babcock

1. EVENT

Location:	Bedford, Massachusetts
Date:	May 31, 2014, 2140 Eastern Daylight Time (EDT)
Aircraft:	Gulfstream GIV, N121JM
Operator:	Arizin Ventures, LLC
NTSB Number:	ERA14MA271

2. GROUP

A group was not convened.

3. SUMMARY

On May 31, 2014, about 2140 eastern daylight time, a Gulfstream Aerospace Corporation GIV, N121JM, operated by Arizin Ventures, LLC, crashed after a rejected takeoff and runway excursion at Laurence G. Hanscom Field (BED), Bedford, Massachusetts. The two pilots, a flight attendant, and four passengers were fatally injured. The airplane was destroyed by impact forces and a postcrash fire. The personal flight, which was destined for Atlantic City International Airport (ACY), Atlantic City, New Jersey, was conducted under the provisions of 14 *Code of Federal Regulations Part 91*. An instrument flight rules flight plan was filed. Night visual meteorological conditions prevailed at the time of the accident. This addendum documents the results of 2 ground test sessions performed in support of the investigation.

4. DETAILS OF INVESTIGATION

The purpose of the ground tests were to document how the gust lock system interacts with the flight control systems and throttle movement aboard the GIV during static and dynamic conditions. Testing took place on July 28-29, 2014, and November 13-14, aboard similar GIV aircraft similar to the one involved in the accident. Each test was witnessed by Gulfstream, NTSB, and FAA representatives. Both aircraft had similar flight control and throttle configurations to the accident aircraft, serial number 1399. Both aircraft were equipped with a flight data recorder (FDR) similar to the FDR installed aboard the accident aircraft as well as a video camera that recorded audio and video of the cockpit environment. This addendum details FDR data recorded during the ground testing. It supplements Gulfstream flight test reports GIV-GER-9980 and GIV-GER-0017 that include additional measurements and observations.

4.1. Time Correlation

The timing on all plots is correlated to the in-cockpit mounted camera elapsed time for each test session.

4.2. Engineering Units Conversions

The engineering units conversions used for the data contained in this report are based on documentation from the aircraft manufacturer. Where applicable, changes to the conversions have been made to ensure the parameters conform to the Safety Board's standard sign convention that climbing right turns are positive (CRT=+).[1]

4.2.1. Parameters Provided and Verified

Appendix A lists the FDR parameters provided and verified in this report, including the associated plot label. The right aileron position sensor on the aircraft used during the July 2014 testing did not appear to function properly.

4.3. FDR Plot Description

For the purposes of this testing, a description of "gust lock on" or "gust lock engaged" indicates that the gust lock handle is positioned in its fully up/aft position (gust lock system locked) (Figure 1). A description of "gust lock off" indicates that the gust lock handle is in its fully down/forward (gust lock system unlocked) (Figure 2). A description of "gust lock handle unlatched" indicates that the gust lock handle is in an intermediate position; between fully forward and fully aft (Figure 3).

[1] CRT=+ means that for any recorded parameter that indicates a climb or right turn, the sign is positive. Also, for any parameter recorded that indicates an action or deflection, if it induces a climb or right turn, the sign is positive. Examples: right roll=+, aileron trailing edge up=+, elevator trailing edge up=+.

Figure 1. Gust lock handle in up/aft and latched (on) position.

Figure 2. Gust lock handle in down/forward and latched (off) position

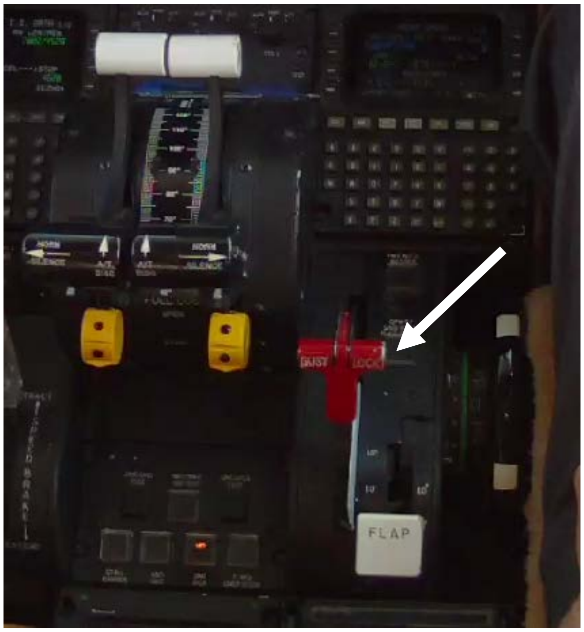

Figure 3. Gust lock handle in unlatched (intermediate) position.

Figures 4 through 8 contain data for tests conducted on July 28, 2014. Figure 4 contains data showing the functionality of the gust lock when an elevator preload was applied. Figure 5 contains data showing a baseline functionality of the gust lock when the flight power shutoff valve (FPSOV) handle was pulled. The gust lock handle was able to be moved from the on position to the off position. There was no flight control preload on the gust lock system for this test. Figure 6 contains data that shows the effect of a rudder preload on the gust lock system when the gust lock handle was in the unlatched position. When the FPSOV handle was pulled the gust lock handle sprang forward to its unlocked position. The “Warn Inhibit” switch was not selected for these two test points. An amber CAS message and audible single chime activated when the FPSOV handle was pulled. Figure 7 contains data showing the PLA resulting from the maximum thrust lever movement when the gust lock handle was on. The maximum thrust lever angle at the pedestal was recorded via a protractor installed on the throttle control head and can be found in the Gulfstream flight test report GIV-GER-9980. Figure 8 contains data demonstrating the results of applying forward force to the left thrust lever with the gust lock in the unlatched position under a rudder preload using rudder trim. Forcing the thrust lever forward against the gust lock/throttle interlock moved the gust handle forward, but the gust lock did not release. Gulfstream was able to show during a company test that the gust lock system was able to release with increased throttle lever force. The force to require for release is a function of the amount of rudder preload applied to the gust lock hook.

Figures 9 through 15 contain data for tests conducted on July 29, 2014. Figure 9 contains an exemplar preflight stall barrier and flight control check. Figure 10 contains data showing the authority of the yaw damper to move the rudder surface with the gust lock on during turns in both directions while taxiing. Figure 11 contains data showing the function of the behavior of the blue “Rudder Limit” crew alerting system (CAS) message and the gust lock handle during turns in both directions with a rudder preload provided by trim input and the gust lock handle unlatched (gust lock hooks remained engaged). Turning to the right caused the “Rudder Limit” light to illuminate. The gust lock handle sprang forward during a turn to the left. Figure 12 contains data from a repeat of this test point. Figure 13 contains data showing the behavior of the autothrottle and engines when the gust lock handle was unlatched to the intermediate position. The PLA reached 30° when the autothrottles were engaged and the engine pressure ratios (EPR) reached their target of 1.59. Figures 14 and 15 show data from additional tests not described in the flight test plan. Figure 14 contains data for an autothrottle engagement at 1.17 EPR with a target of 1.59 EPR with the gust lock on. The thrust levers moved to the gust lock interlock and PLA angles increased to 21.4° and 22.8° before retreating to 18.7°. The autothrottles disconnected within three seconds. Figure 15 contains data for an autothrottle engagement with the thrust levers positioned against the gust lock interlock. The PLA angles momentarily increased and the autothrottles disconnected within three seconds.

Figures 16 through 25 contain data for tests conducted on November 13, 2014. Figures 16 and 17 document the EPR/PLA relationship on the test day. These test points were conducted prior to the start of the video recording so time is represented in raw subframe counts. Figures 18 and 19 document the EPR that can be attained on the test day when the power levers are moved to the gust lock interlock, both with no pilot pressure against the interlock and with firm pressure against the interlock. Figure 20 documents the speed at which the control column began to move aft due to air loads during a high speed taxi with the gust lock off, approximately 70 knots. Figures 21 through 23 contain data for high speed taxi tests with the gust lock on. The intent of these test runs was to investigate and replicate the reduction in PLA and EPR as recorded on the accident takeoff FDR (see Figure 10 of the FDR Factual Report for comparison). The aircraft accelerated to 70 knots with autothrottle on and the copilot attempted to unlatch the gust lock handle. On the first run (Figure 21), the copilot was unable to unlatch the gust lock handle. On the repeat test runs (Figures 22 and 23), the flight observer was able to unlock the gust lock to where it moved to the fully forward, unlocked position. On the second repeat run (Figure 23), the observer began to unlatch the gust lock handle at 80 knots instead of 70 knots to determine the effect of higher air loads on the gust lock hook. Figures 24 and 25 document high speed taxi tests with the gust luck handle unlatched using FLEX EPR. The intent of these test runs was to investigate and replicate the reduction in PLA and EPR as recorded on the accident takeoff FDR (see Figure 10 of the FDR Factual Report for comparison). The attempt to use rudder pedal input to preload the gust lock system during the first two tests was unsuccessful to hold the gust lock handle in the unlatched (intermediate) position. The gust lock sprung to its full forward position, releasing the gust lock, during the first two attempts (Figure 24). During the third attempt, rudder trim input was used to preload the gust lock system, and the gust lock handle remained unlatched after being pulled back by the observer (Figure 25). A reduction in PLA and EPR was observed coincident with the gust lock handle being pulled back.

Figures 26 through 28 contain data for tests conducted on November 14, 2014. They document high speed taxi tests with the gust lock handle unlatched using Rated EPR. The gust lock snapped forward without pilot input during the first two attempts (Figures 26 and 27). The gust lock handle remained in the unlatched position with no pilot input for the entirety of this test (Figure 28). The yaw damper was disengaged for this attempt due to wind gusts.

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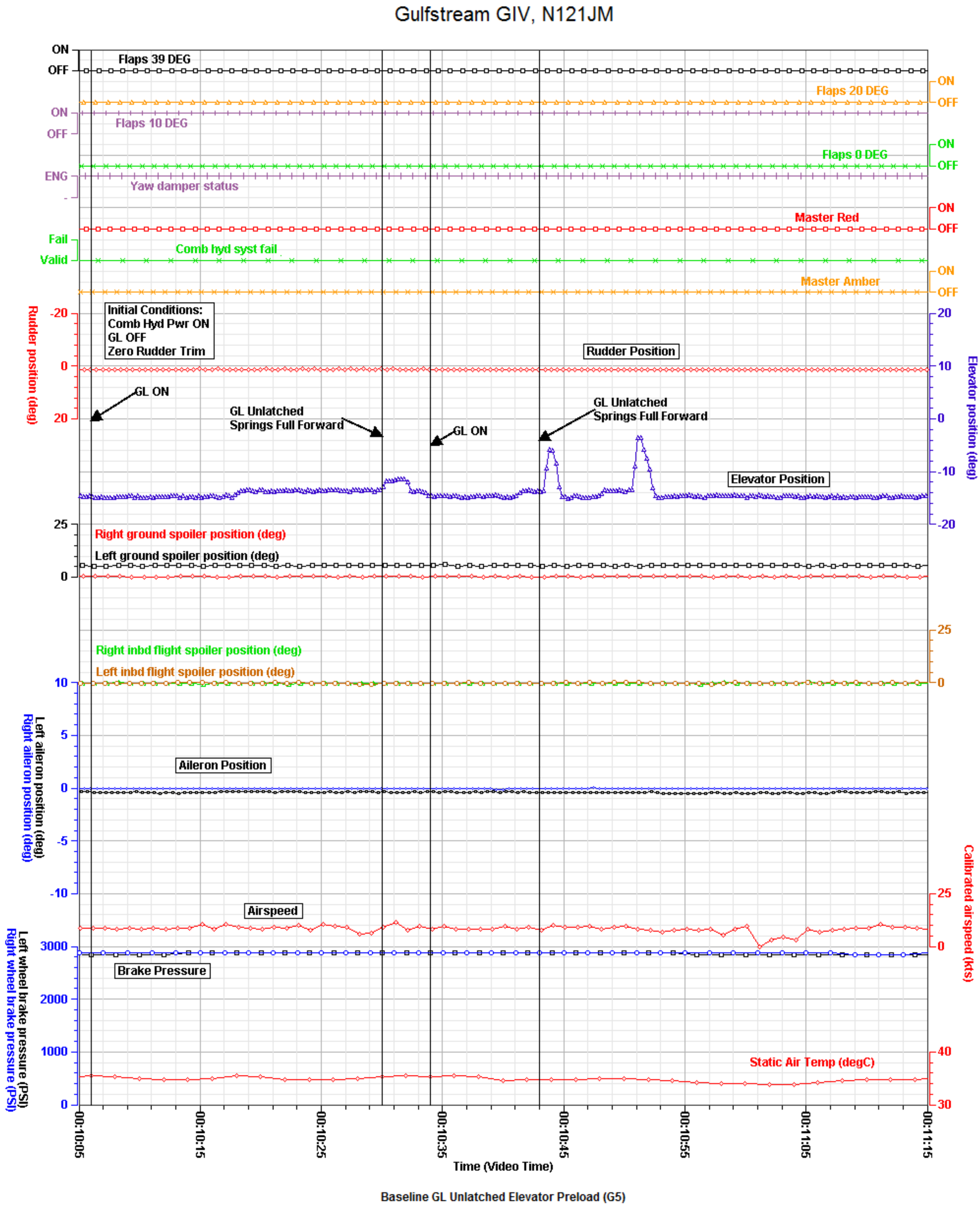

Figure 4. Baseline gust lock unlatched - elevator preload (GIV-GER-9980 Test G5).

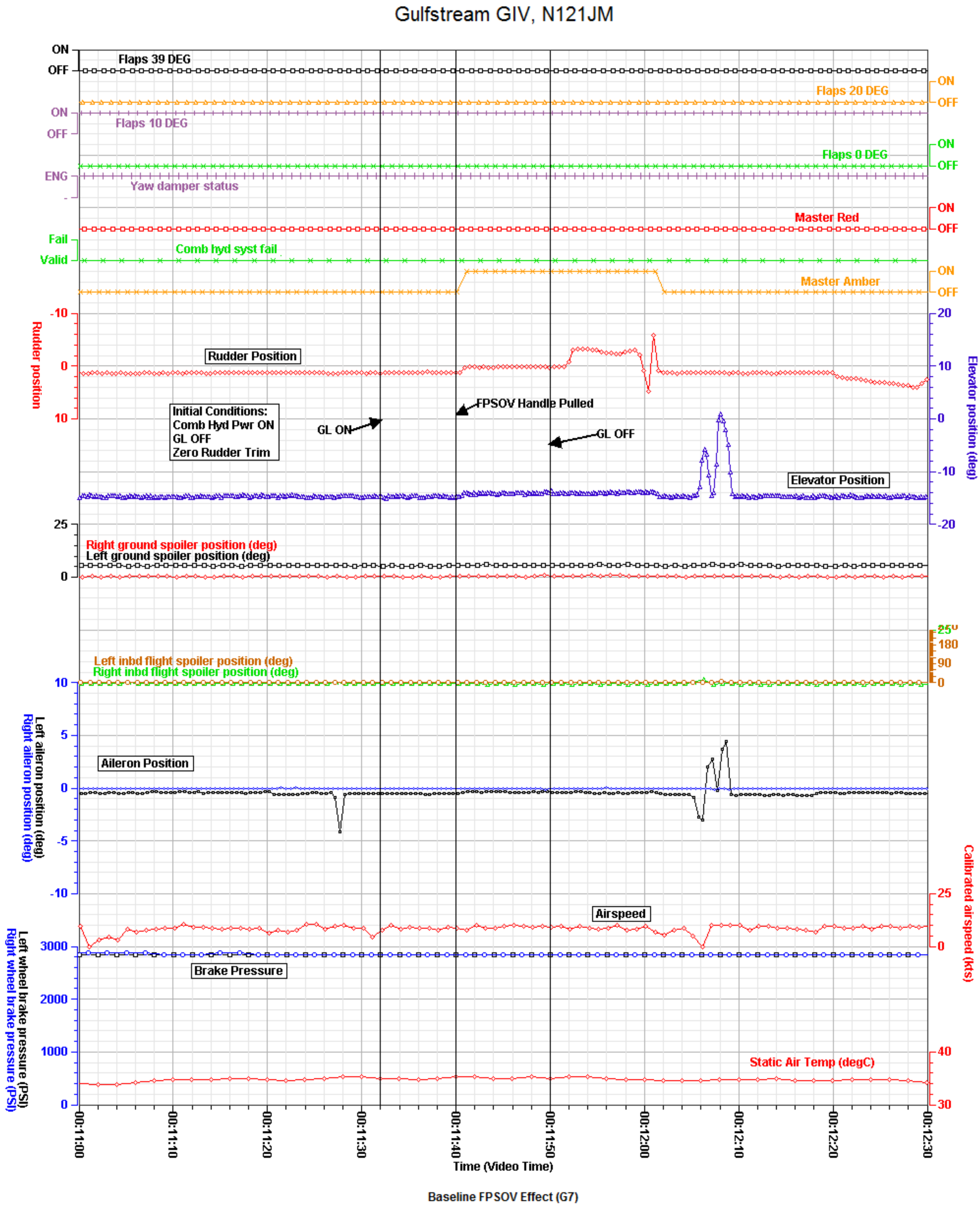

Figure 5. Ground stationary test - baseline FPSOV effect (GIV-GER-9980 Test G7).

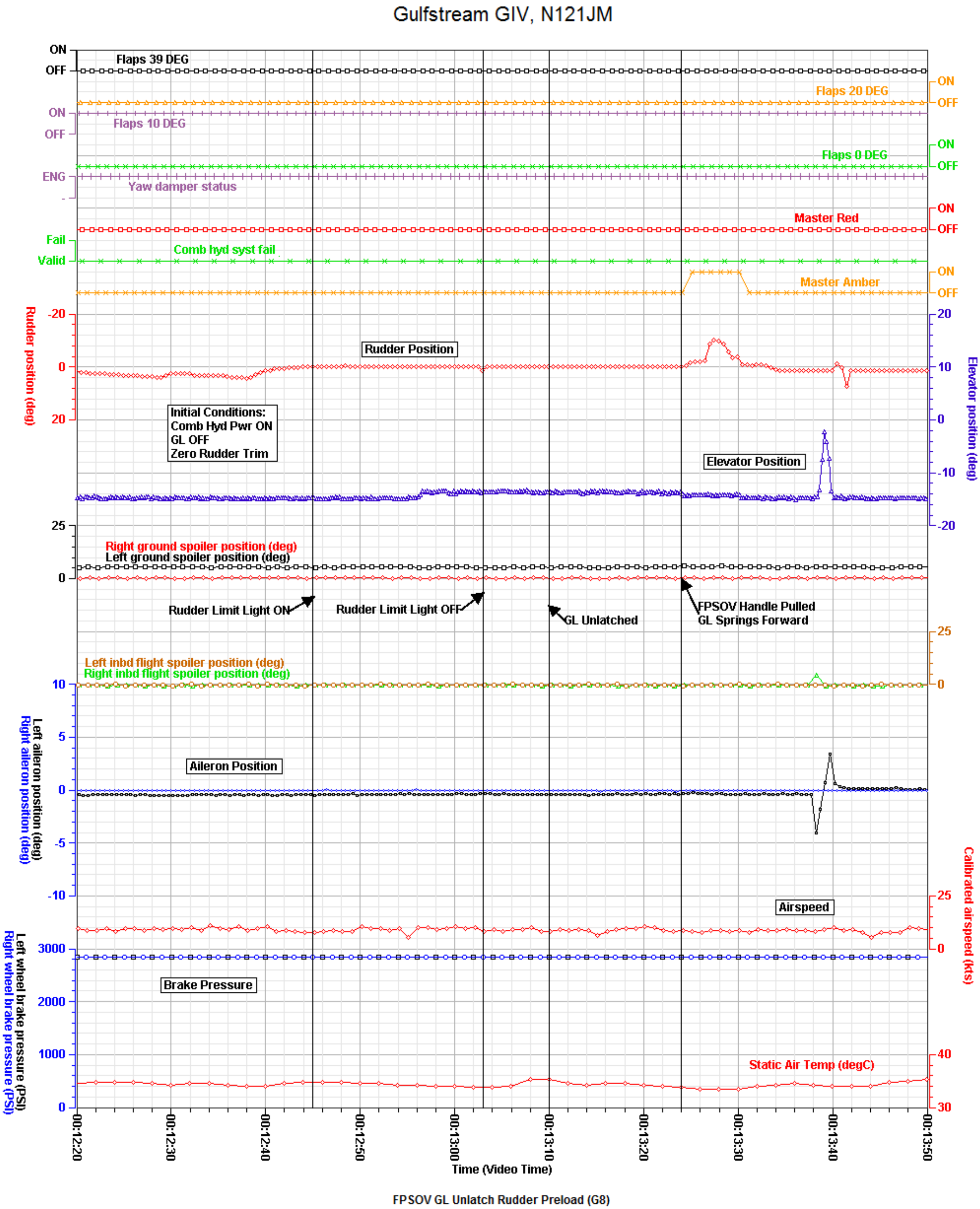

Figure 6. Ground stationary test - FPSOV gust lock unlatch with rudder preload (GIV-GER-9980 Test G8).

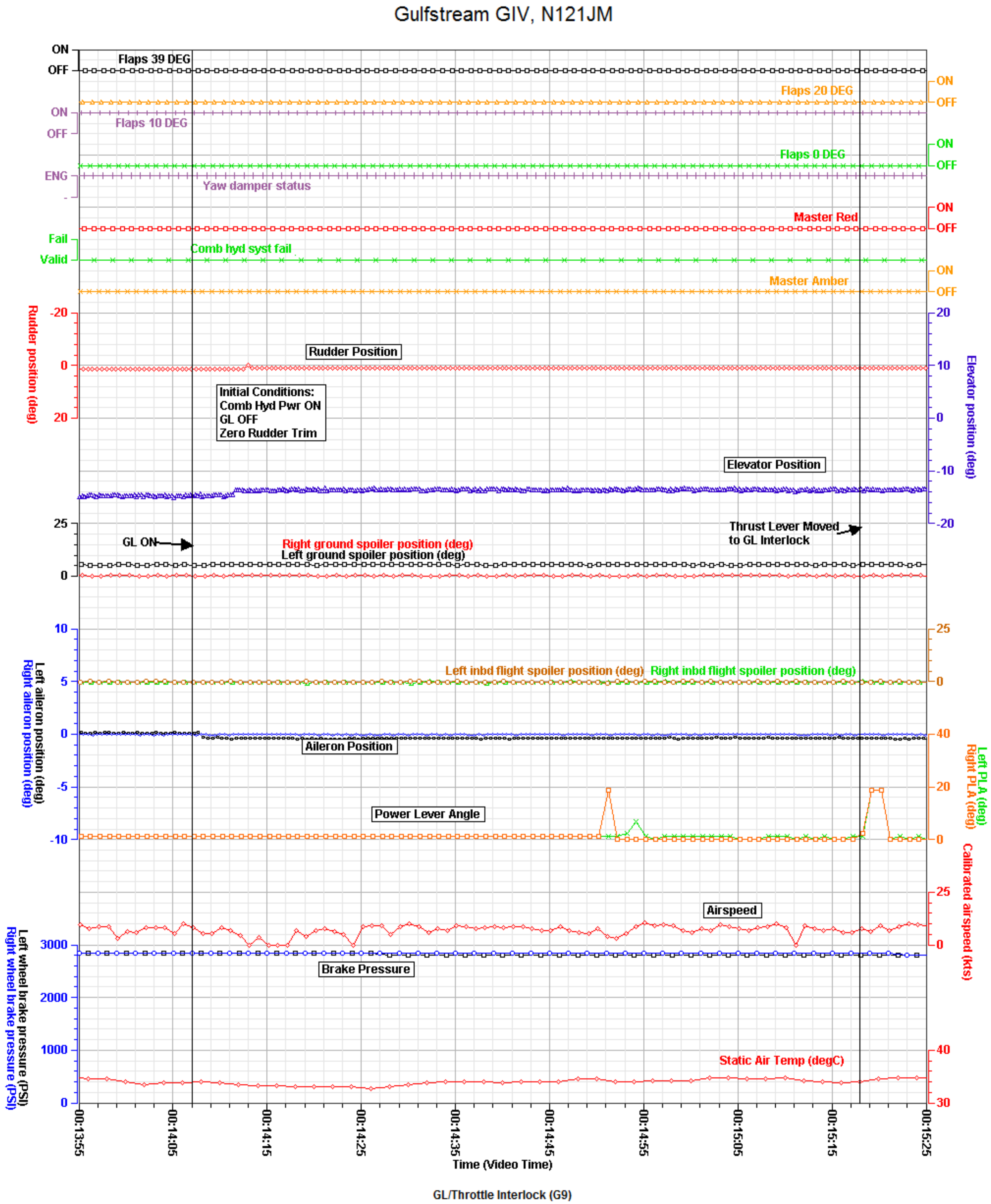

Figure 7. Ground stationary test - baseline gust lock/throttle interlock (GIV-GER-9980 Test G9).

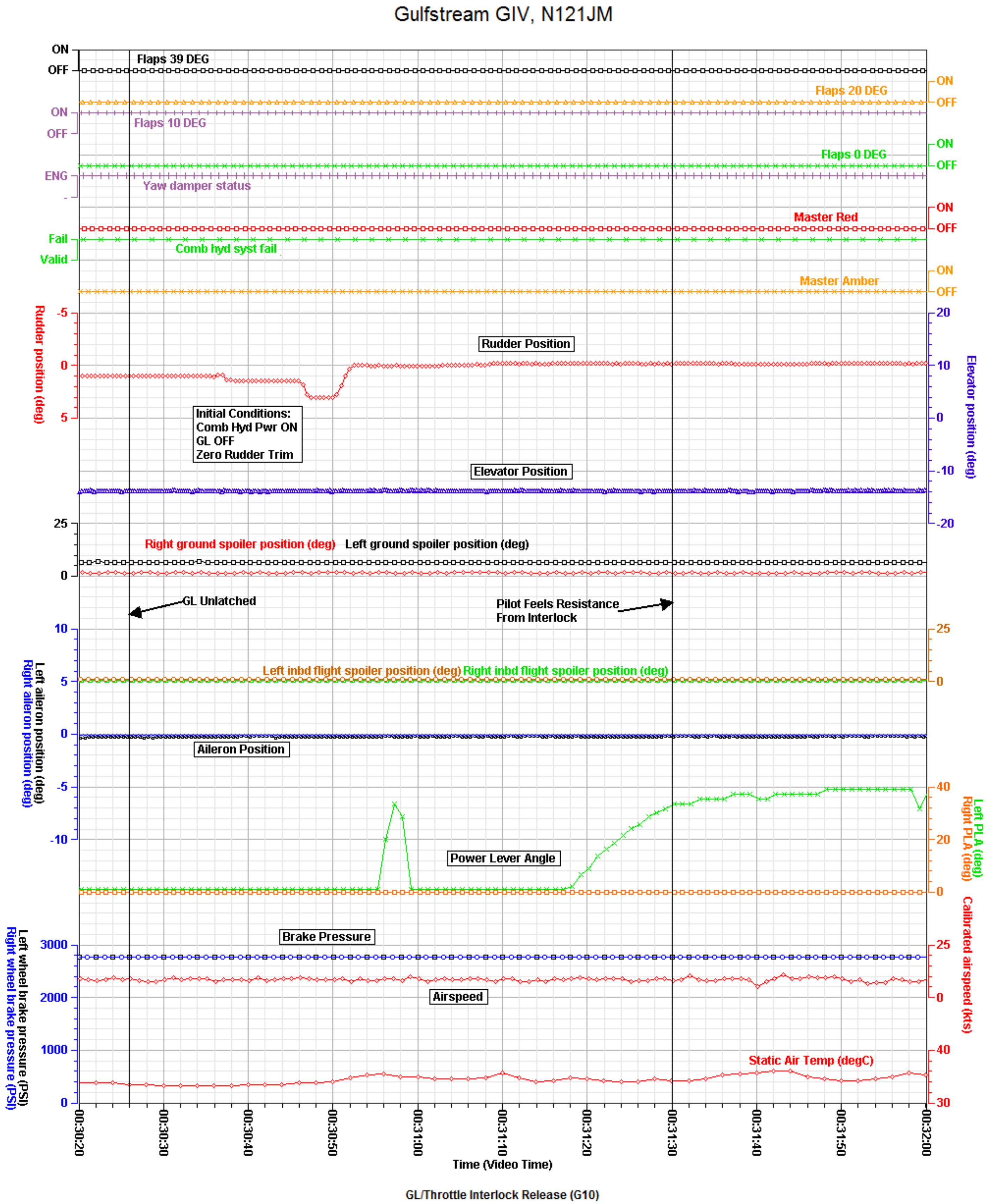

Figure 8. Ground stationary test - gust lock/throttle interlock release (GIV-GER-9980 Test G10).

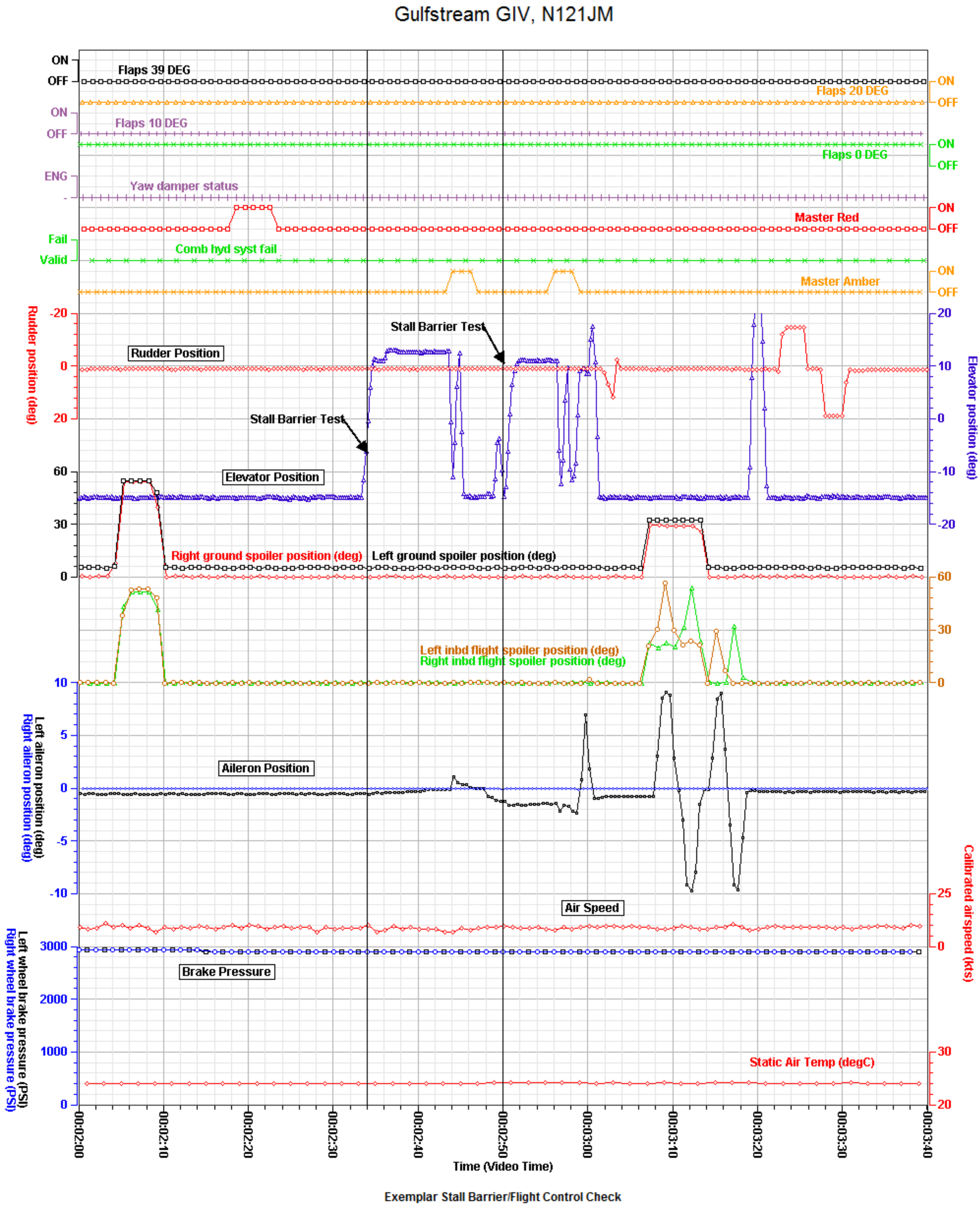

Figure 9. Exemplar stall barrier/flight control check.

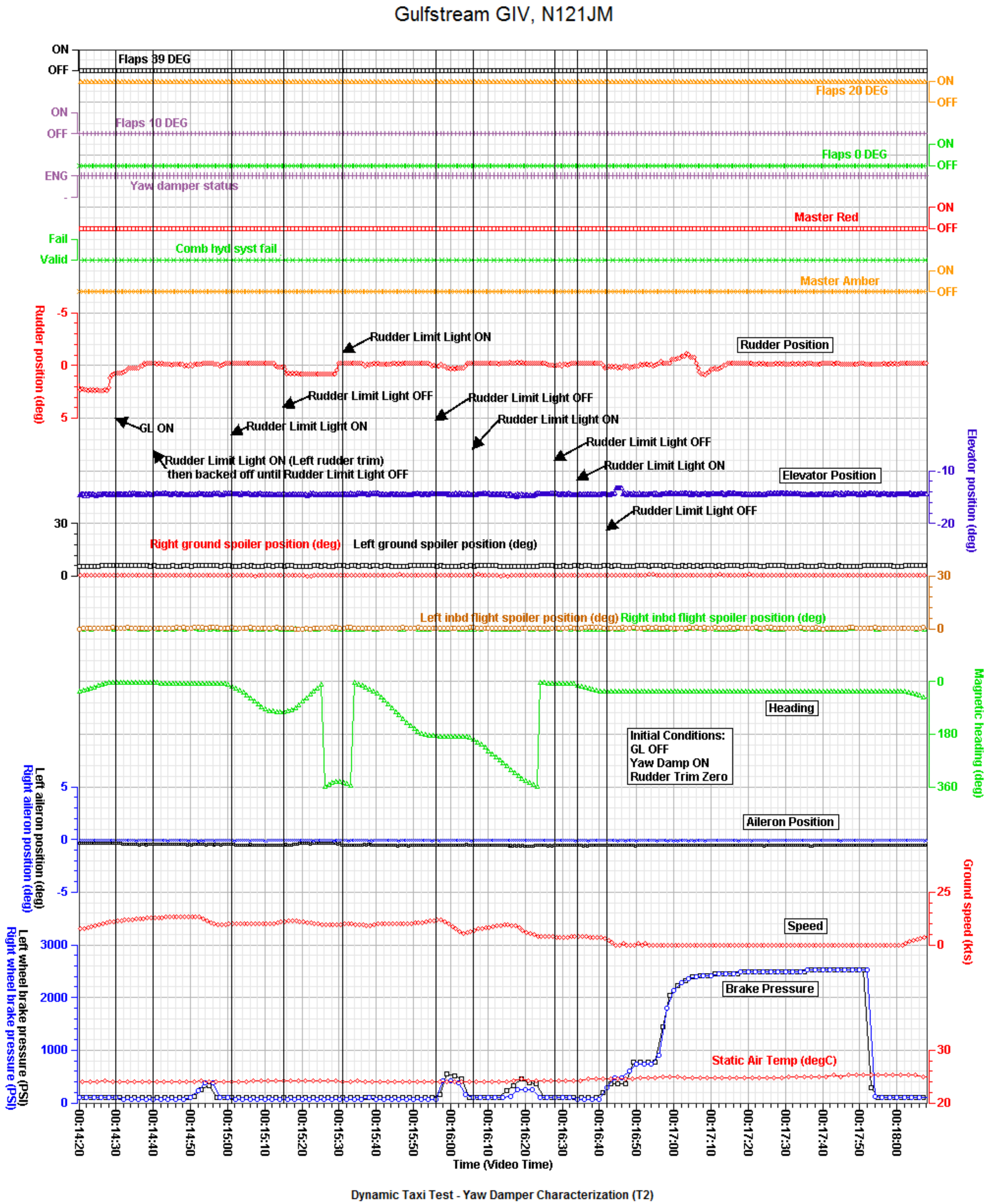

Figure 10. Dynamic taxi test - yaw damper characterization (GIV-GER-9980 Test T2).

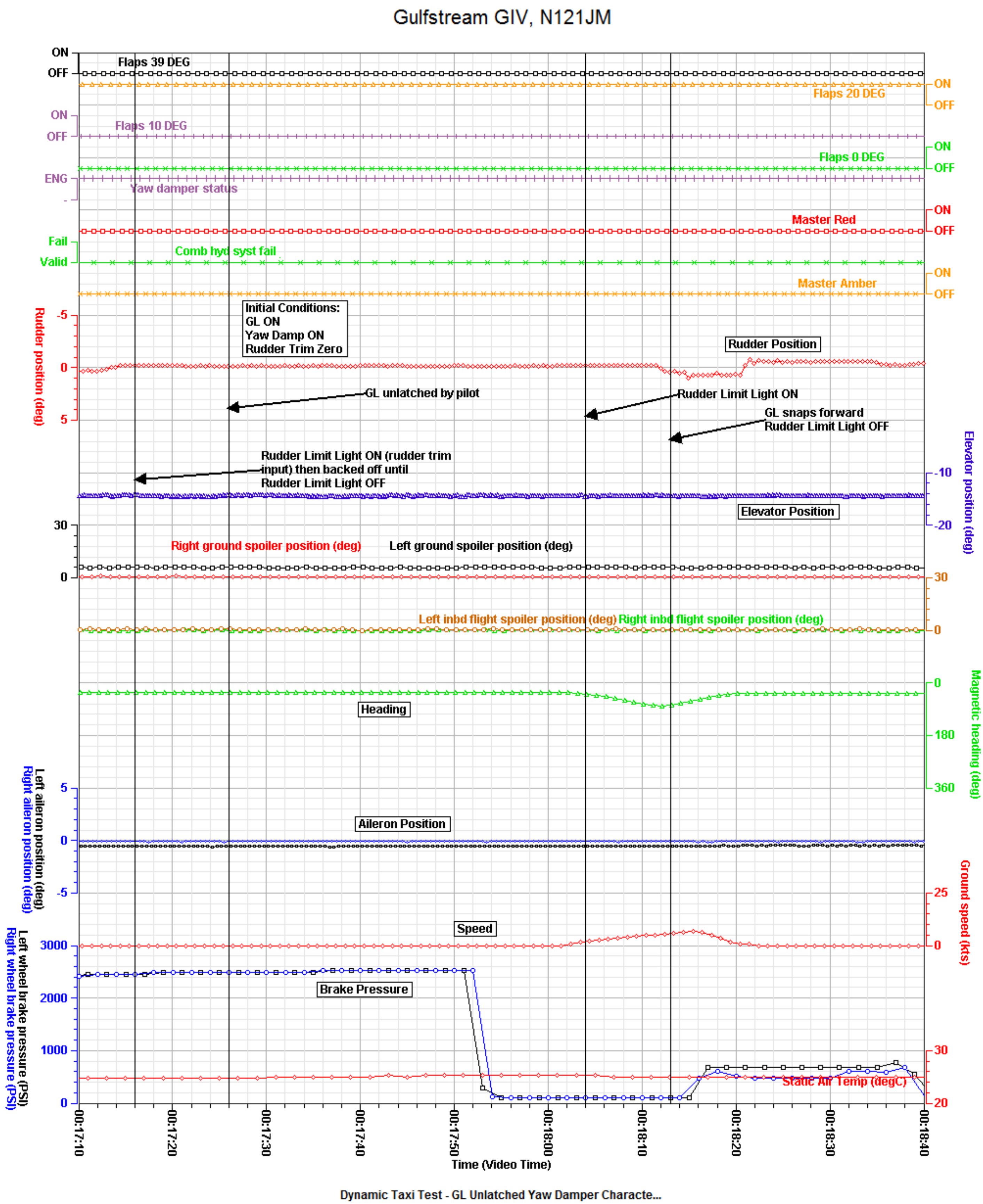

Figure 11. Dynamic taxi test - gust lock unlatched yaw damper characterization (GIV-GER-9980 Test T4).

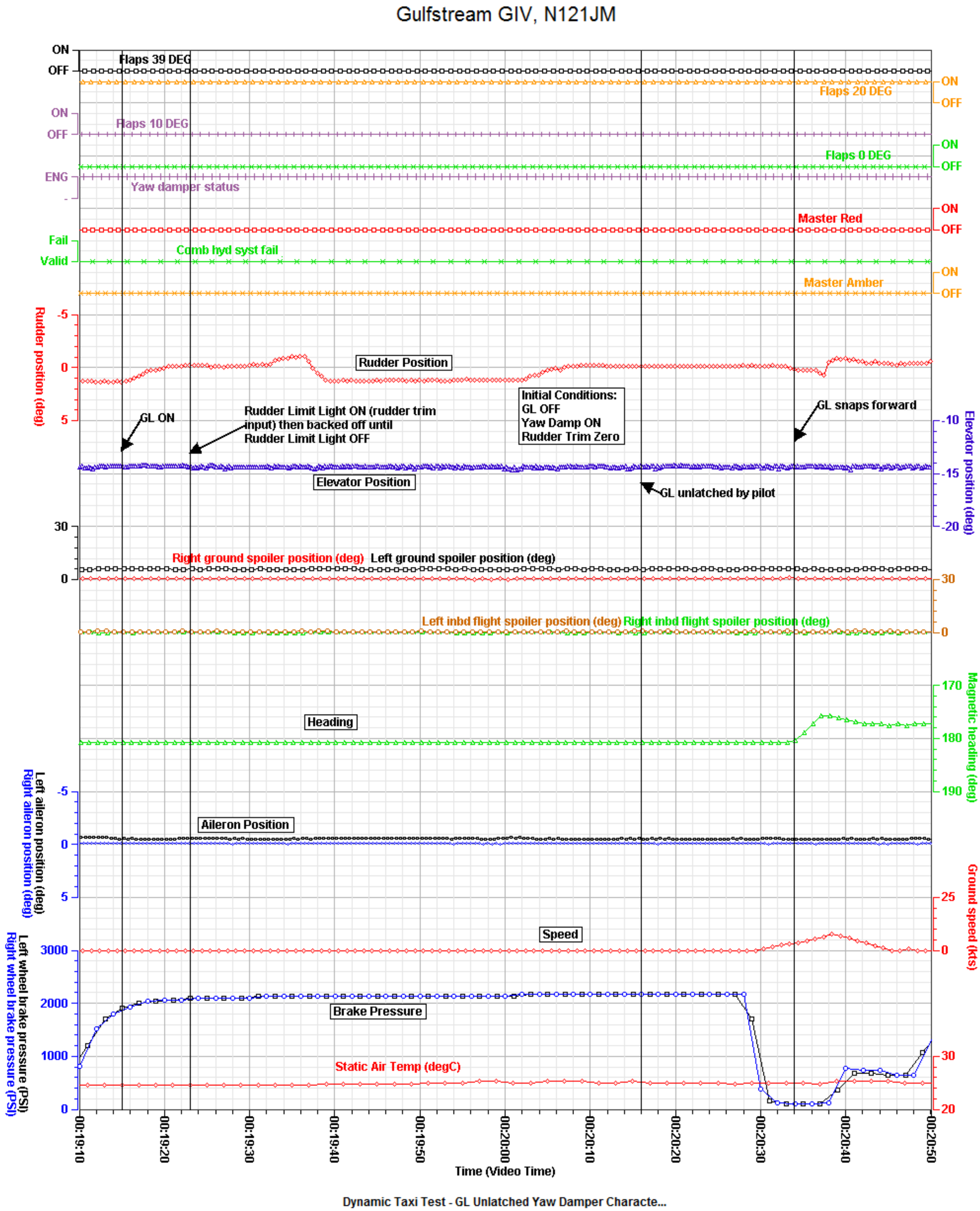

Figure 12. Repeat of dynamic taxi test - gust lock unlatched yaw damper characterization (GIV-GER-9980 Test T4).

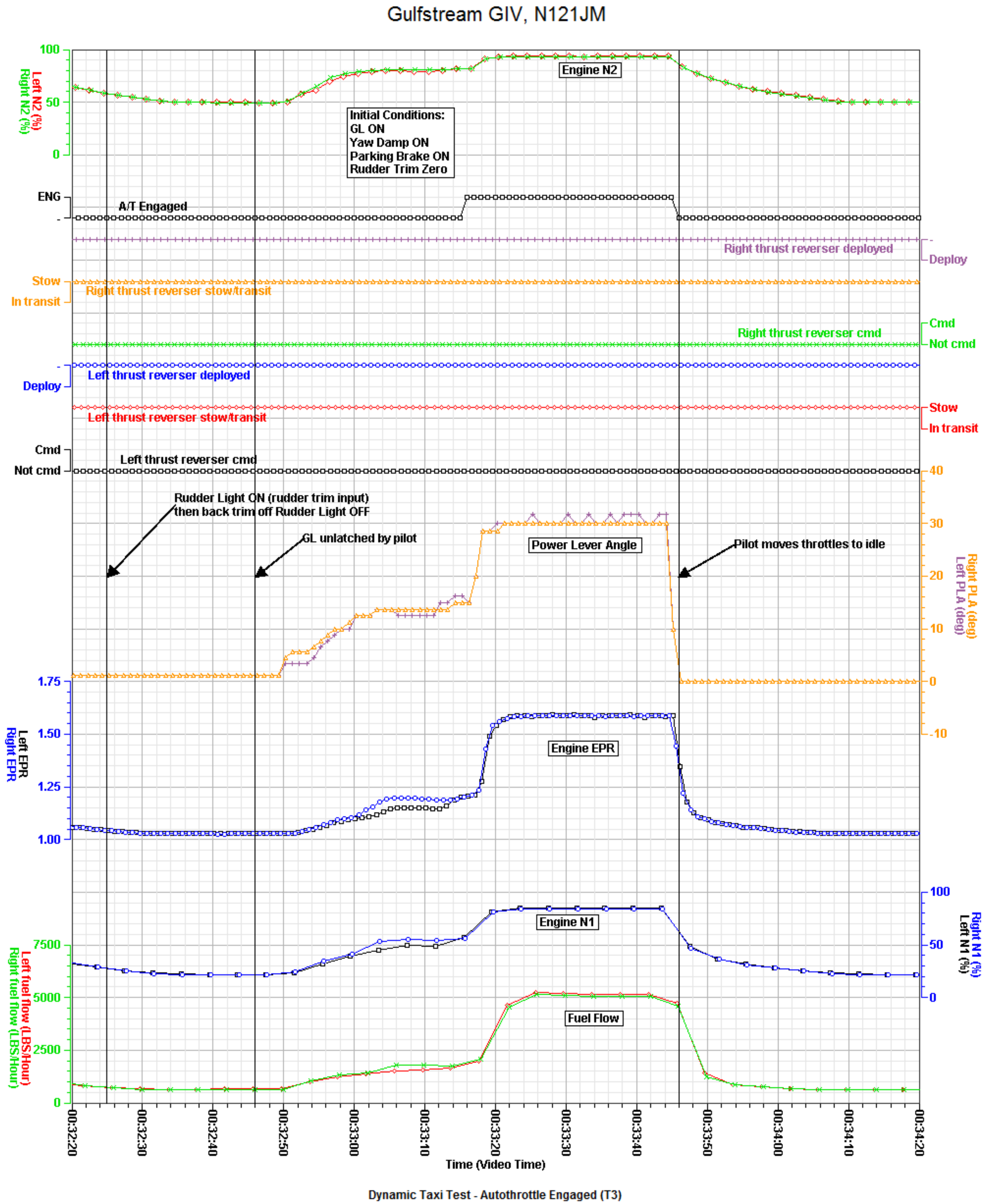

Figure 13. Dynamic taxi test - autothrottle engaged (GIV-GER-9980 T3).

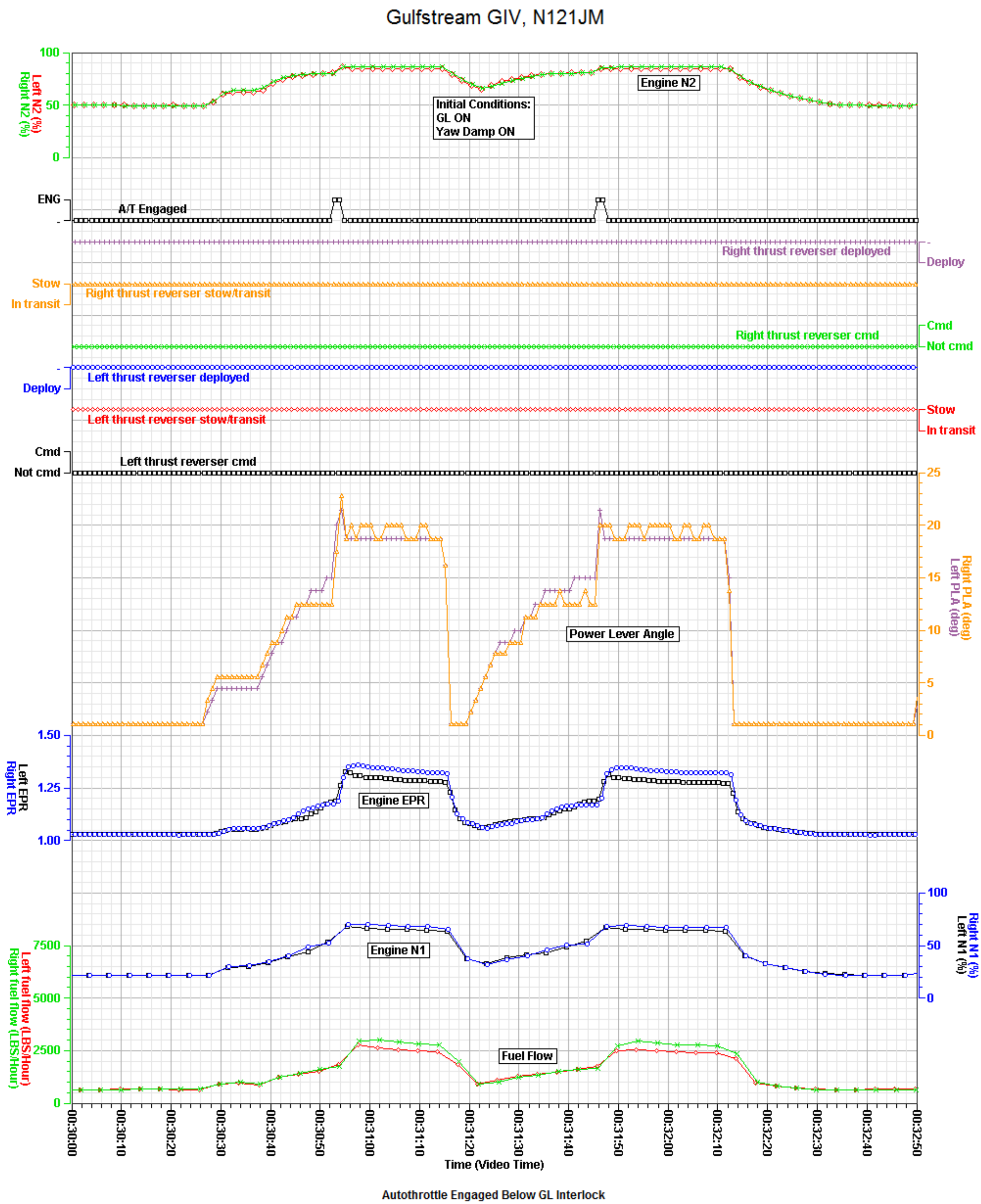

Figure 14. Autothrottle engage below gust lock interlock (min engage EPR) (with repeat test).

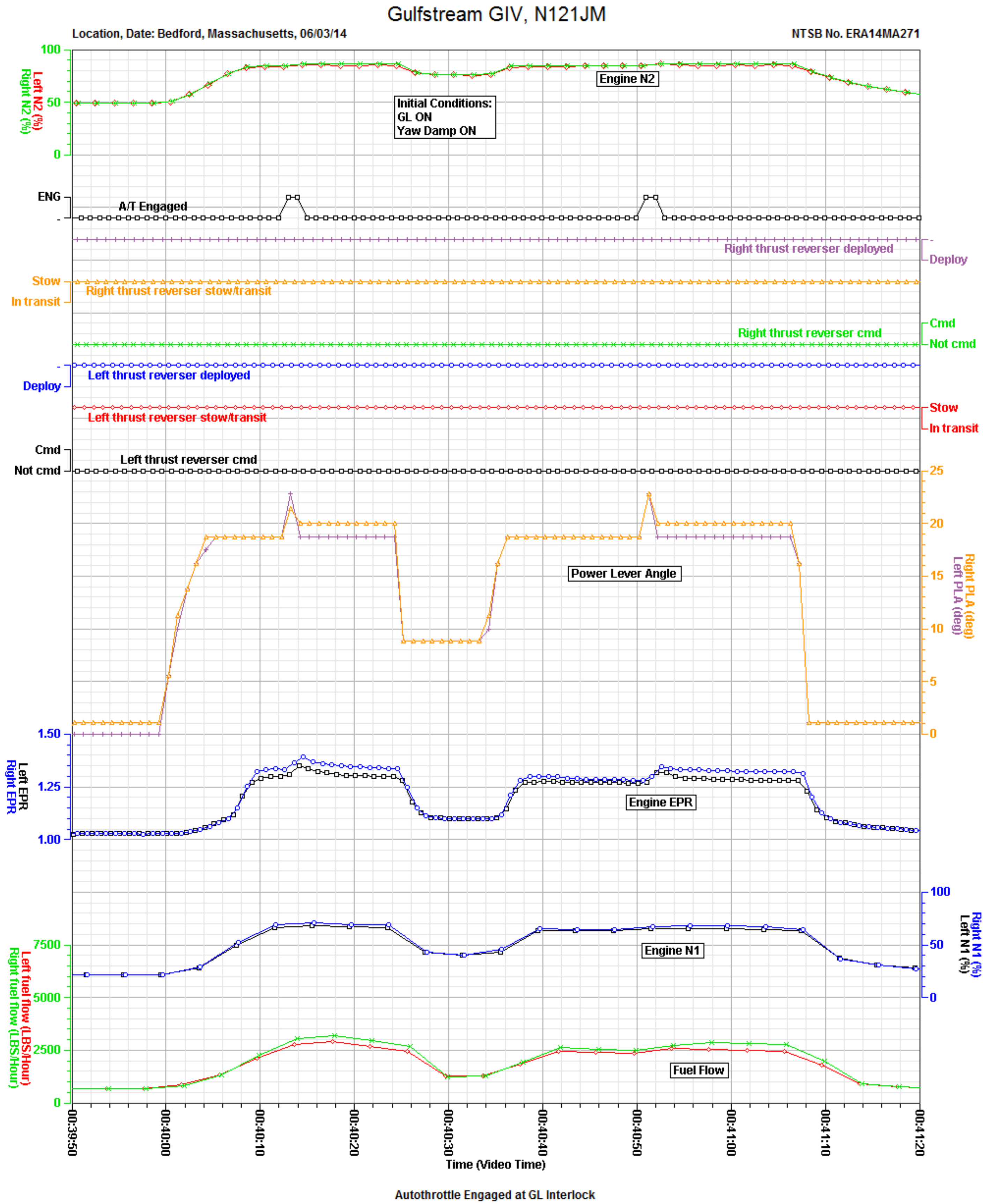

Figure 15. Autothrottle engage at gust lock interlock.

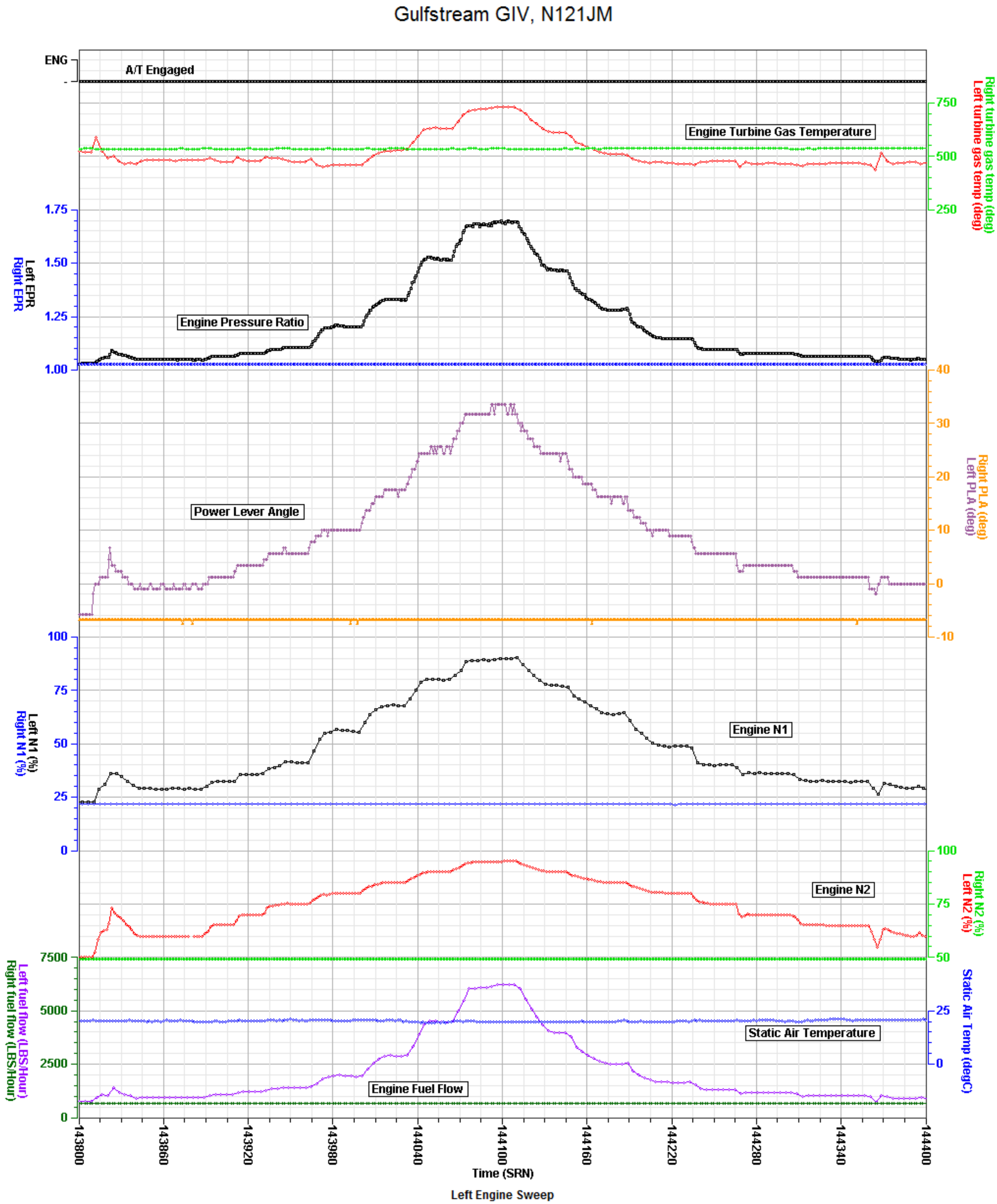

Figure 16. Left engine sweep.

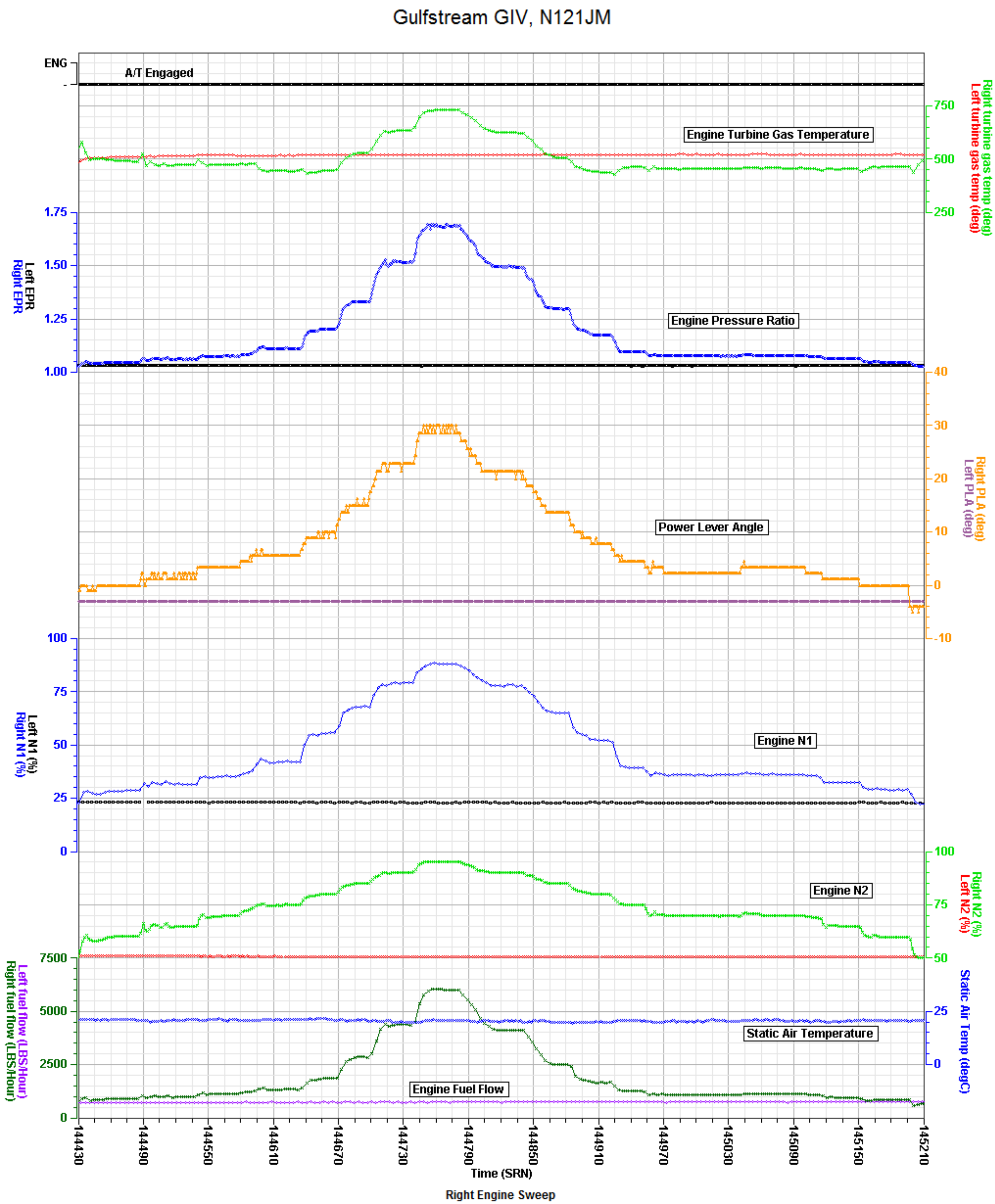

Figure 17. Right engine sweep.

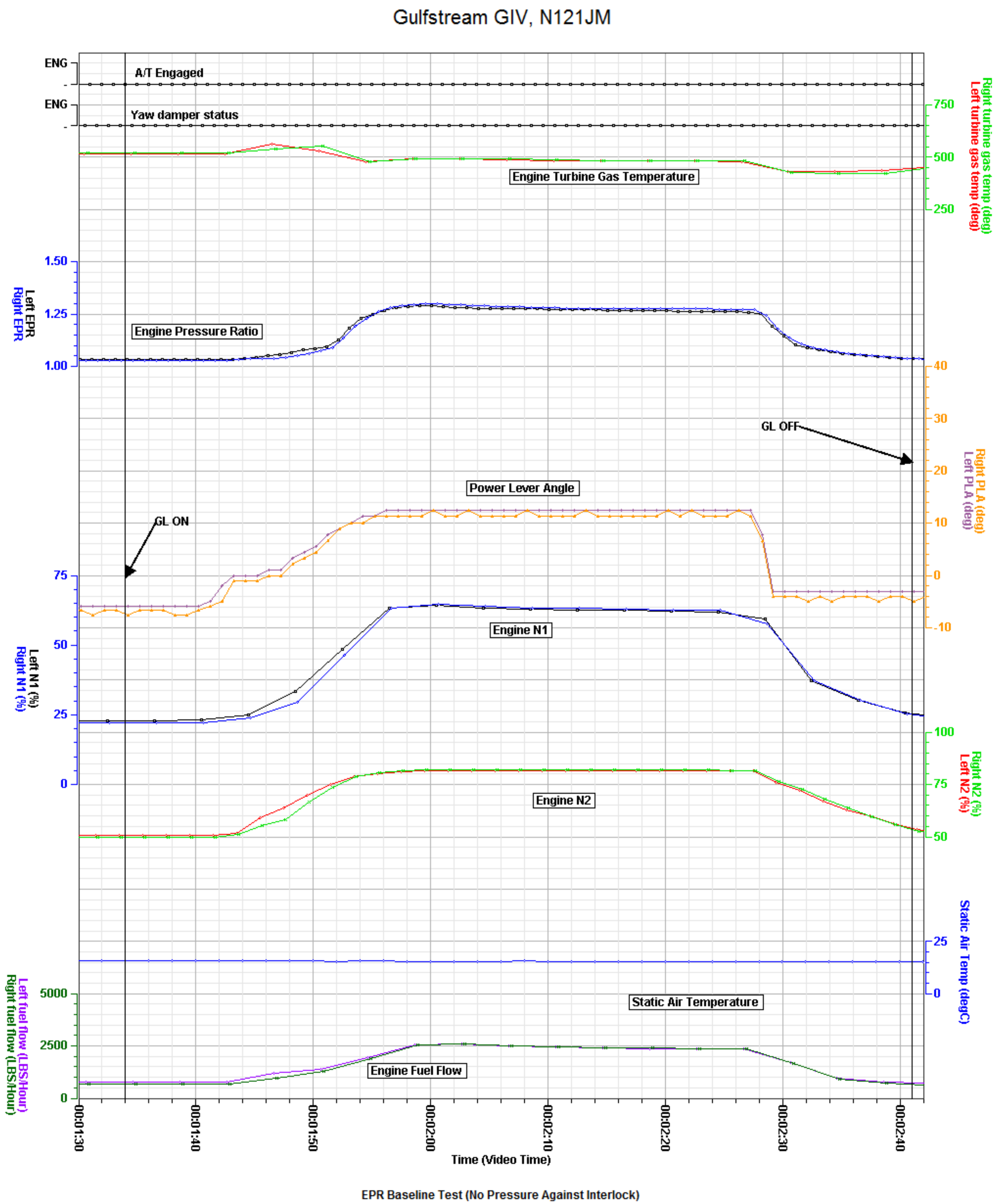

Figure 18. EPR baseline test.

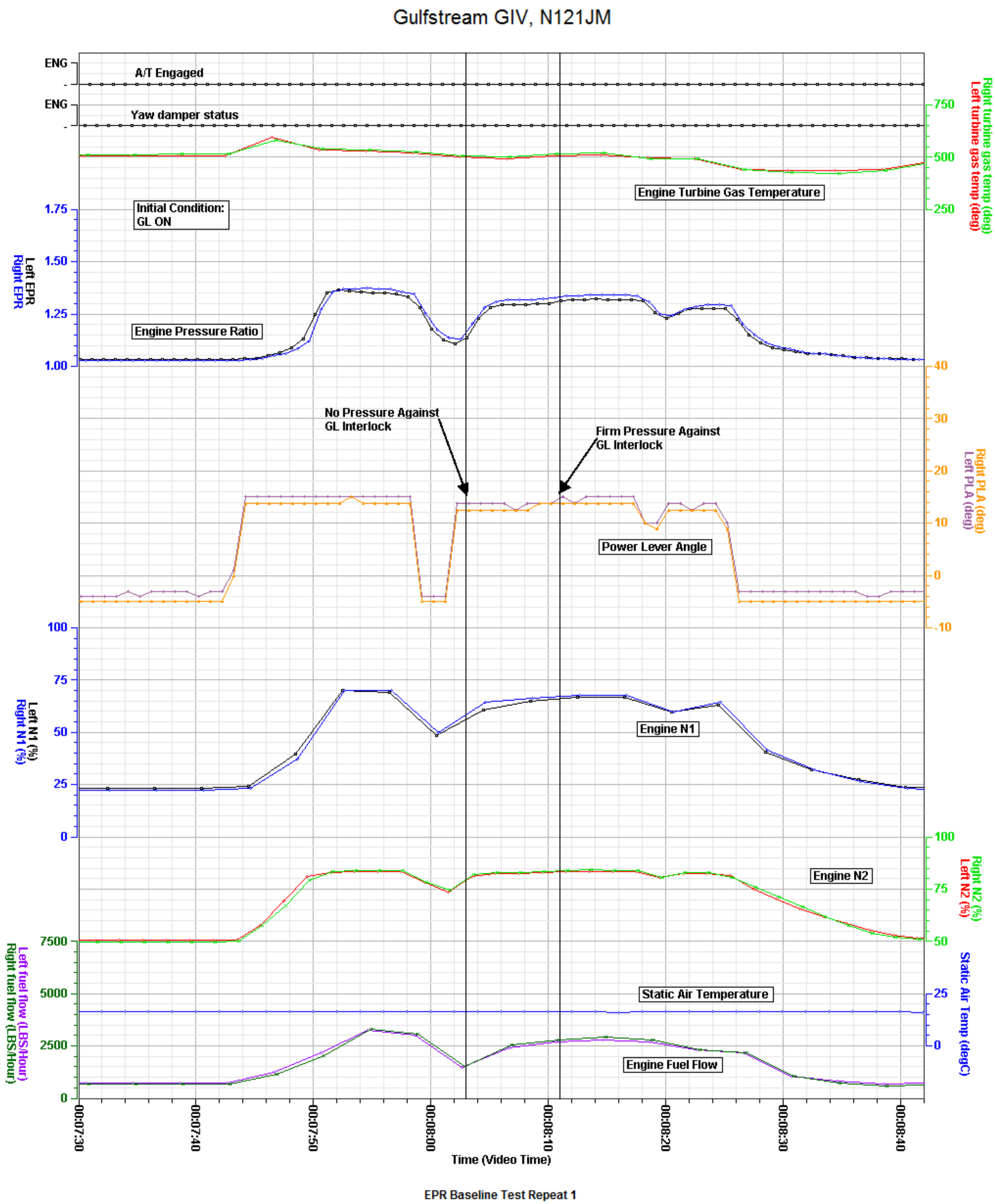

Figure 19. Repeat of EPR baseline test (with firm pressure).

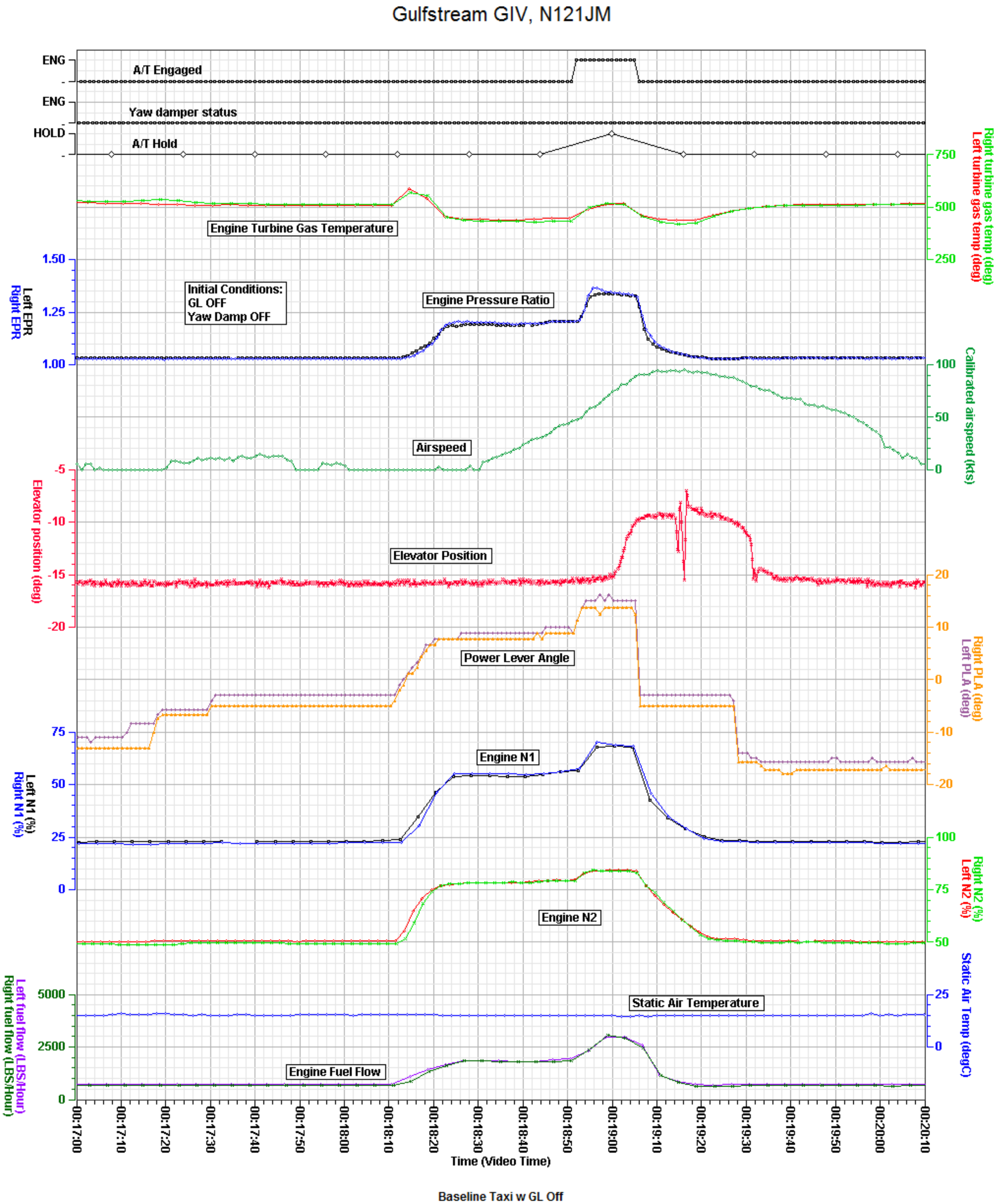

Figure 20. Baseline taxi test with gust luck off.

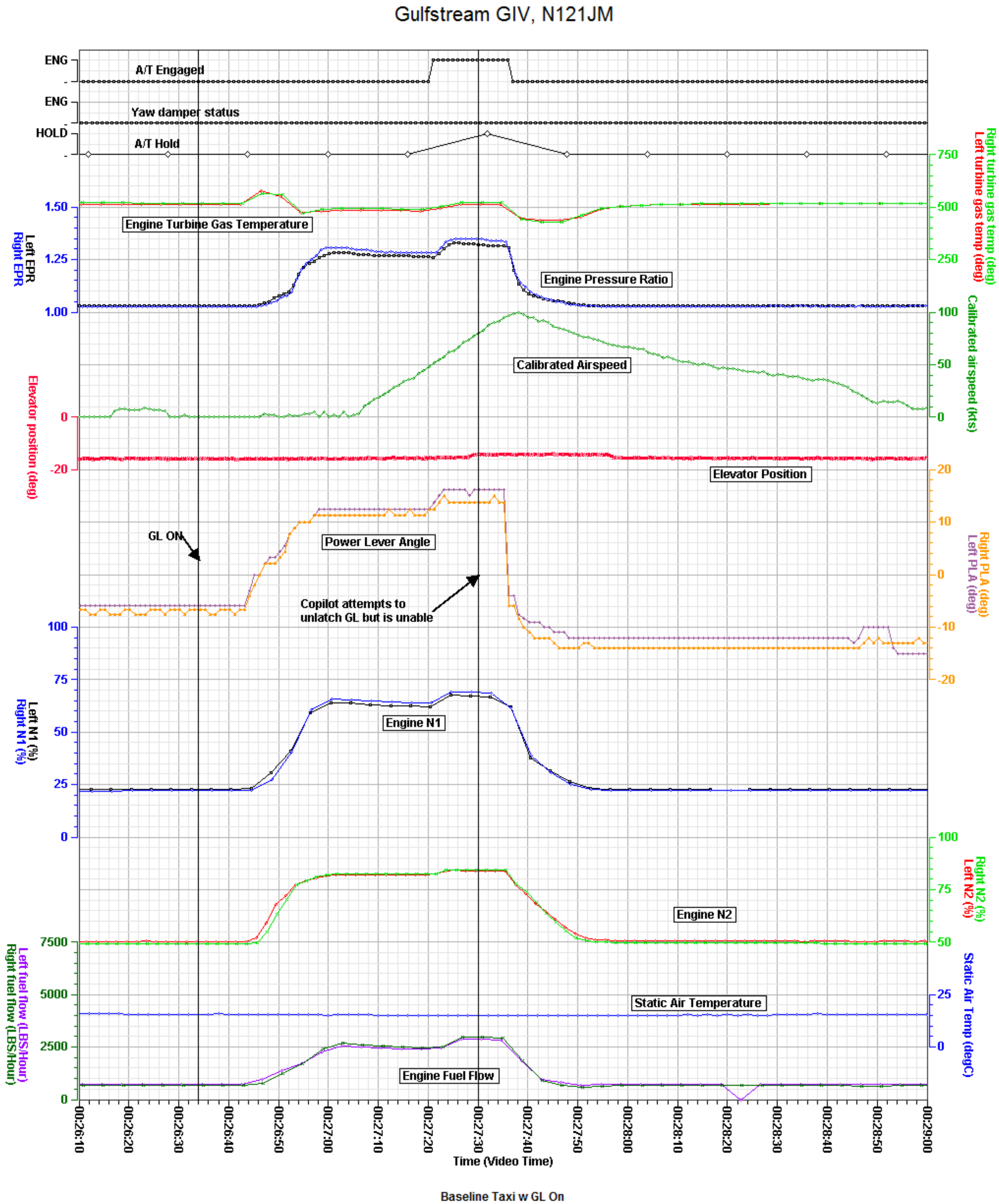

Figure 21. Baseline taxi test with gust lock on.

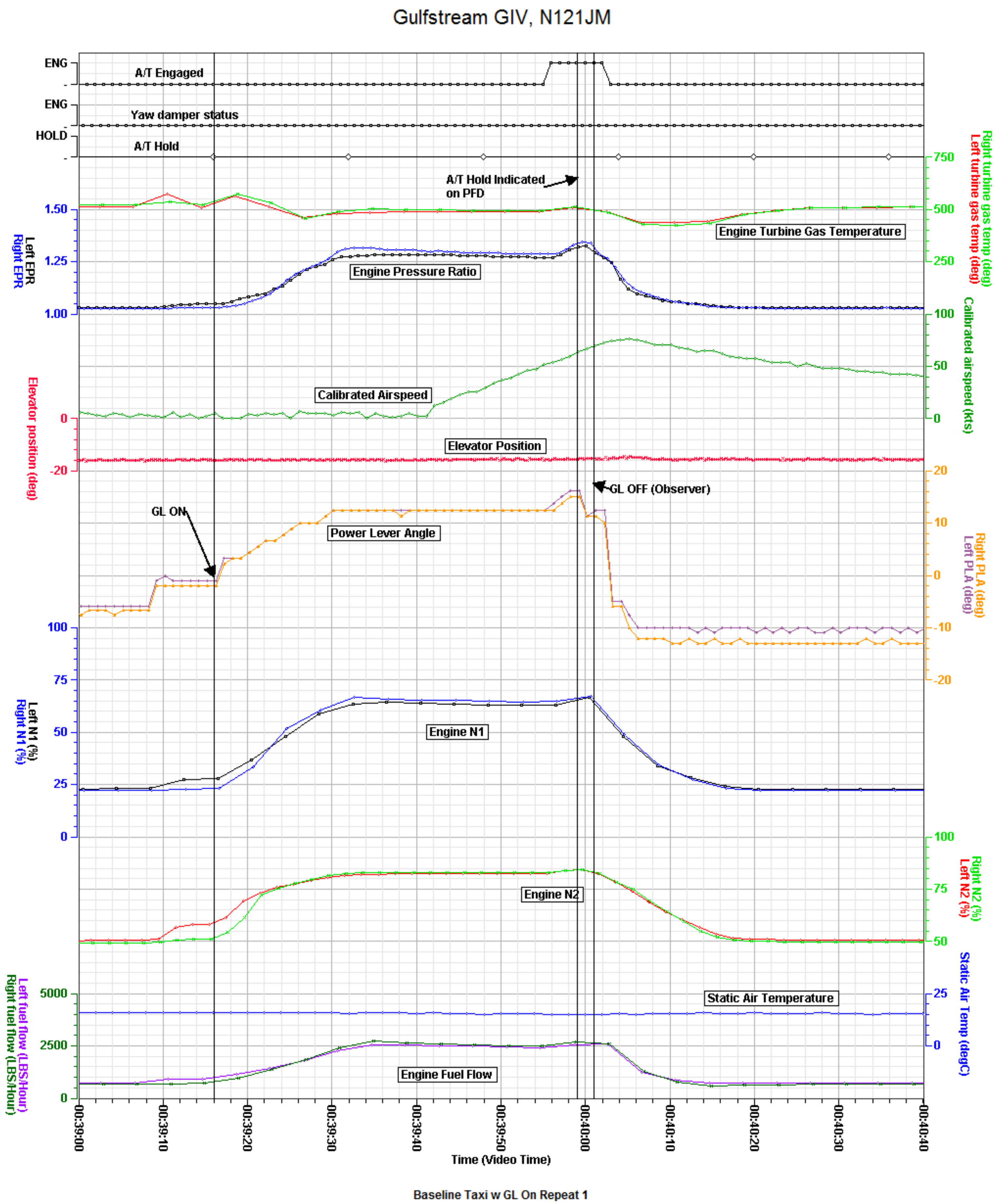

Figure 22. Repeat of baseline taxi test with gust lock on.

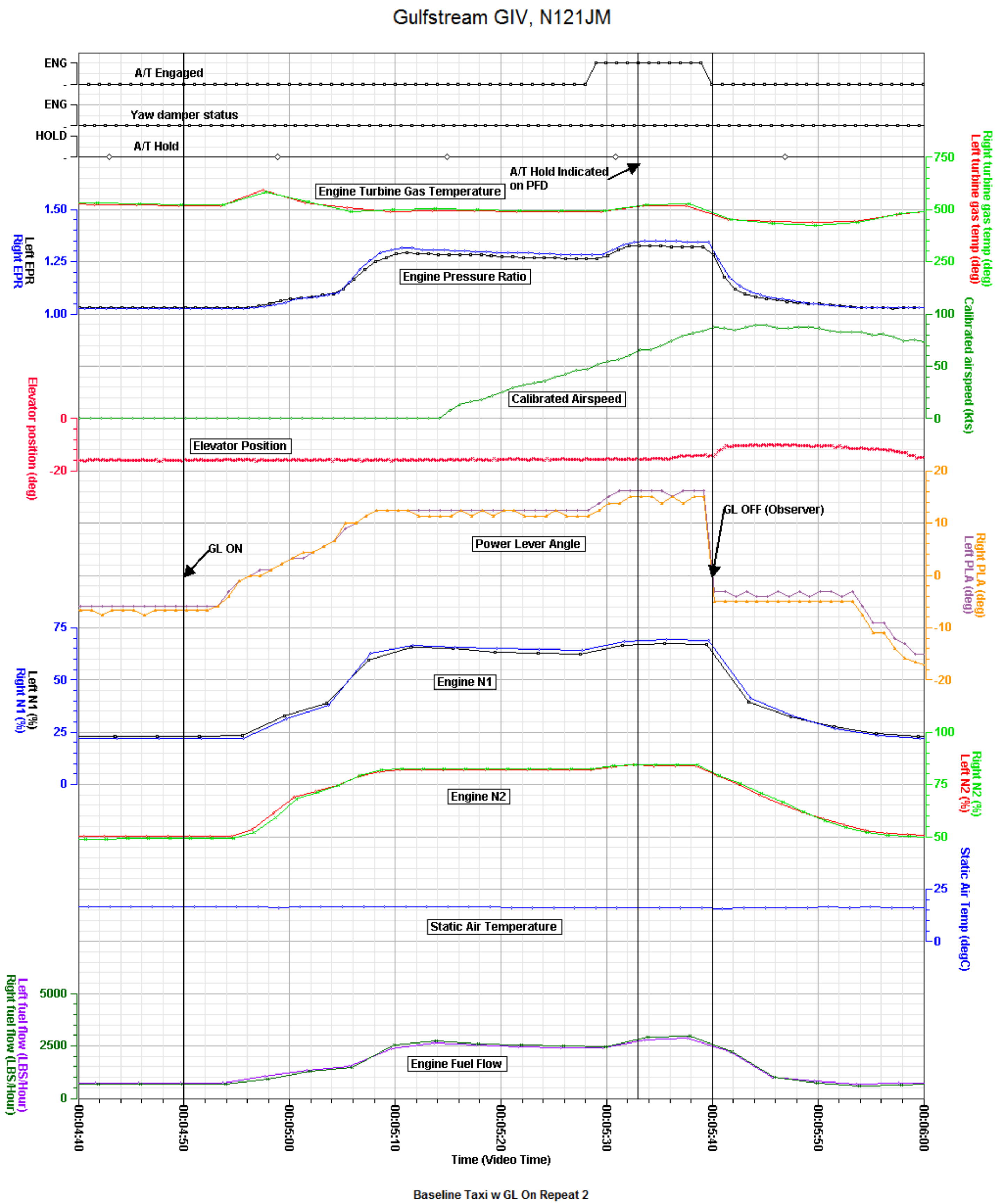

Figure 23. Second repeat of baseline taxi test with gust lock on.

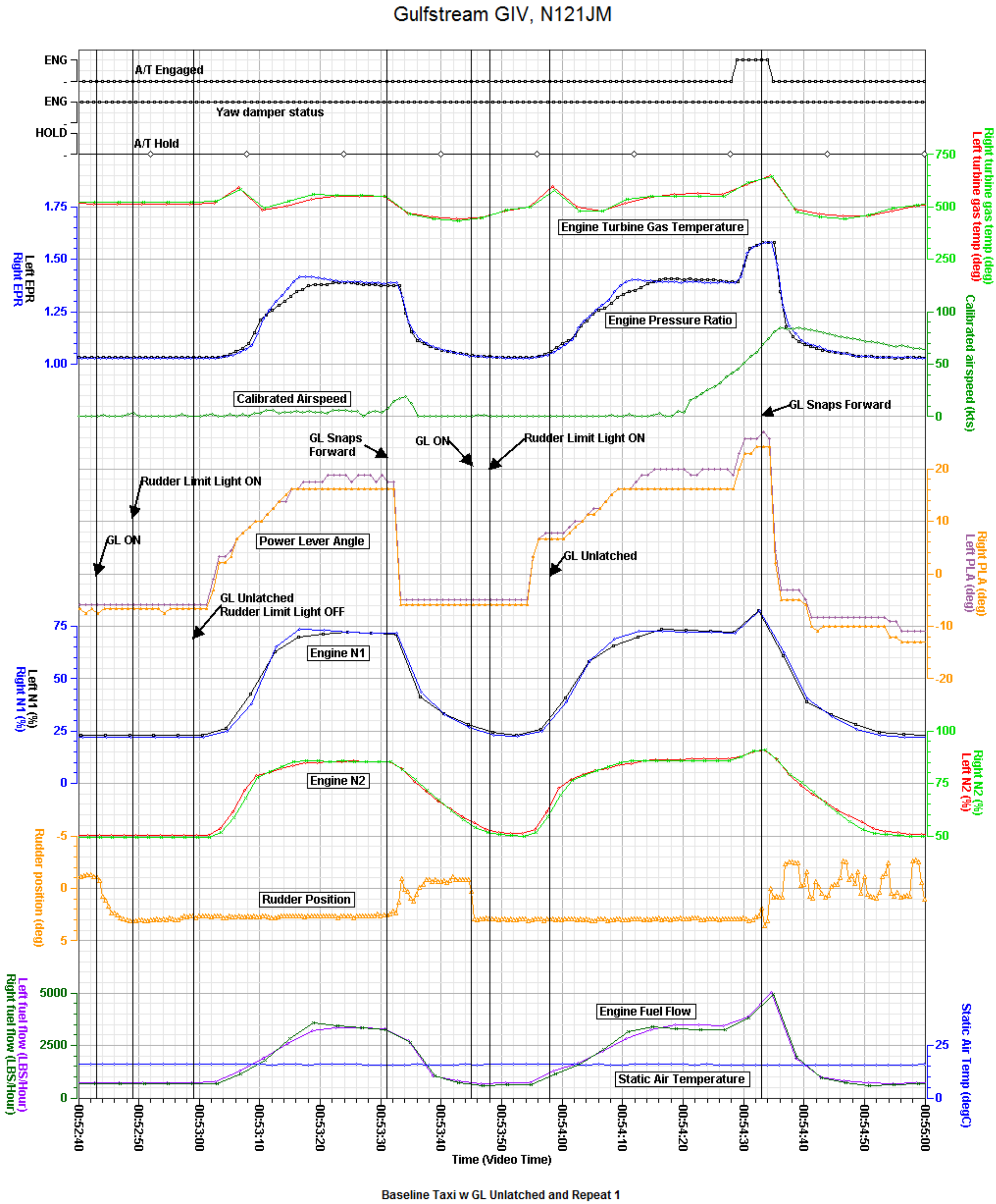

Figure 24. Taxi test with gust lock unlatched (Flex EPR) and first repeat.

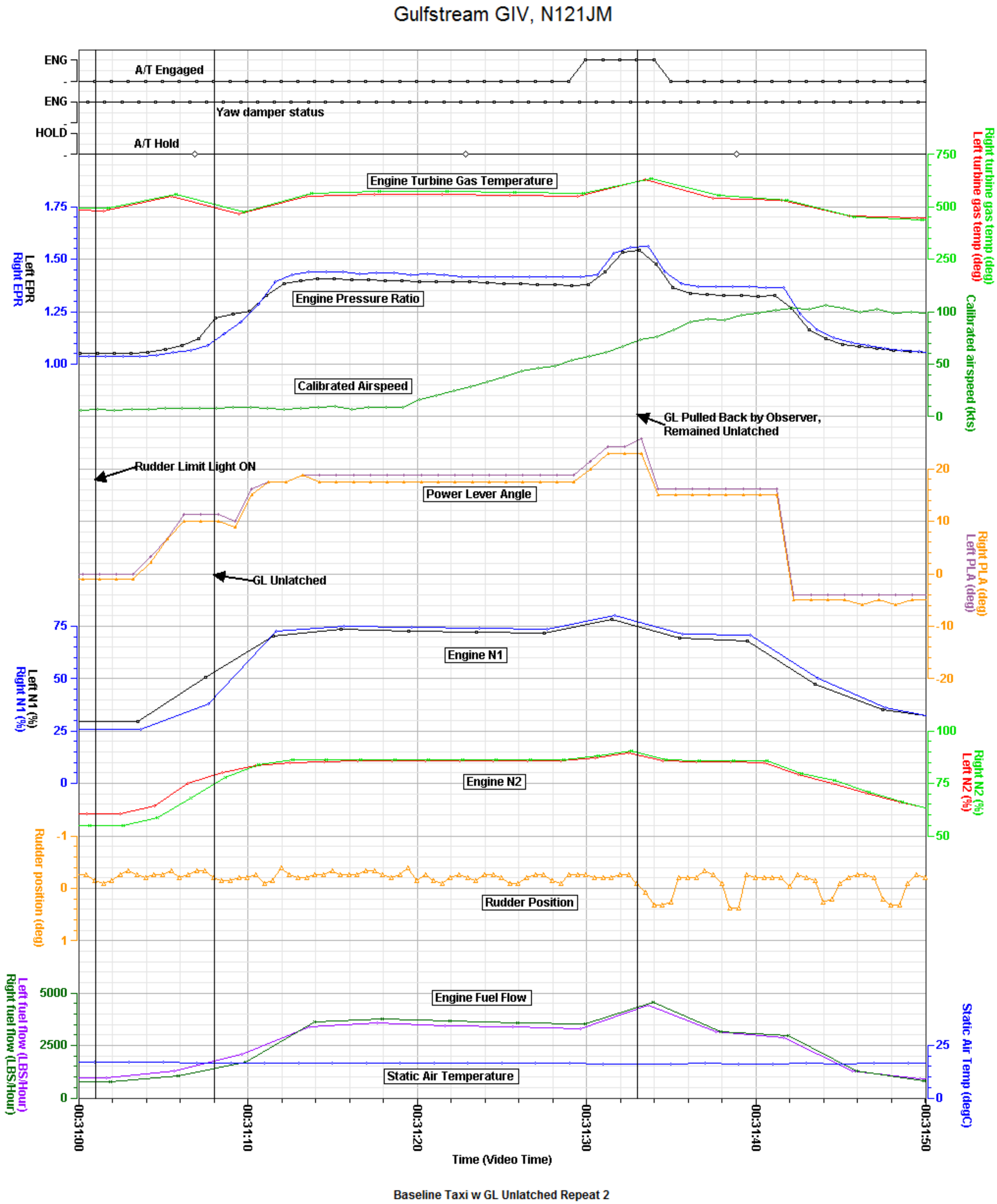

Figure 25. Second repeat of taxi test with gust lock unlatched (Flex EPR).

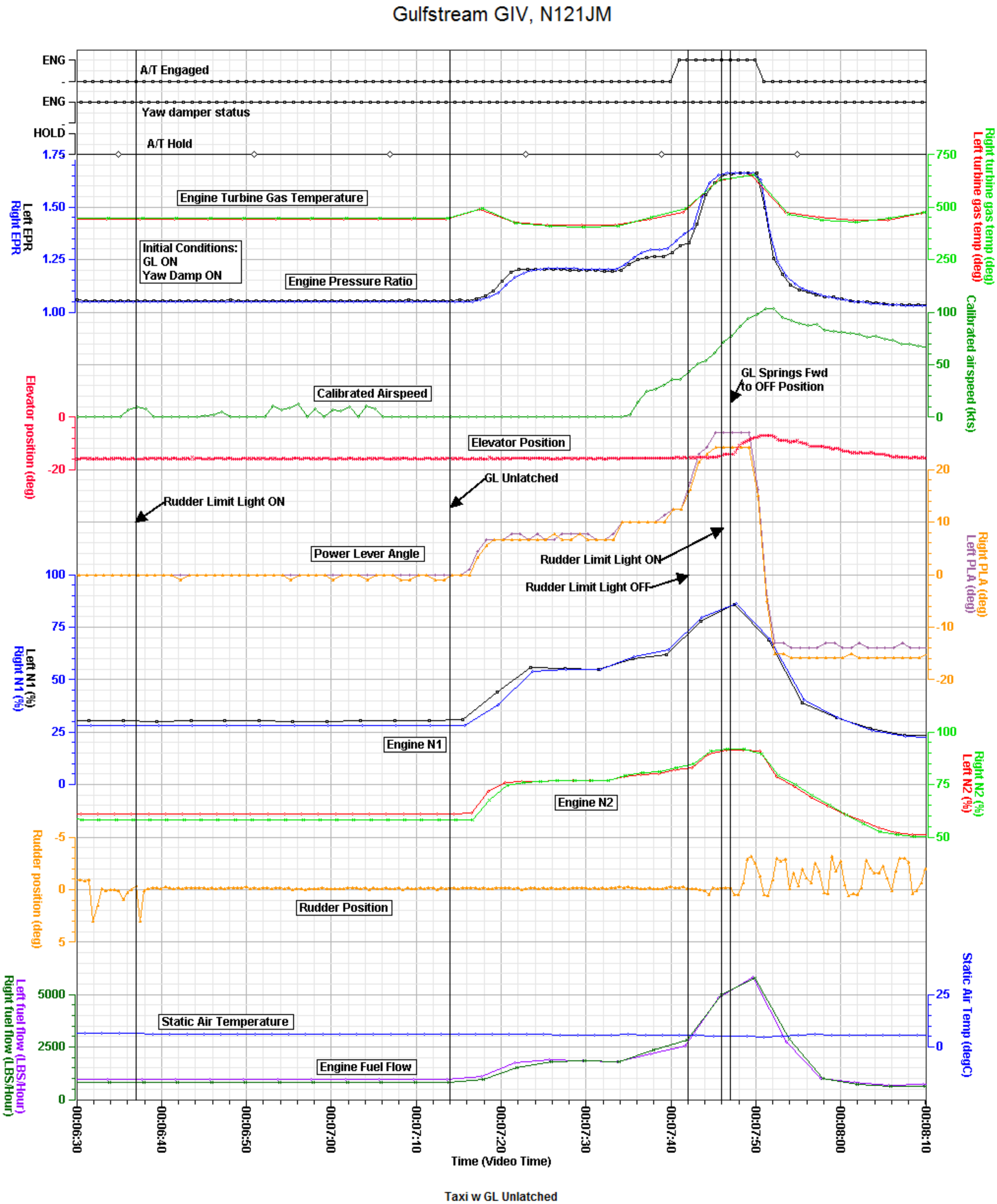

Figure 26. Taxi test with gust lock unlatched (Rated EPR).

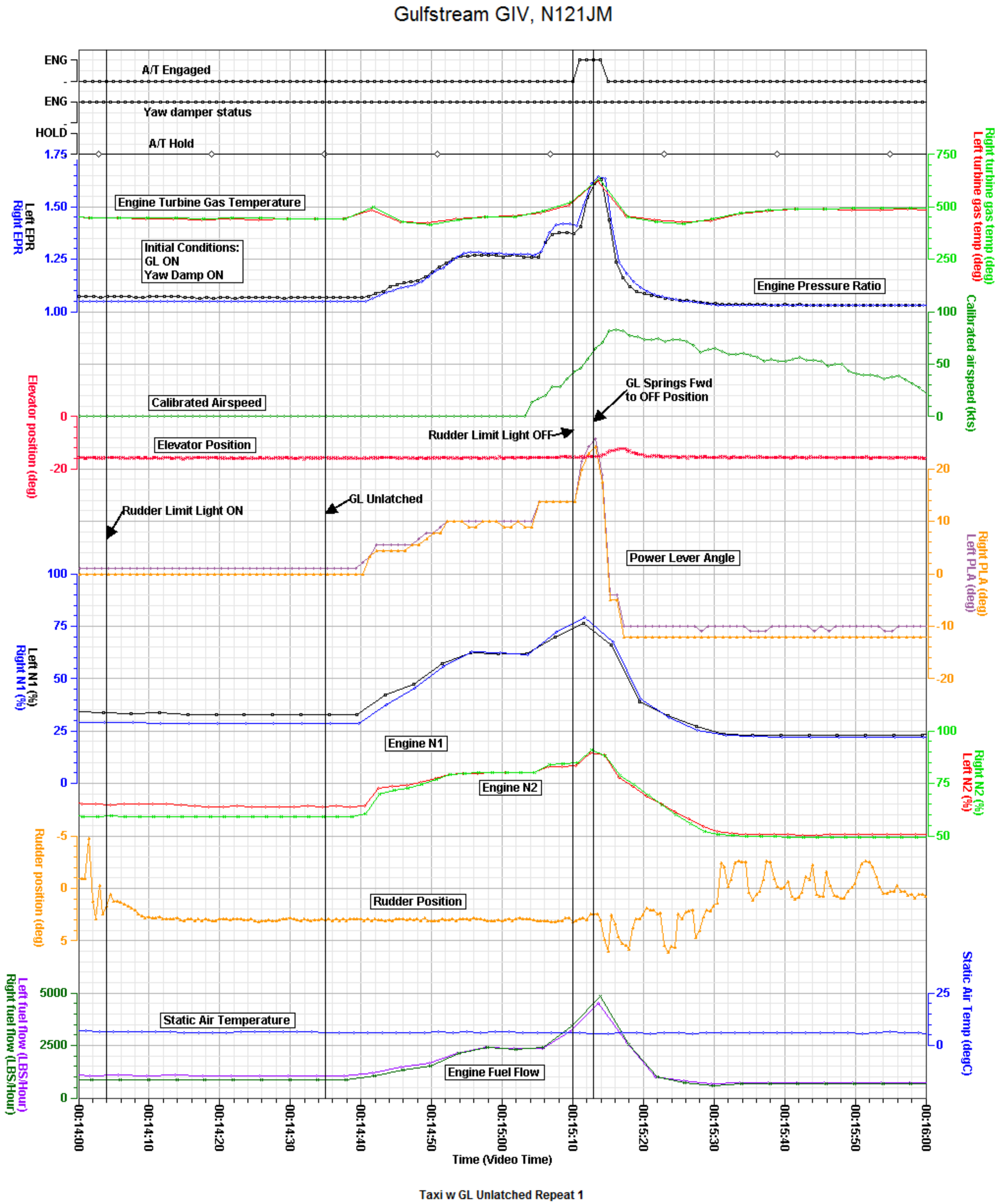

Figure 27. Repeat of taxi test with gust lock unlatched (Rated EPR).

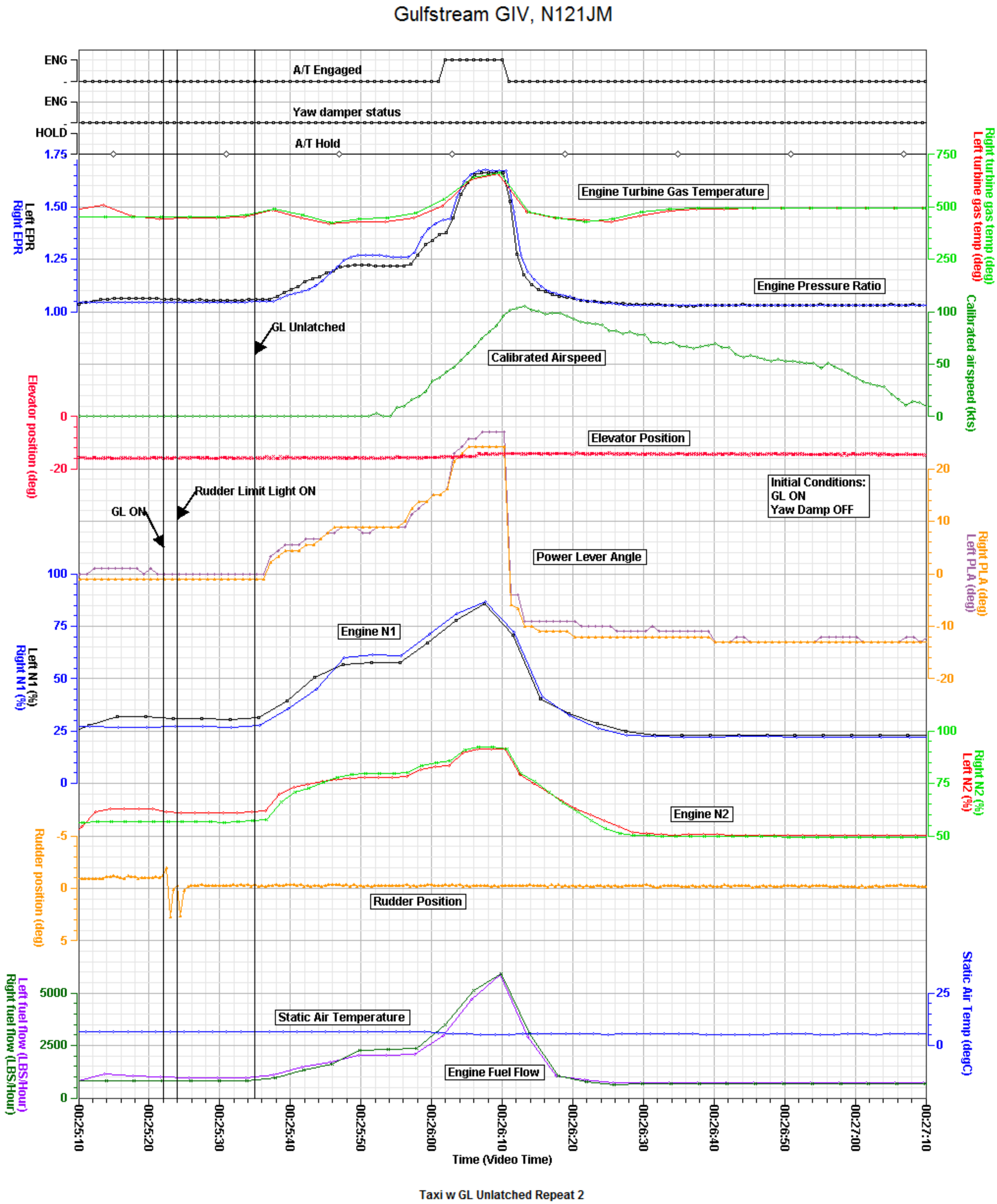

Figure 28. Second repeat of taxi test with gust lock unlatched (Rated EPR).

Appendix A

Table A-1. Provided and verified parameters.

Plot Label	Parameter Description	Sample Rate (Hz)
A/T Engaged	Autothrottle Engaged Discrete	1
A/T Hold	Autothrottle Hold Mode Discrete	1/16
Calibrated airspeed (kts)	Calibrated Airspeed	1
Comb hyd sys fail	Combined Hydraulic System Failure Discrete	1/2
Elevator position (deg)	Elevator Deflection	4
Flaps 0 DEG (deg)	Flap Handle Position 0 Degree Discrete	1
Flaps 10 DEG (deg)	Flap Handle Position 10 Degree Discrete	1
Flaps 20 DEG (deg)	Flap Handle Position 20 Degree Discrete	1
Flaps 39 DEG (deg)	Flap Handle Position 39 Degree Discrete	1
FLT hyd syst fail	Flight Hydraulic System Failed Discrete	1/2
Ground speed (kts)	Ground Speed	1
Left aileron position (deg)	Left Aileron Deflection	2
Left EPR	Left Engine Pressure Ratio	1
Left fuel flow (lbs/hr)	Left Engine Fuel Flow	1/4
Left ground spoiler position (deg)	Left Ground Spoiler Position	1
Left inbd flight spoiler position (deg)	Left Inboard Flight Spoiler Deflection	1
Left N1 (%)	Left Engine N1 Speed	1/4
Left N2 (%)	Left Engine N2 Speed	1/2
Left PLA (deg)	Left Engine Power Lever Angle	1
Left thrust reverser cmd	Left Thrust Reverser Command Discrete	1
Left thrust reverser deployed	Left Thrust Reverser Deployed Discrete	1
Left thrust reverser stow/transit	Left Thrust Reverser In Transit Discrete	1
Left wheel brake pressure (psi)	Left Gear Brake Pressure	1/2
Magnetic heading (deg)	Magnetic Heading	1
Master amber	Master Caution Discrete	1
Master red	Master Warning Discrete	1
Right aileron position (deg)	Right Aileron Deflection	2
Right EPR	Right Engine Pressure Ratio	1
Right fuel flow (lbs/hr)	Right Engine Fuel Flow	1/4
Right ground spoiler position (deg)	Right Ground Spoiler Position	1
Right inbd flight spoiler position (deg)	Right Inboard Flight Spoiler Deflection	1
Right N1 (%)	Right Engine N1 Speed	1/4
Right N2 (%)	Right Engine N2 Speed	1/2
Right PLA (deg)	Right Engine Power Lever Angle	1
Right thrust reverser cmd	Right Thrust Reverser Command Discrete	1
Right thrust reverser deployed	Right Thrust Reverser Deployed Discrete	1
Right thrust reverser stow/transit	Right Thrust Reverser In Transit Discrete	1
Right wheel brake pressure (psi)	Right Gear Brake Pressure	1/2
Roll angle(deg)	Roll	2
Rudder position (deg)	Rudder Deflection	2
Static Air Temp (degC)	Static Air Temperature	1/2
True track angle (deg)	True Course Over Ground	1
Yaw damper status	Yaw Damper Status Discrete	1

Table A-2. Unit abbreviations.

Units Abbreviation	Description
deg	degrees
kts	knots
discrete	discrete
ft	feet
in	inches
sec	second
hr	hour
psi	pounds per square inch

NOTE: For parameters with a unit description of discrete, a discrete is typically a 1-bit parameter that is either a 0 state or a 1 state where each state is uniquely defined for each parameter.