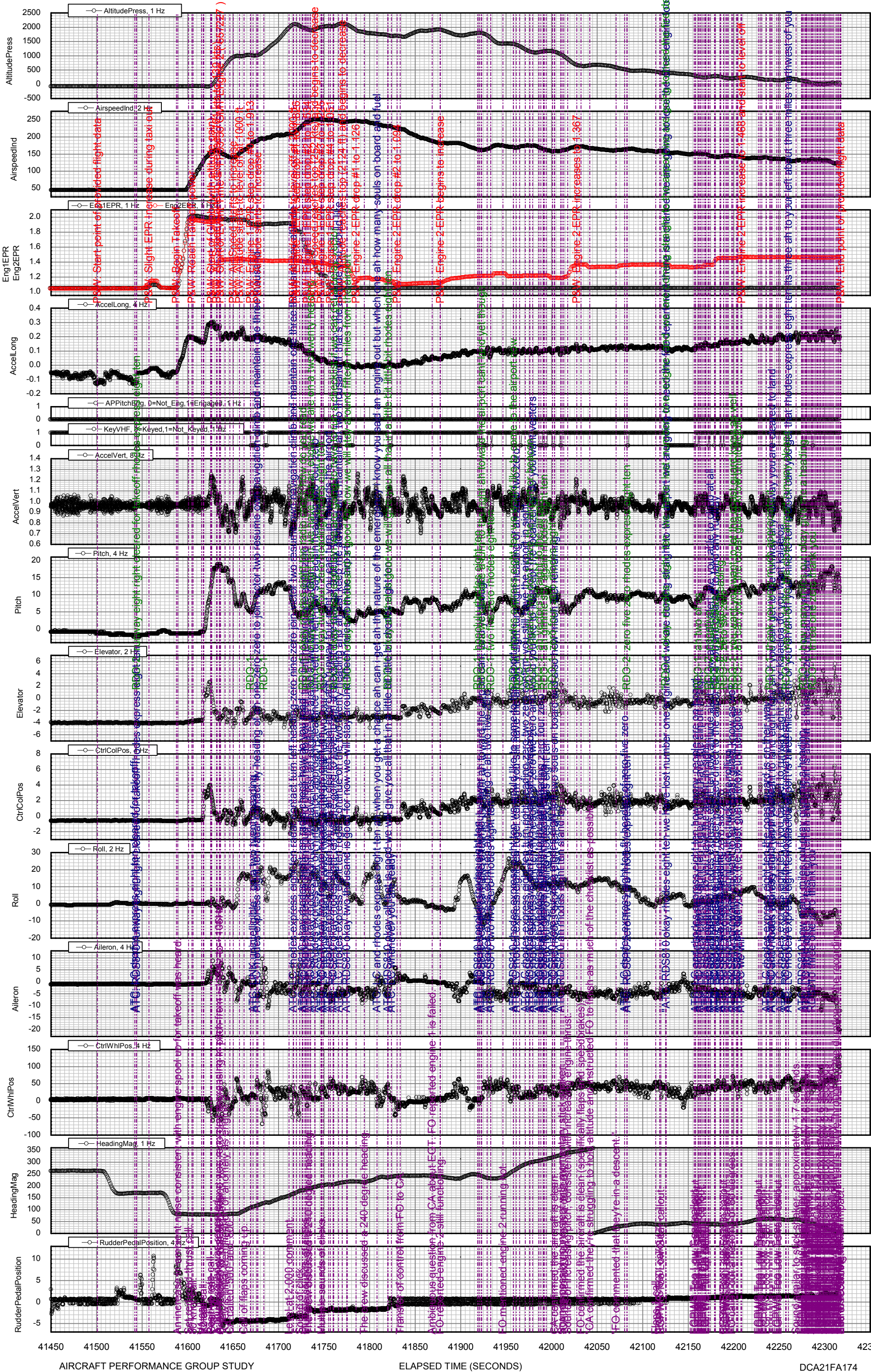
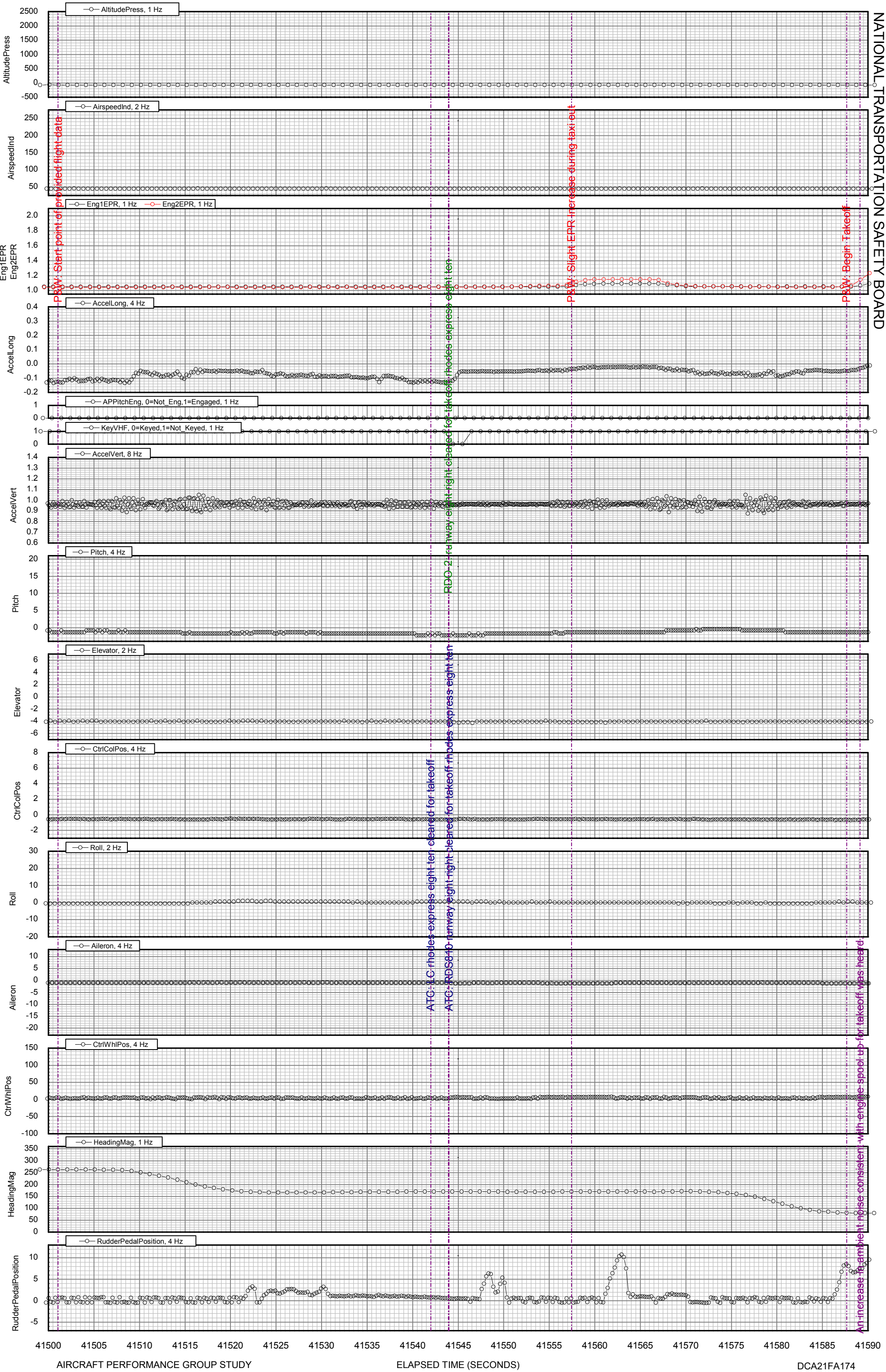


ATTACHMENT 5: FLIGHT DATA RECORDER (FDR) DATA

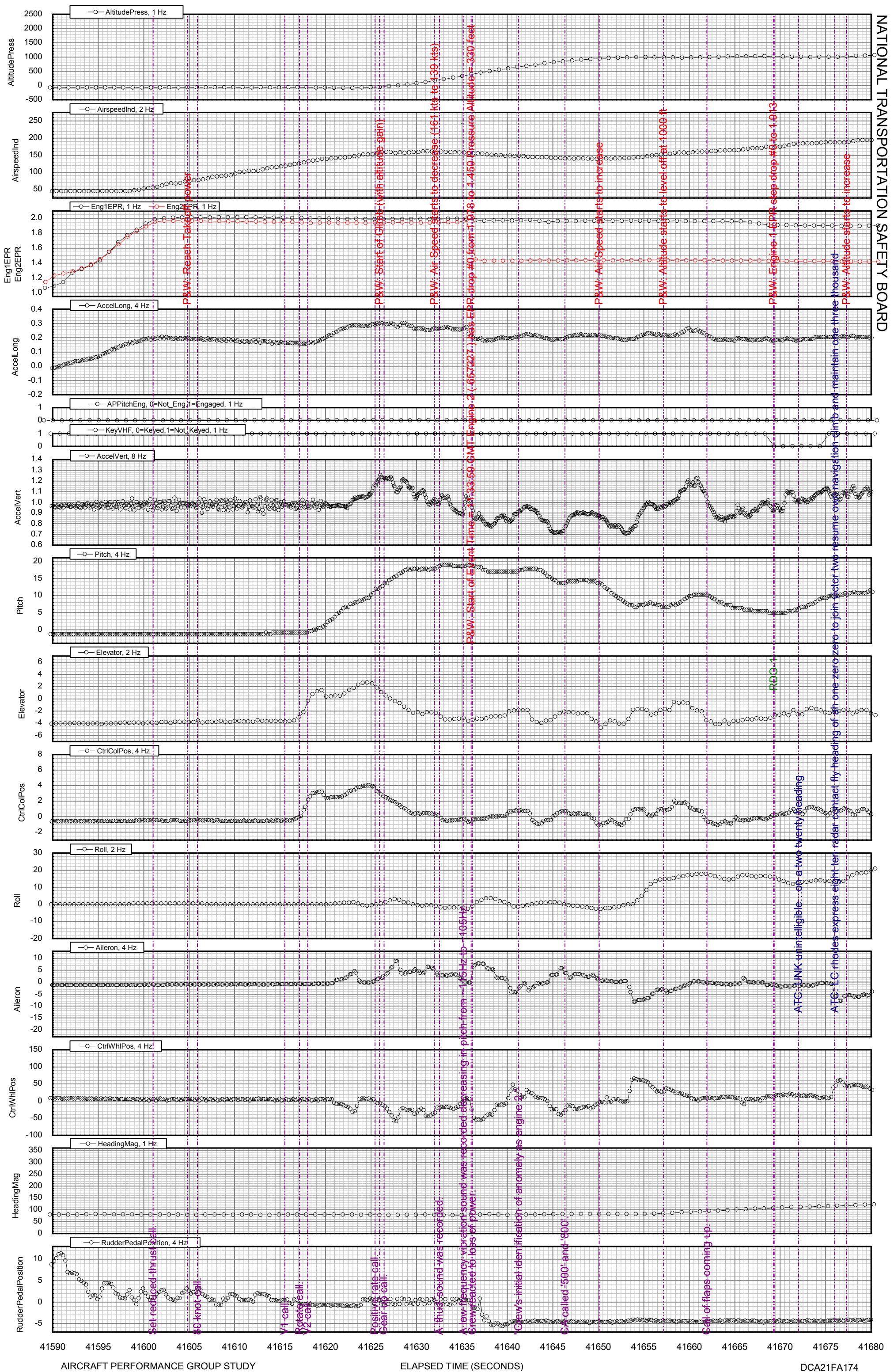
RHOADES AVIATION INC. BOEING 737-200ADV (N810TA) TAKEOFF ACCIDENT [FDR, PARAPHRASED CVR, & ATC DATA]
 RUNWAY 08R, DANIEL K. INOYE INTERNATIONAL AIRPORT (HNL), HONOLULU, HAWAII, JULY 2, 2021 (NTS: DCA21FA174)



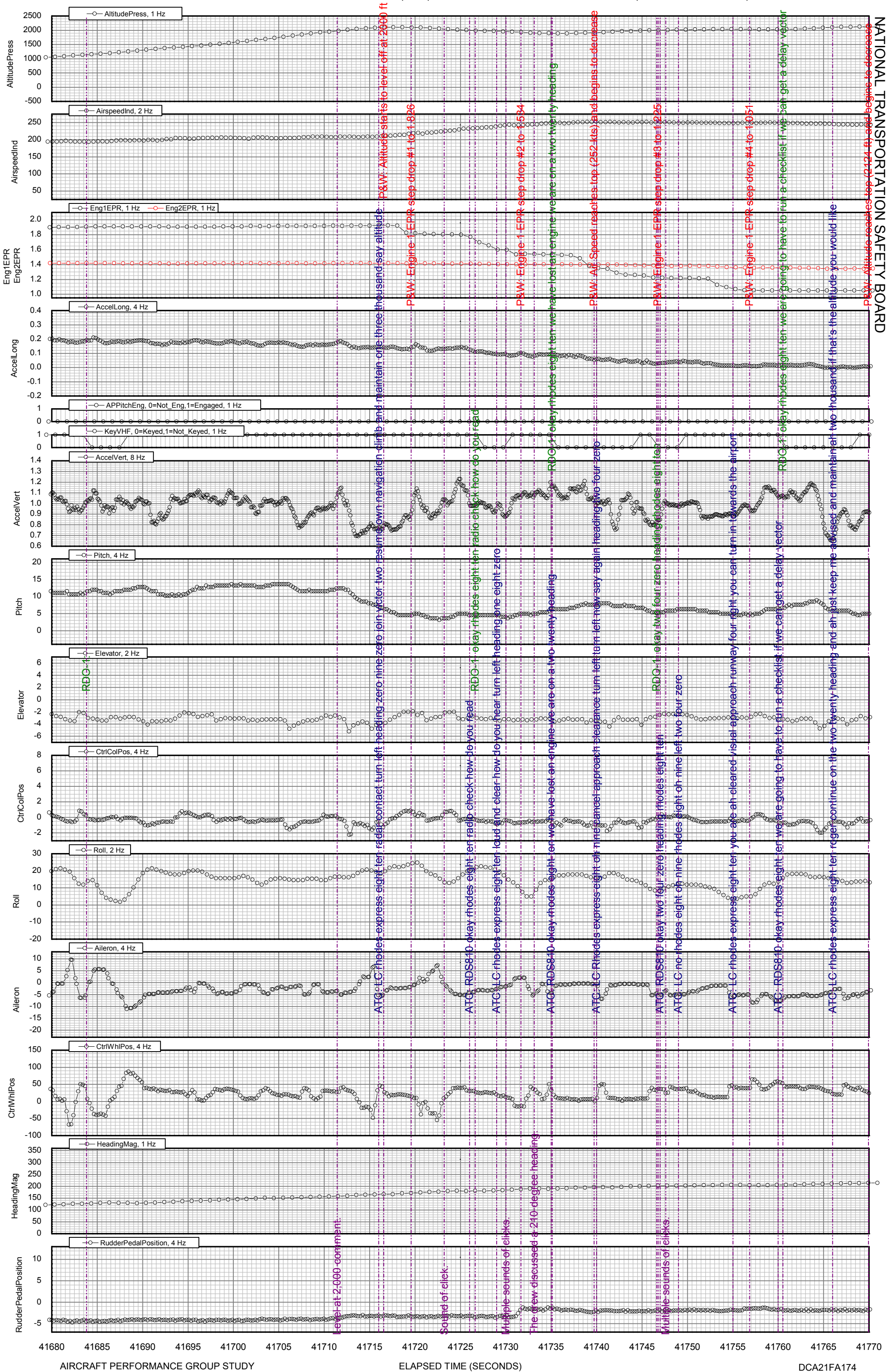
RHOADES AVIATION INC. BOEING 737-200ADV (N810TA) TAKEOFF ACCIDENT [FDR, PARAPHRASED CVR, & ATC DATA]
RUNWAY 08R, DANIEL K. INOUE INTERNATIONAL AIRPORT (HNL), HONOLULU, HAWAII, JULY 2, 2021 (NTSB DCA21FA174)



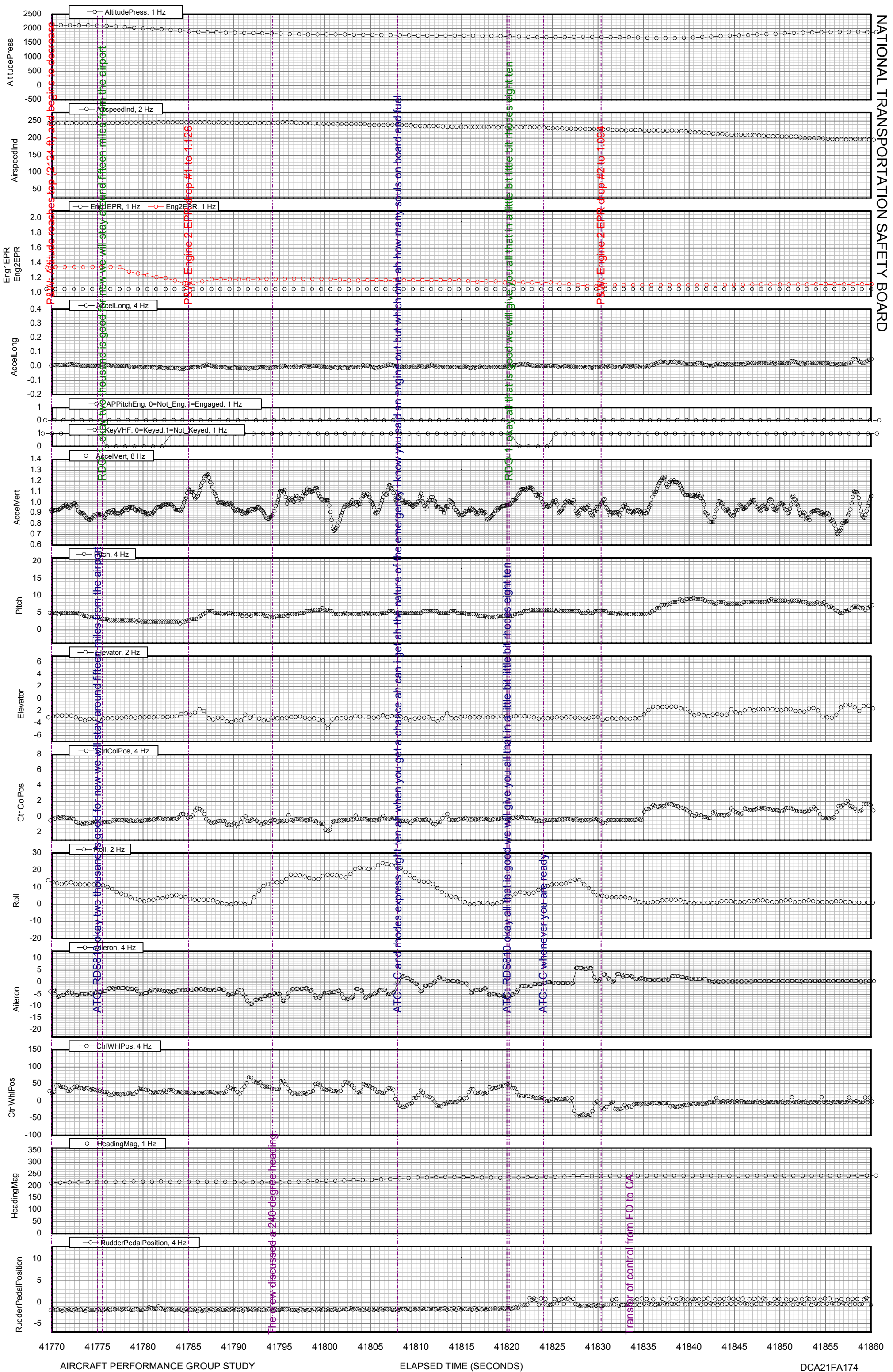
RHOADES AVIATION INC. BOEING 737-200ADV (N810TA) TAKEOFF ACCIDENT [FDR, PARAPHRASED CVR, & ATC DATA]
 RUNWAY 08R, DANIEL K. INOUE INTERNATIONAL AIRPORT (HNL), HONOLULU, HAWAII, JULY 2, 2021 (NTSB DCA21FA174)



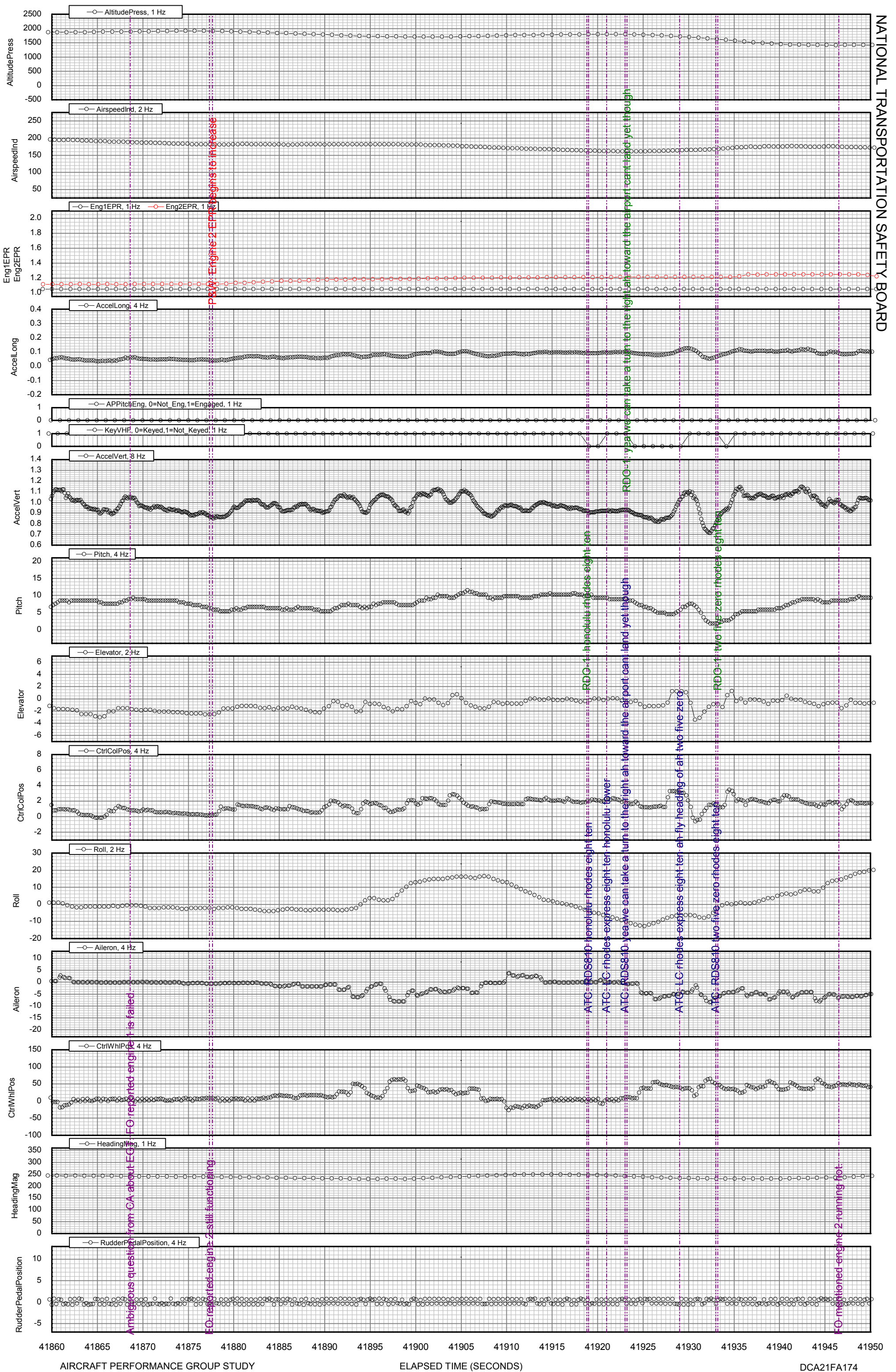
RHOADES AVIATION INC. BOEING 737-200ADV (N810TA) TAKEOFF ACCIDENT [FDR, PARAPHRASED CVR, & ATC DATA]
 RUNWAY 08R, DANIEL K. INOUE INTERNATIONAL AIRPORT (HNL), HONOLULU, HAWAII, JULY 2, 2021 (NTSB DCA21FA174)



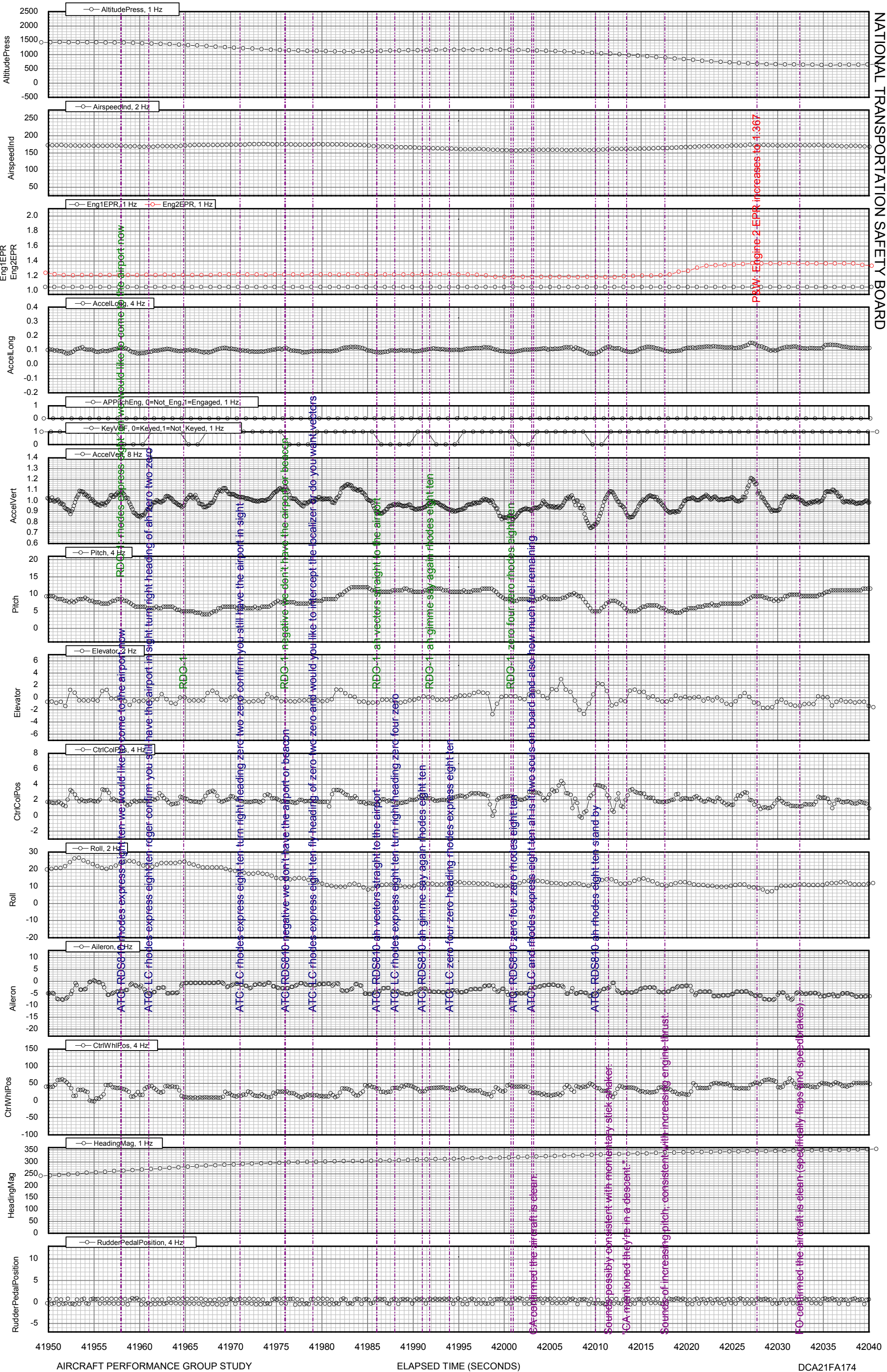
RHOADES AVIATION INC. BOEING 737-200ADV (N810TA) TAKEOFF ACCIDENT [FDR, PARAPHRASED CVR, & ATC DATA]
 RUNWAY 08R, DANIEL K. INOUE INTERNATIONAL AIRPORT (HNL), HONOLULU, HAWAII, JULY 2, 2021 (NTSB DCA21FA174)



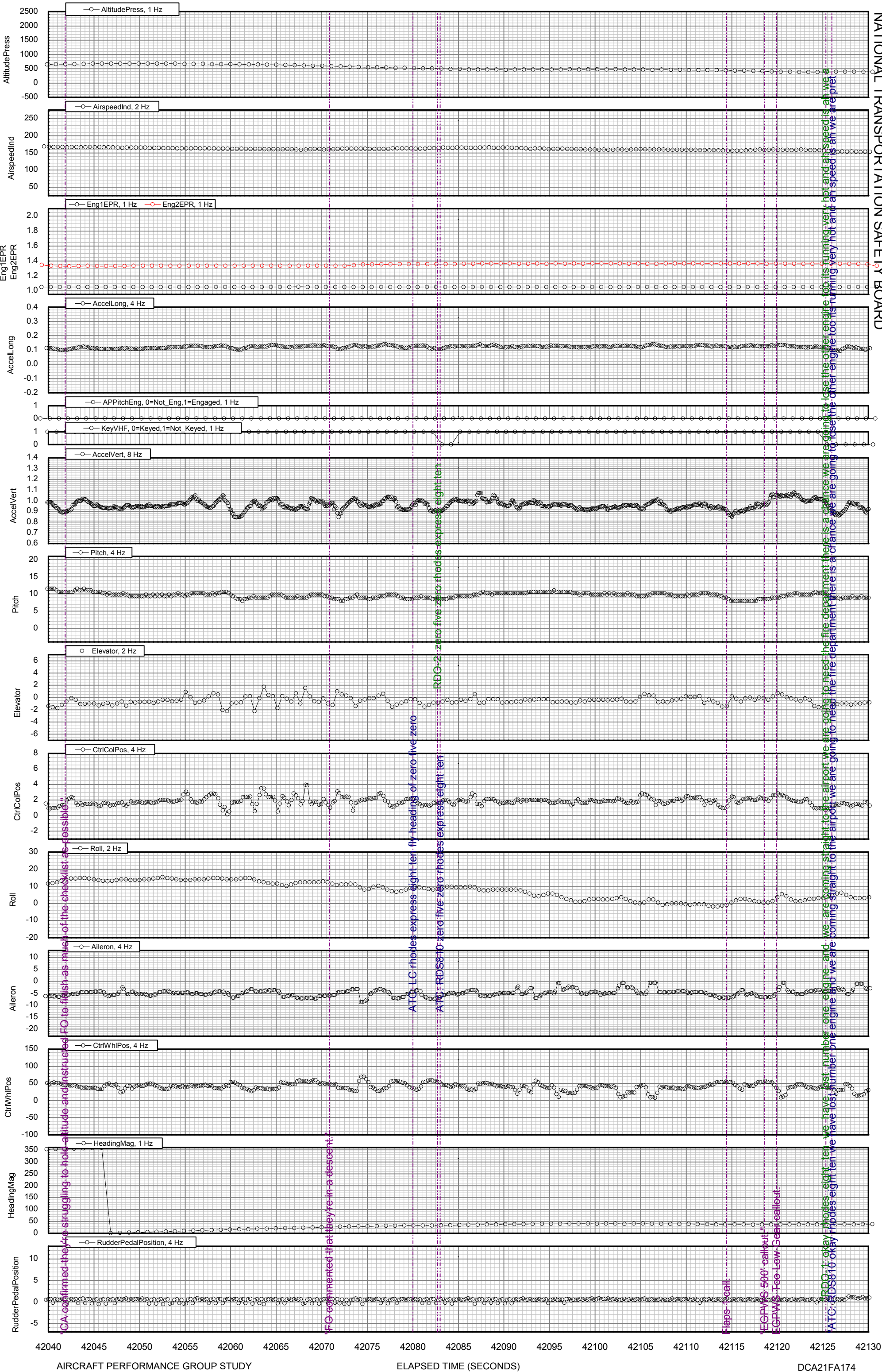
RHOADES AVIATION INC. BOEING 737-200ADV (N810TA) TAKEOFF ACCIDENT [FDR, PARAPHRASED CVR, & ATC DATA]
 RUNWAY 08R, DANIEL K. INOUE INTERNATIONAL AIRPORT (HNL), HONOLULU, HAWAII, JULY 2, 2021 (NTSB DCA21FA174)



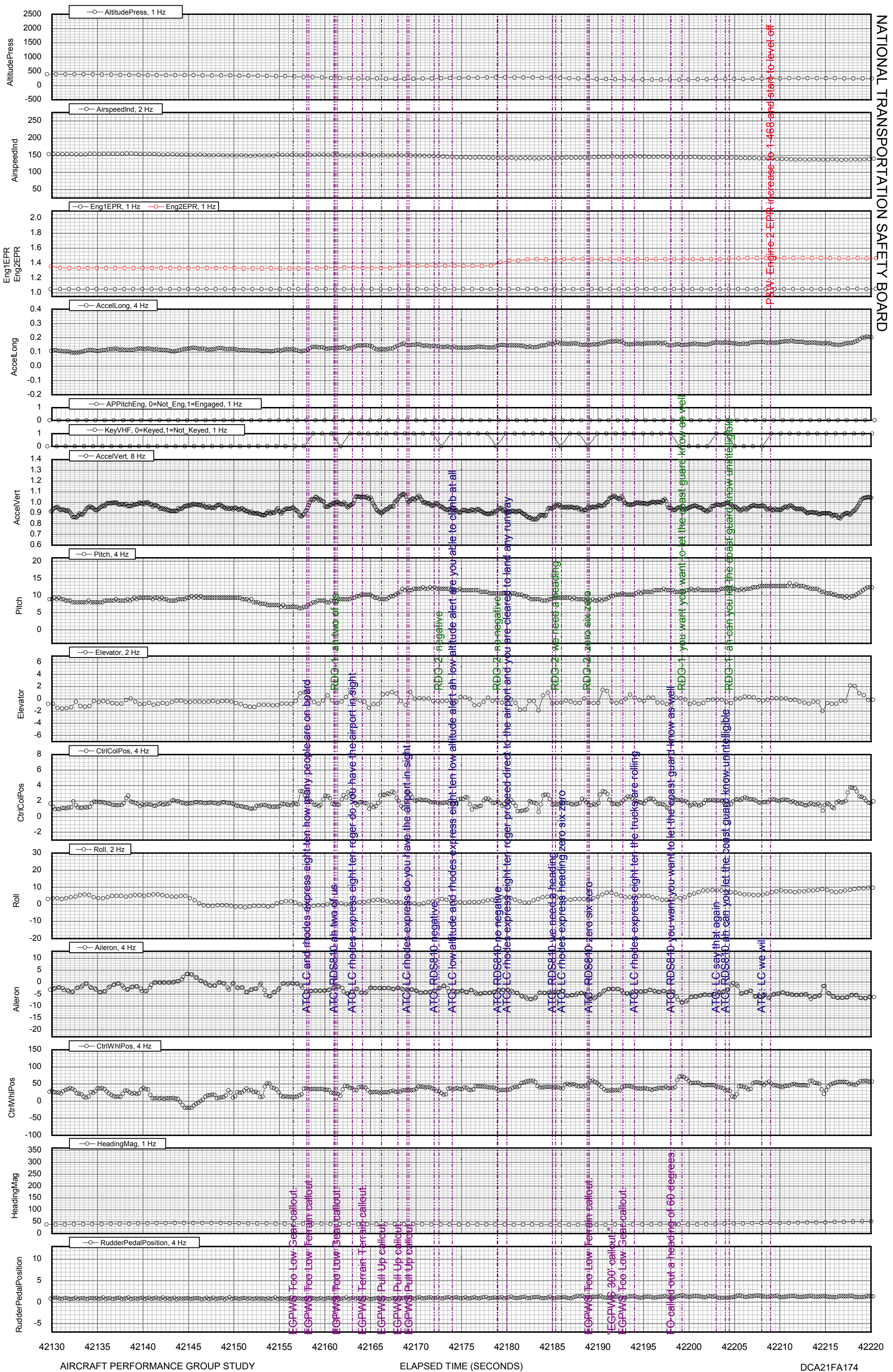
RHOADES AVIATION INC. BOEING 737-200ADV (N810TA) TAKEOFF ACCIDENT [FDR, PARAPHRASED CVR, & ATC DATA]
RUNWAY 08R, DANIEL K. INOUE INTERNATIONAL AIRPORT (HNL), HONOLULU, HAWAII, JULY 2, 2021 (NTSB DCA21FA174)



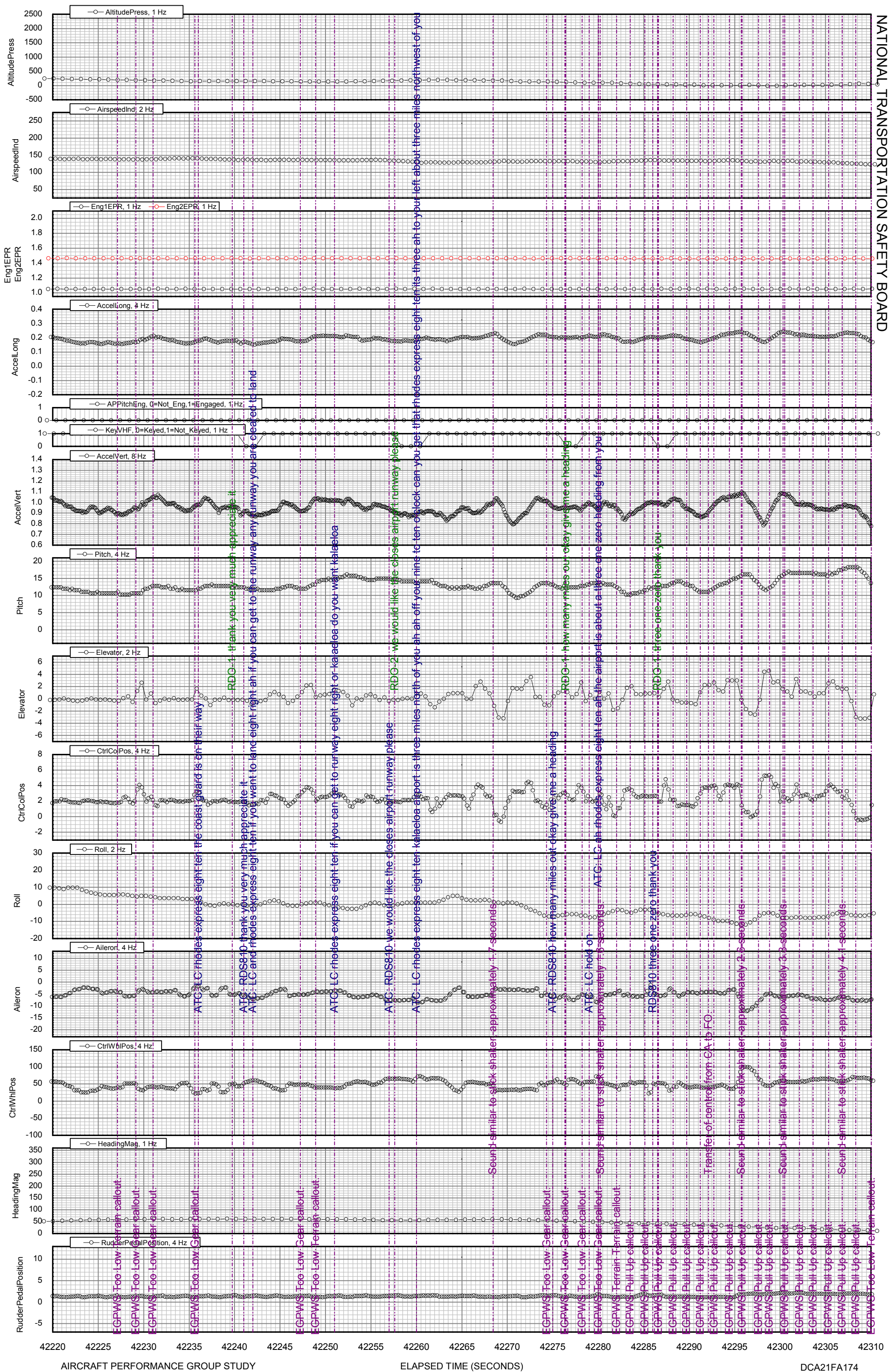
RHOADES AVIATION INC. BOEING 737-200ADV (N810TA) TAKEOFF ACCIDENT [FDR, PARAPHRASED CVR, & ATC DATA]
RUNWAY 08R, DANIEL K. INOUE INTERNATIONAL AIRPORT (HNL), HONOLULU, HAWAII, JULY 2, 2021 (NTSB DCA21FA174)



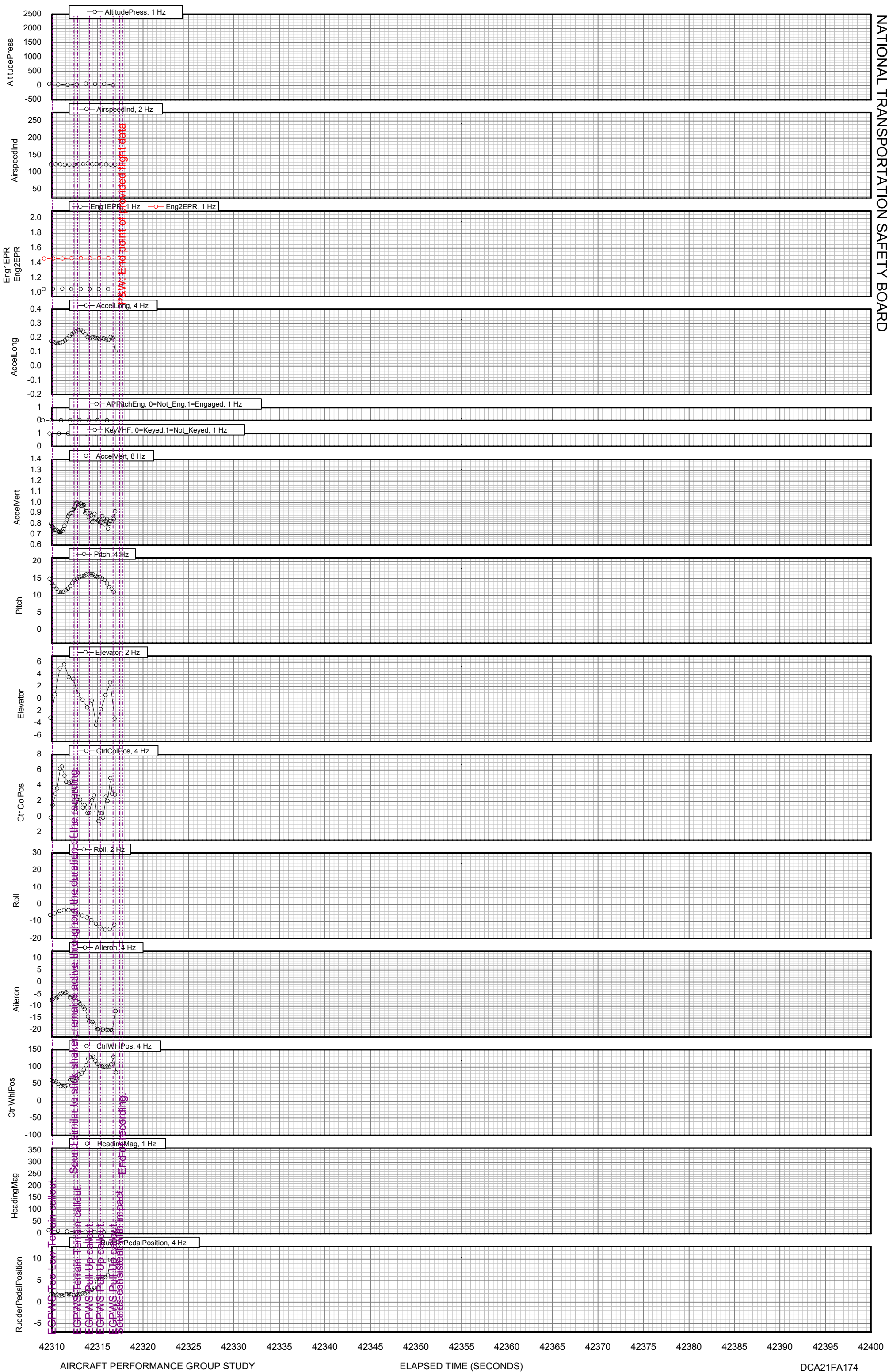
RHOADES AVIATION INC. BOEING 737-200ADV (N810TA) TAKEOFF ACCIDENT [FDR, PARAPHRASED CVR, & ATC DATA]
 RUNWAY 08R, DANIEL K. INOUE INTERNATIONAL AIRPORT (HNL), HONOLULU, HAWAII, JULY 2, 2021 (NTSB DCA21FA174)



RHOADES AVIATION INC. BOEING 737-200ADV (N810TA) TAKEOFF ACCIDENT [FDR, PARAPHRASED CVR, & ATC DATA]
 RUNWAY 08R, DANIEL K. INOUE INTERNATIONAL AIRPORT (HNL), HONOLULU, HAWAII, JULY 2, 2021 (NTSB DCA21FA174)

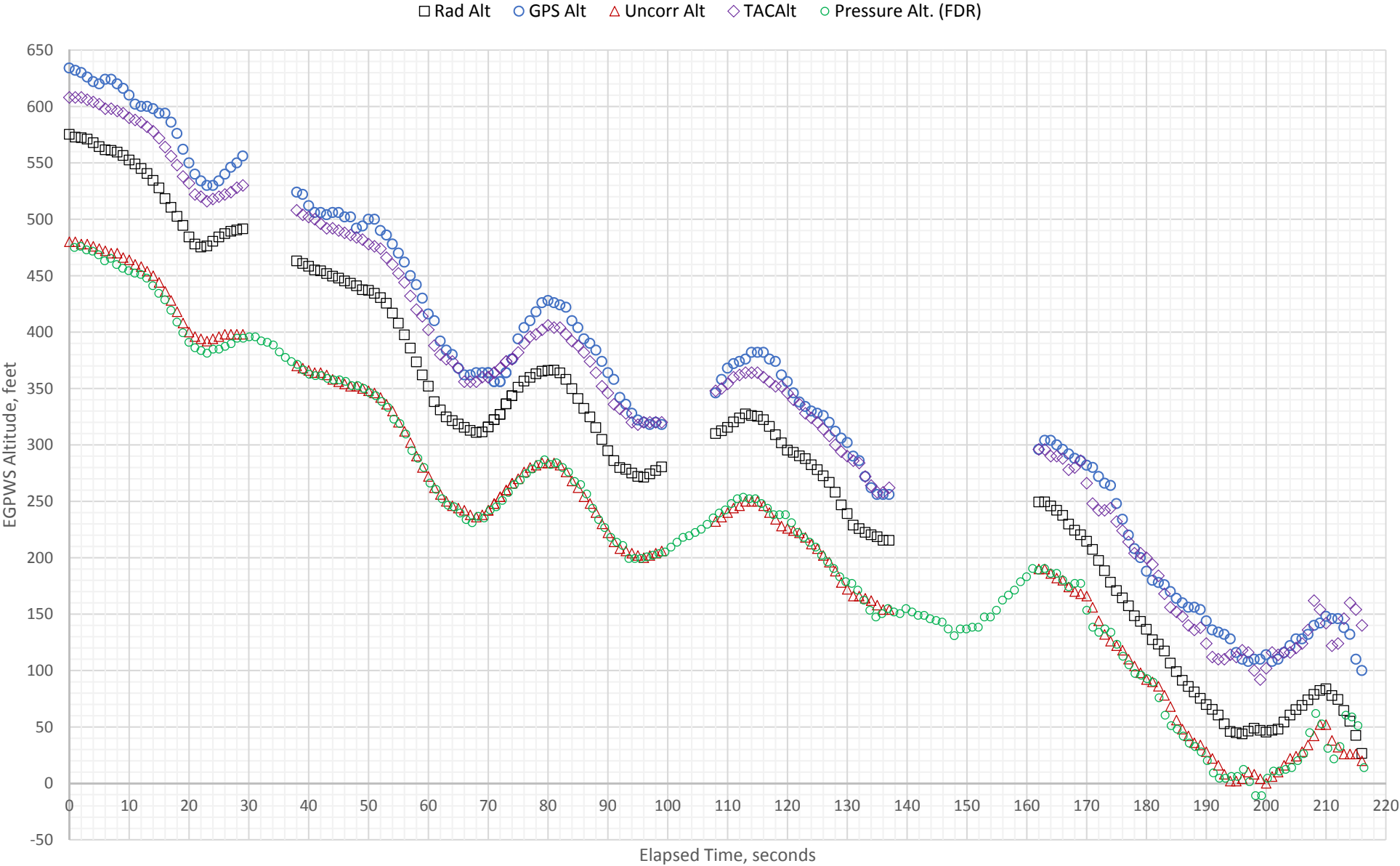


RHOADES AVIATION INC. BOEING 737-200ADV (N810TA) TAKEOFF ACCIDENT [FDR, PARAPHRASED CVR, & ATC DATA]
 RUNWAY 08R, DANIEL K. INOUE INTERNATIONAL AIRPORT (HNL), HONOLULU, HAWAII, JULY 2, 2021 (NTSB DCA21FA174)



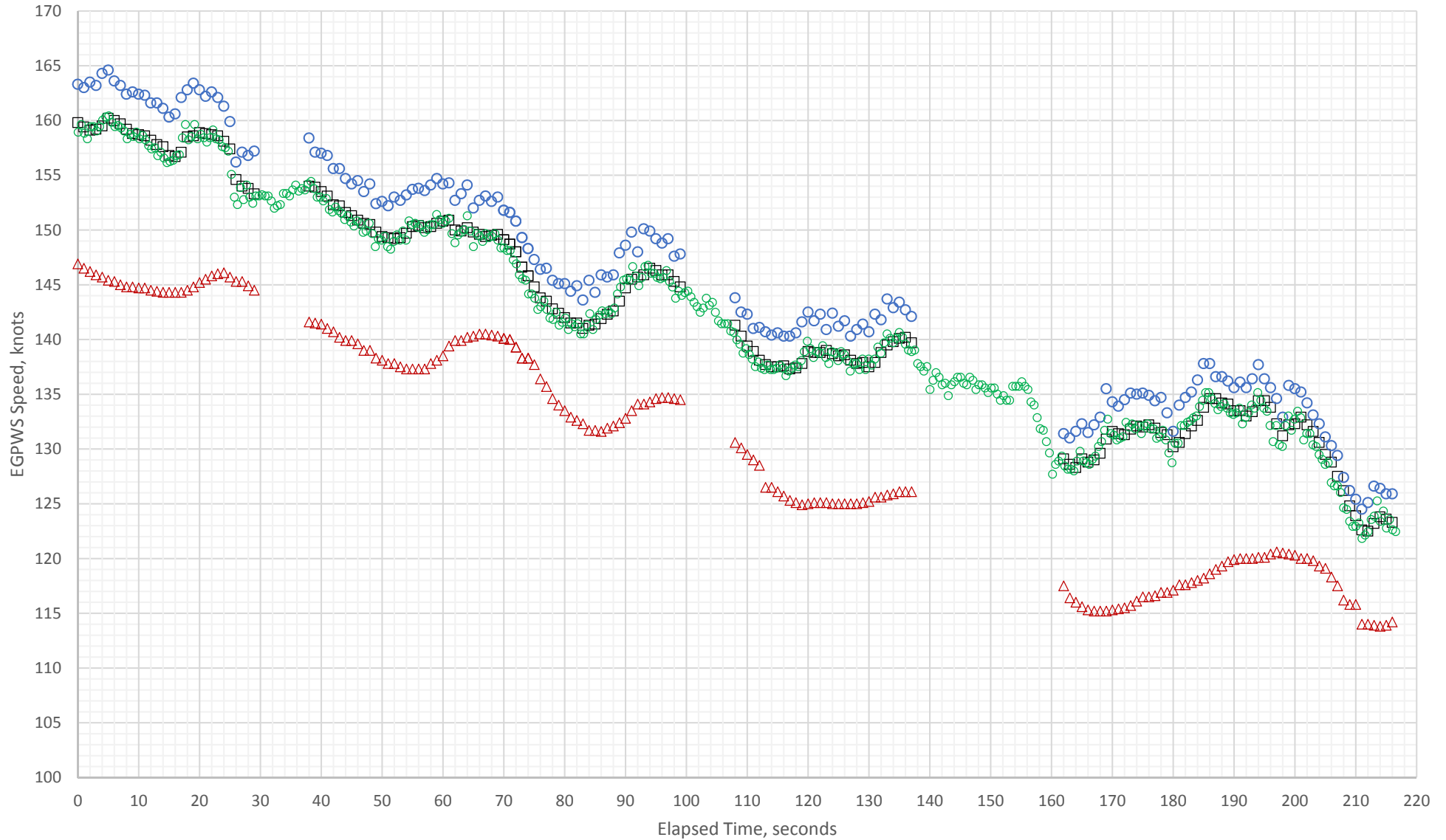
ATTACHMENT 6: EGPWS DATA

EGPWS Rad, GPS, Uncorr, and TAC Alt, Transair B737-200 (Honolulu, HI)

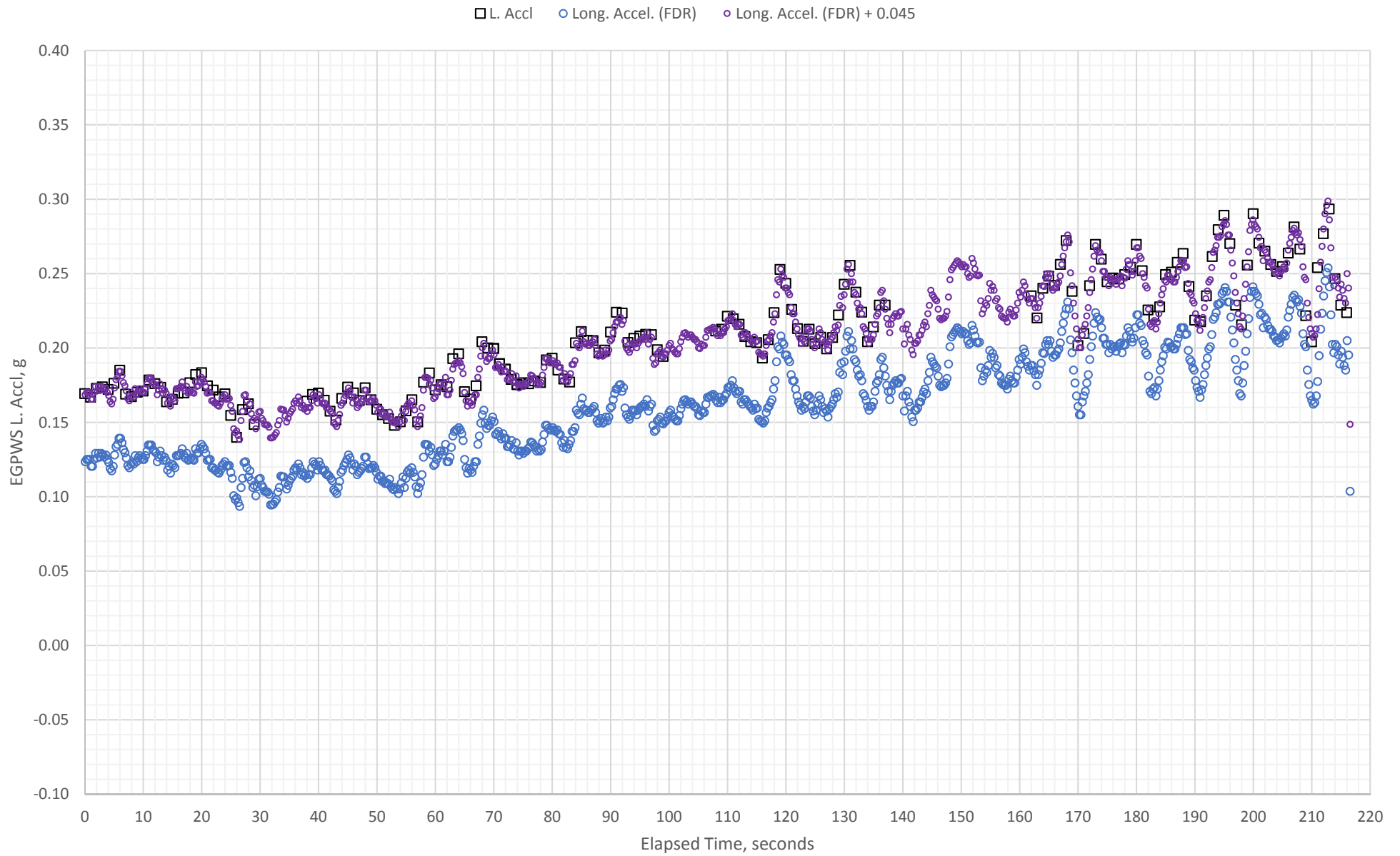


EGPWS CAS, TAS, & Gspd, Transair B737-200 (Honolulu, HI)

□ CAS ○ TAS △ Gspd ● Airspeed (FDR)

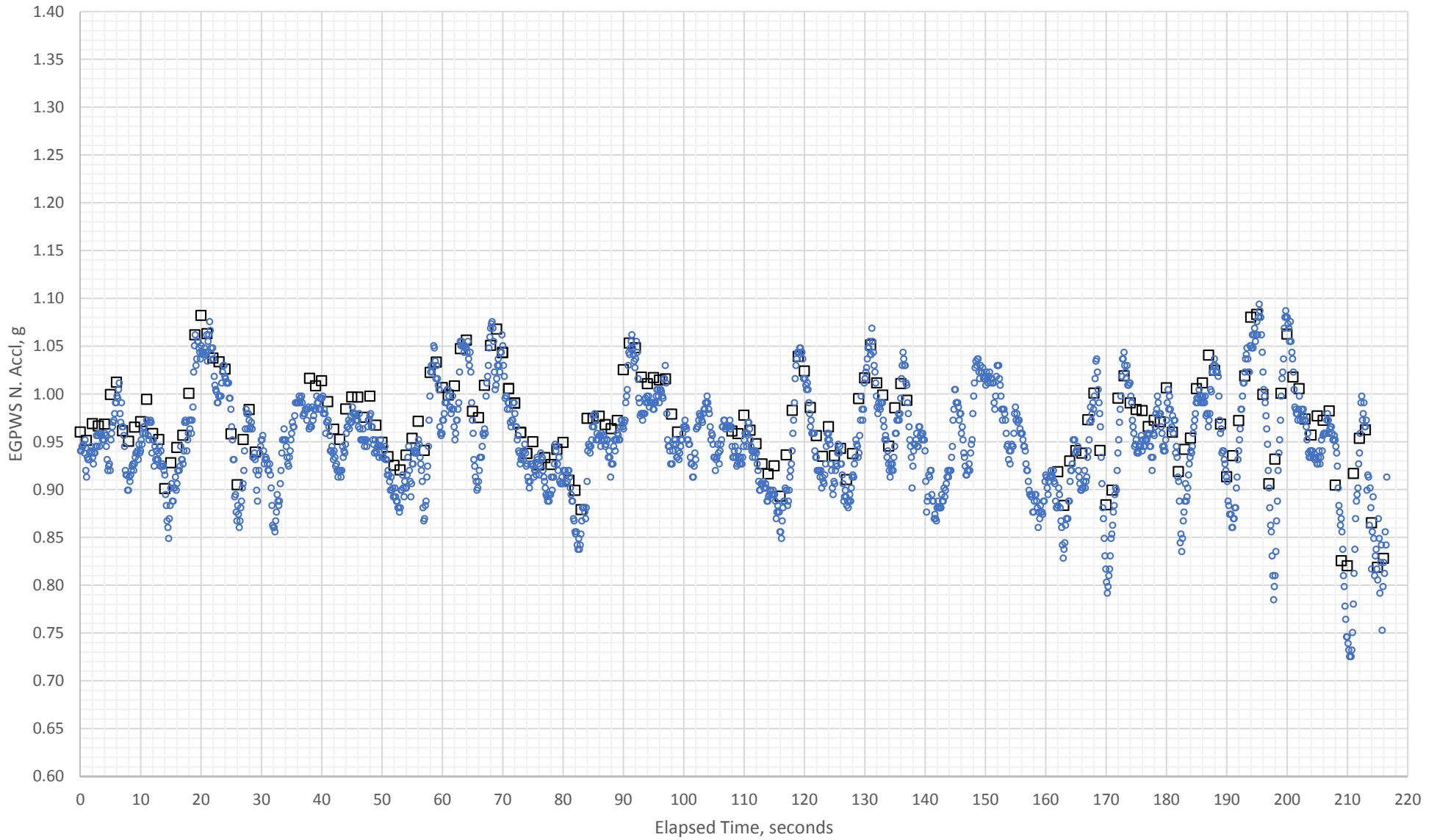


EGPWS L. Accl, Transair B737-200 (Honolulu, HI)



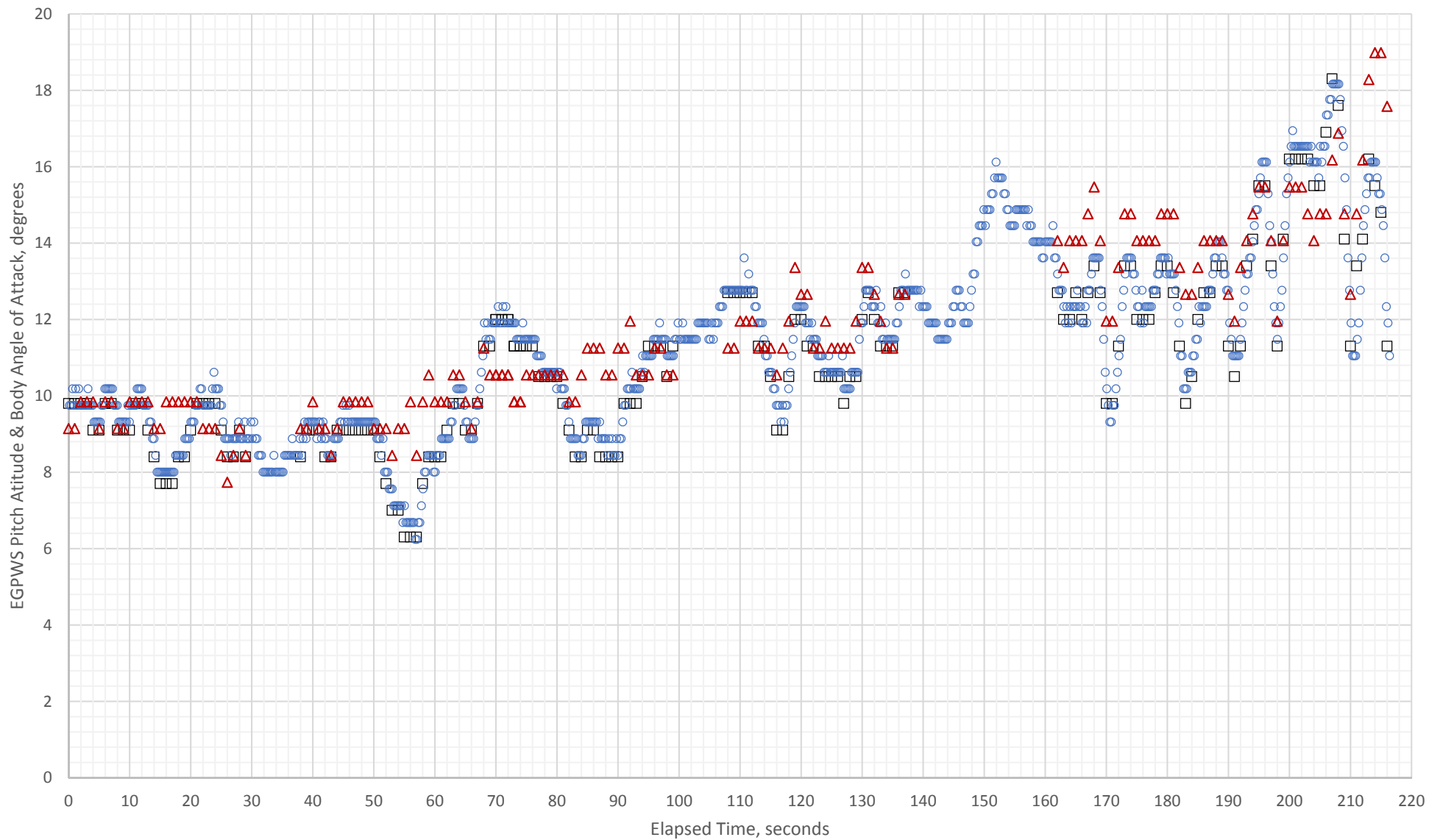
EGPWS N. Accl, Transair B737-200 (Honolulu, HI)

□ N. Accl ○ Normal Accel. (FDR)

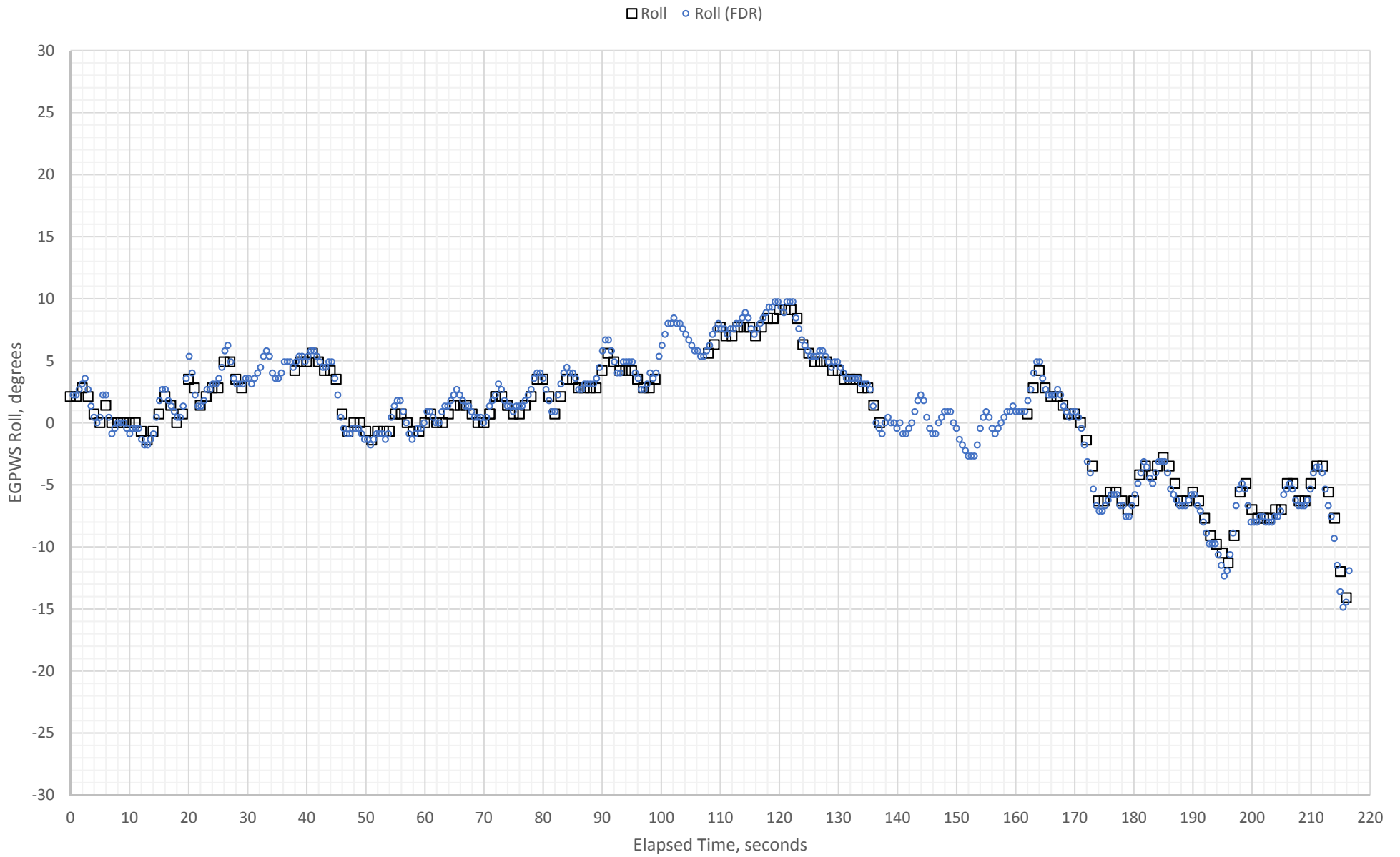


EGPWS Pitch & BAOA, Transair B737-200 (Honolulu, HI)

□ Pitch ○ Pitch (FDR) ▲ BAOA

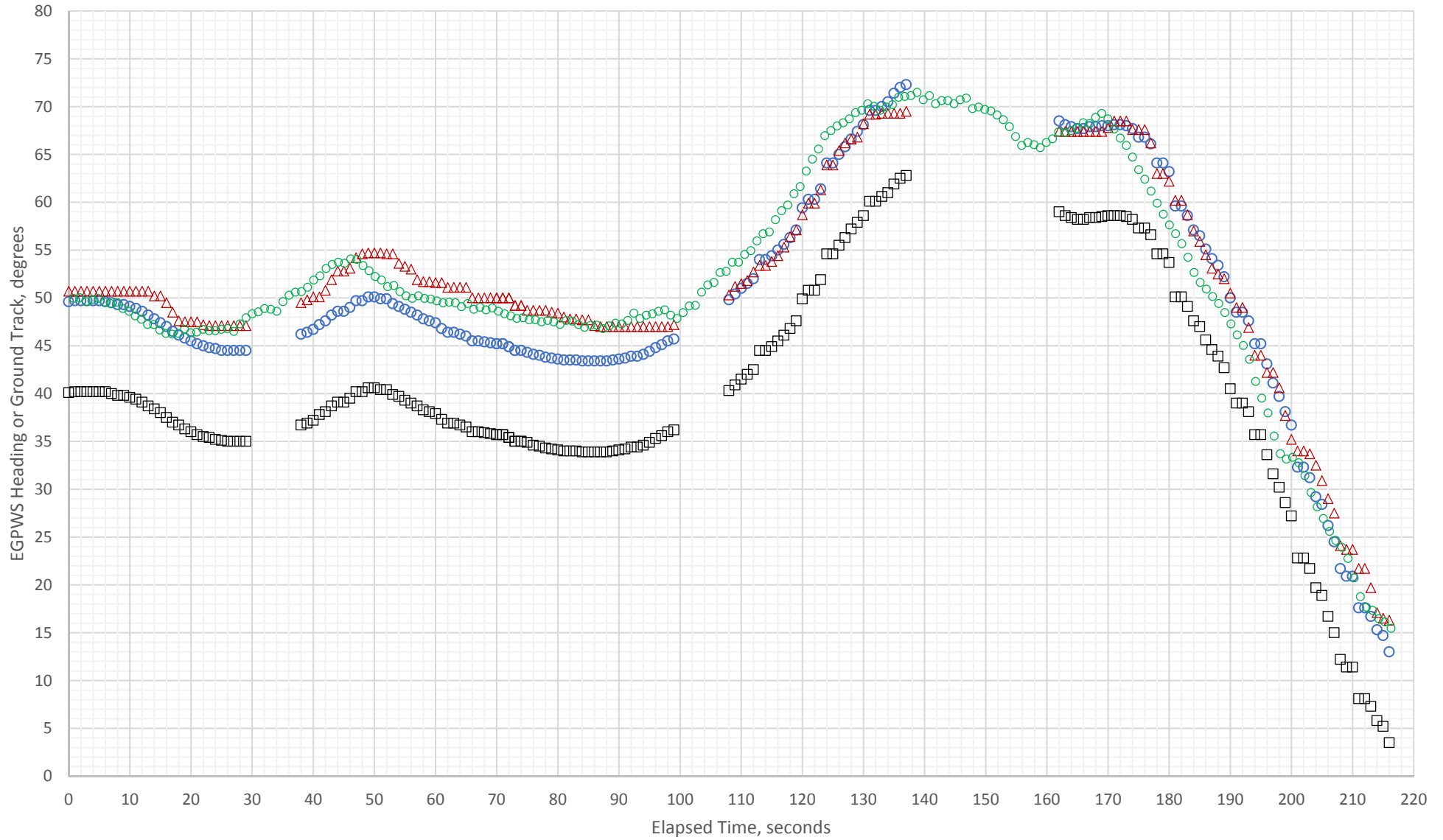


EGPWS Roll, Transair B737-200 (Honolulu, HI)



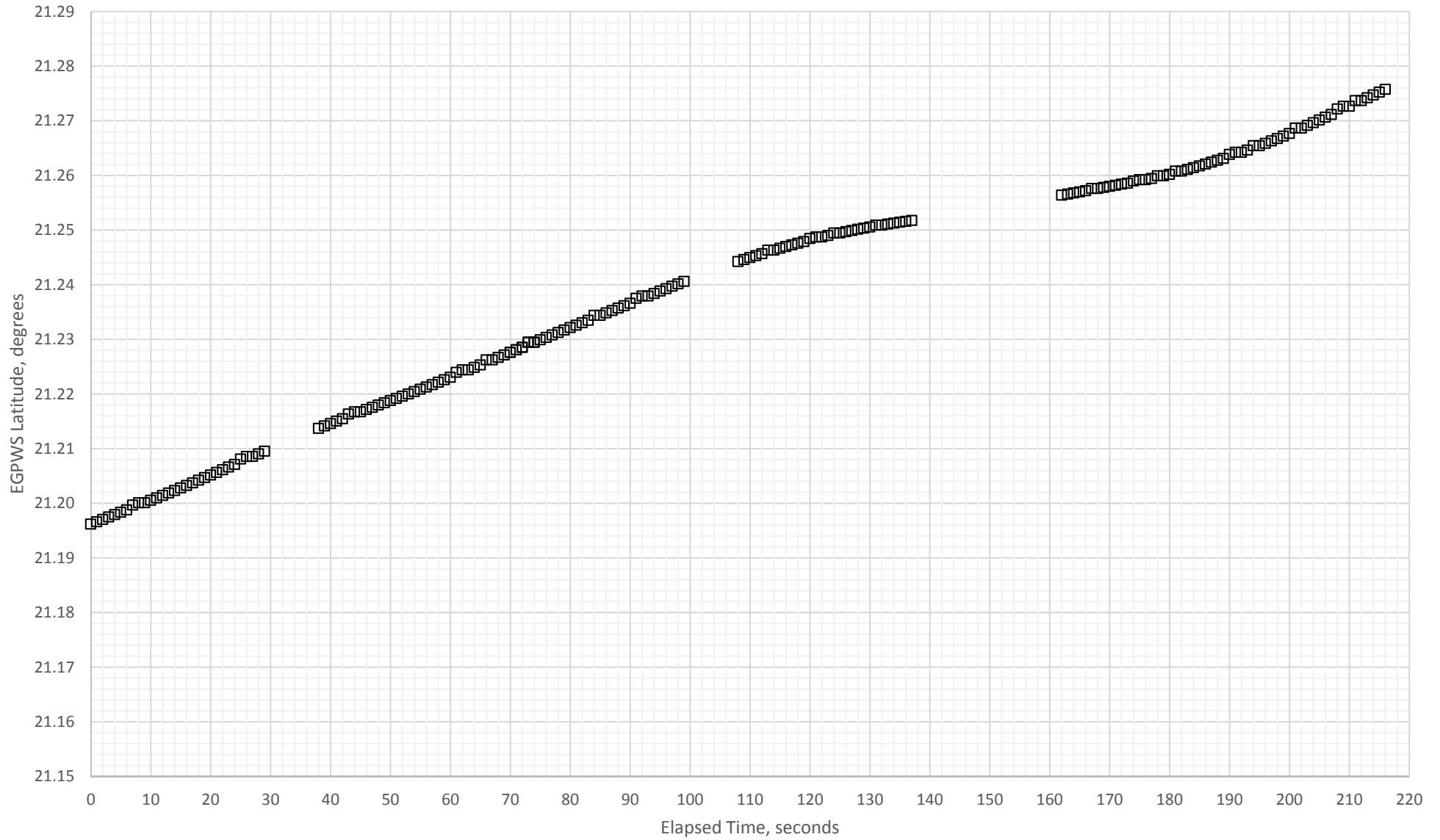
EGPWS Mag Trk, Tru Trk, Tru Hd, Transair B737-200 (Honolulu, HI)

□ Mag Trk ○ Tru Trk ▲ Tru Hd ● Heading, Mag (FDR)



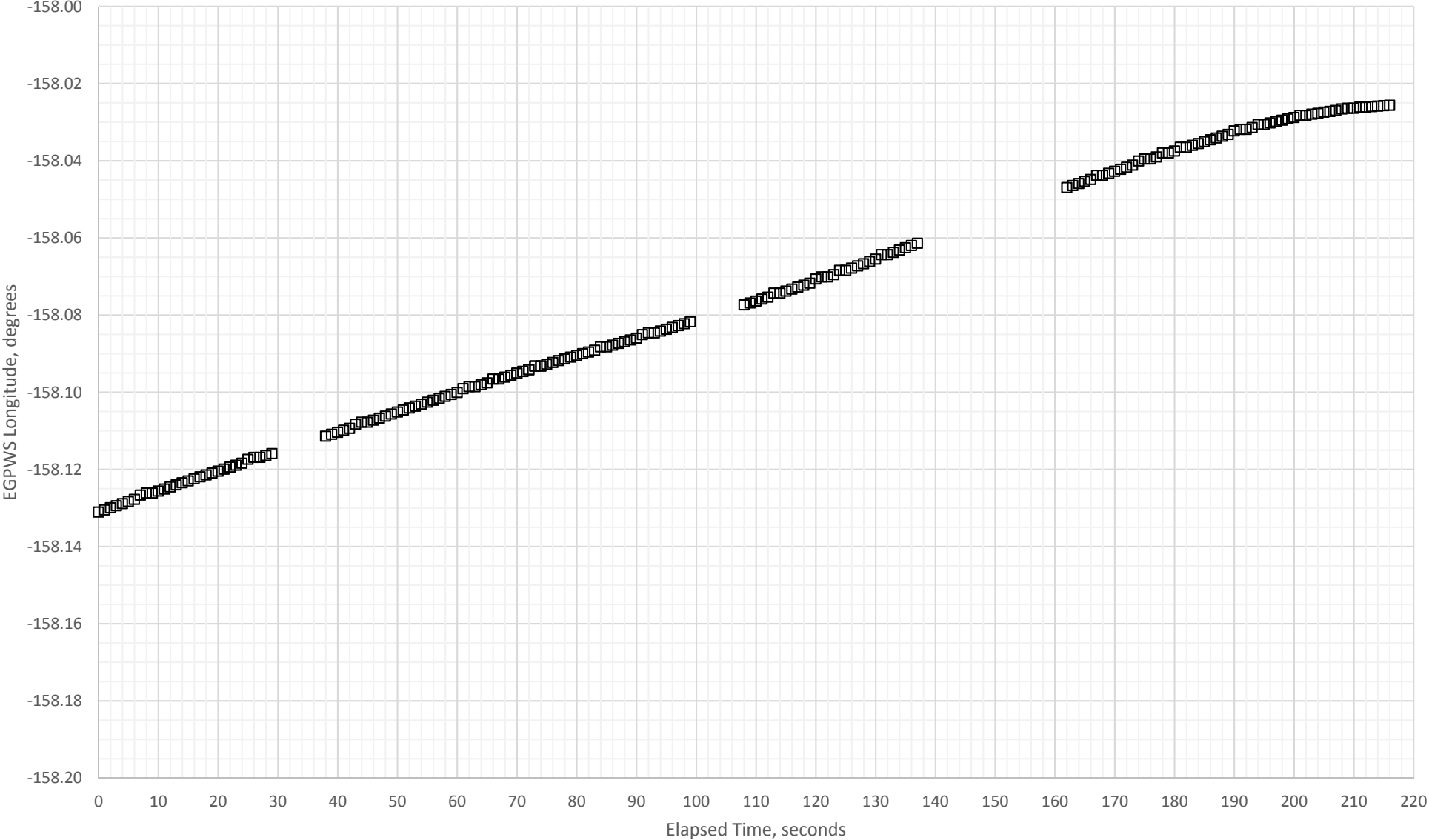
EGPWS Latitude, Transair B737-200 (Honolulu, HI)

□ Lat



EGPWS Longitude, Transair B737-200 (Honolulu, HI)

□ Long



ATTACHMENT 7: PRATT & WHITNEY JT8D-9 ENGINE MODEL DATA

Attachment 7 content on pages A7.2 through A7.31 was reviewed by NTSB legal staff against United States of America export control requirements and deemed to be suitable for public release.

EVENT FLIGHT TIMELINE

EPR = Engine Pressure Ratio
 GMT = Greenwich Mean Time
 kts = knots = 1 nautical mile / hour
 ft = feet

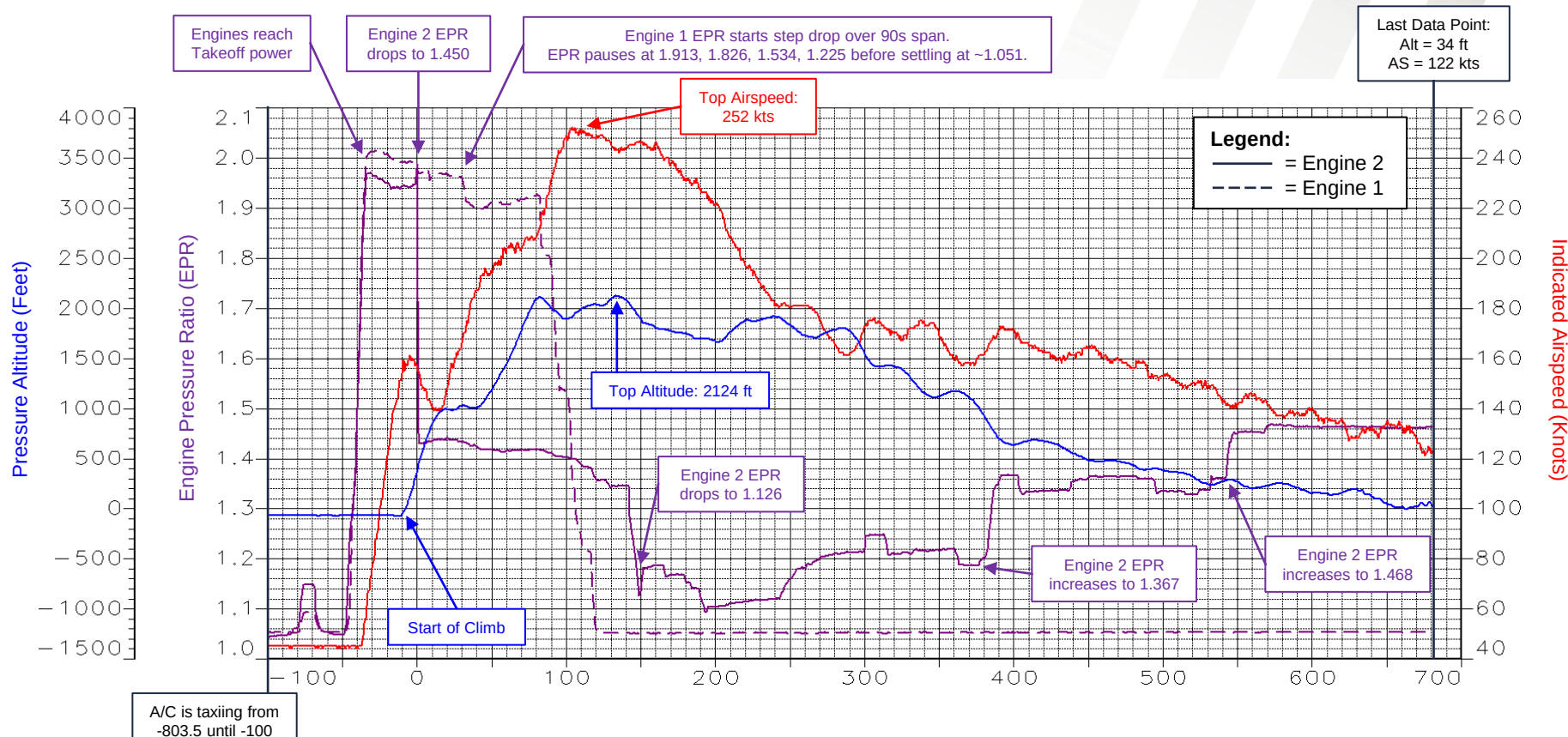
Elapsed Time Relative to 11:33:55.5 GMT (Seconds)	Event Description
-803.5	Start point of provided flight data
-632.3	Slight EPR Increase during taxi out #1
-250.7	Slight EPR Increase during taxi out #2
-85.6	Slight EPR Increase during taxi out #3
-48.3	Begin Takeoff
-31.2	Reach Takeoff power
-10.1	Start of Climb (with altitude gain)
-4.0	Air Speed starts to decrease (161 kts to 139 kts)
0.0	Start of Event • Time = 11:33:55.5 GMT • Engine 2 (657227) has EPR drop #0 from 1.978 to 1.450 • Pressure Altitude = 330 feet
+15.1	Air Speed starts to increase
+19.1	Altitude starts to level off at 1000 ft
+33.2	Engine 1 EPR step drop #0 to 1.913
+41.3	Altitude starts to increase

EVENT FLIGHT TIMELINE

Elapsed Time Relative to 11:33:55.5 GMT (Seconds)	Event Description
+80.5	Altitude starts to level off at 2000 ft
+83.6	Engine 1 EPR step drop #1 to 1.826
+95.7	Engine 1 EPR step drop #2 to 1.534
+103.7	Air Speed reaches top (252 kts) and begins to decrease
+110.8	Engine 1 EPR step drop #3 to 1.225
+120.8	Engine 1 EPR step drop #4 to 1.051
+133.5	Altitude reaches top (2124 ft) and begins to decrease
+149.1	Engine 2 EPR drop #1 to 1.126
+193.4	Engine 2 EPR drop #2 to 1.094
+243.7	Engine 2 EPR begins to increase
+391.7	Engine 2 EPR increases to 1.367
+573.0	Engine 2 EPR increase to 1.468 and start to level off
+680.7	End point of provided flight data

EVENT TIMELINE FROM FLIGHT DATA

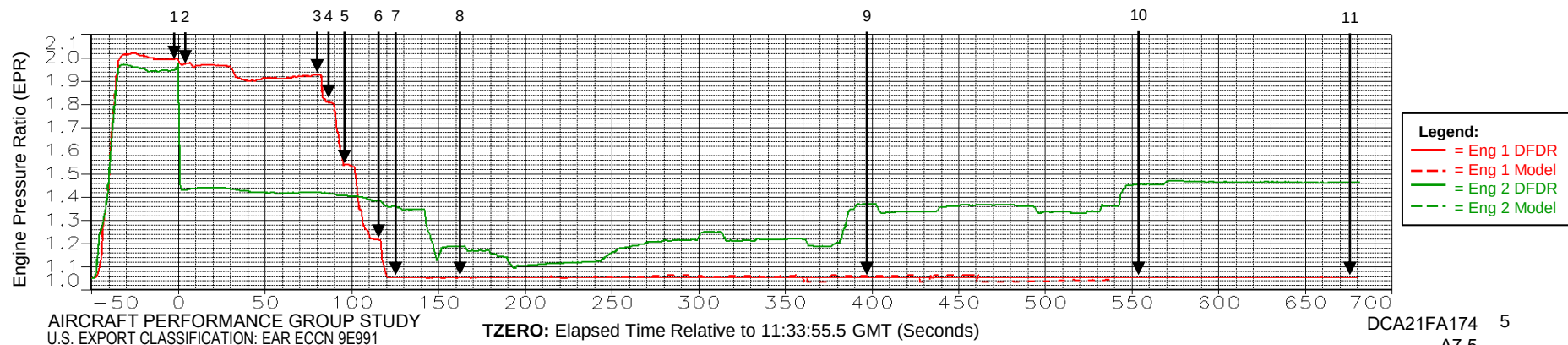
Event starts ~10s after aircraft takeoff, with sudden drop of engine #2 EPR to 1.450 from 1.978, while Altitude = 330 ft and Airspeed = 158 kts



ENG #1 BASE JT8D-9 SIMULATION ANALYSIS

Simulation assumes base JT8D-9 configuration without effects of deterioration or the AvAero Hush Kit

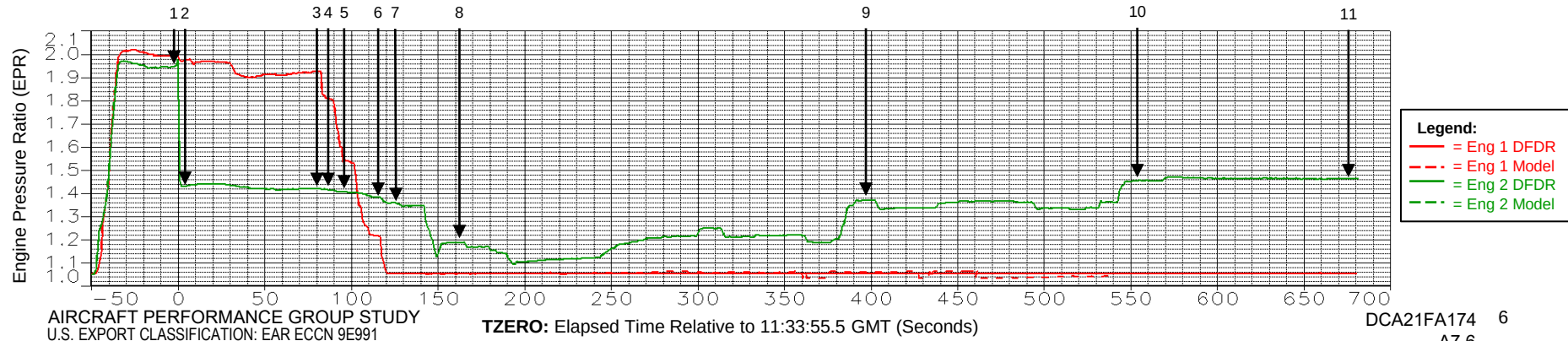
Point	TZERO (s)	Air Speed (kts)	Altitude (ft)	EPR	Net Thrust (lbs)	Ram Drag (lbs)	Gross Thrust (lbs)	PLA (Degrees)	N1 Speed (RPM)	N2 Speed (RPM)	Fuel Flow (lb/hr)	EGT (Deg F)
1	-1.0	158	298	1.994	12348	2681	15027	122	8011	11343	8317	970
2	3.0	150	524	1.970	12029	2513	14542	120	7938	11285	8004	955
3	80.5	208	2094	1.928	10729	3392	14121	118	7836	11207	7503	936
4	85.6	218	2082	1.811	9533	3454	12987	112	7541	11021	6690	894
5	96.7	242	1921	1.542	6732	3490	10222	98	6868	10547	4915	783
6	115.8	249	2025	1.214	3053	2756	5809	81	5527	9565	2621	631
7	125.9	248	2034	1.051	1202	2002	3204	76	4051	8430	1726	669
8	161.1	246	1797	1.051	1197	1983	3180	76	4030	8411	1726	670
9	397.8	170	634	1.051	1085	1181	2266	74	3558	7888	1498	683
10	553.9	142	261	1.052	945	901	1846	73	3278	7530	1360	688
11	676.7	122	27	1.052	916	716	1634	72	3135	7343	1299	695



ENG #2 BASE JT8D-9 SIMULATION ANALYSIS

Simulation assumes base JT8D-9 configuration without effects of deterioration or the AvAero Hush Kit

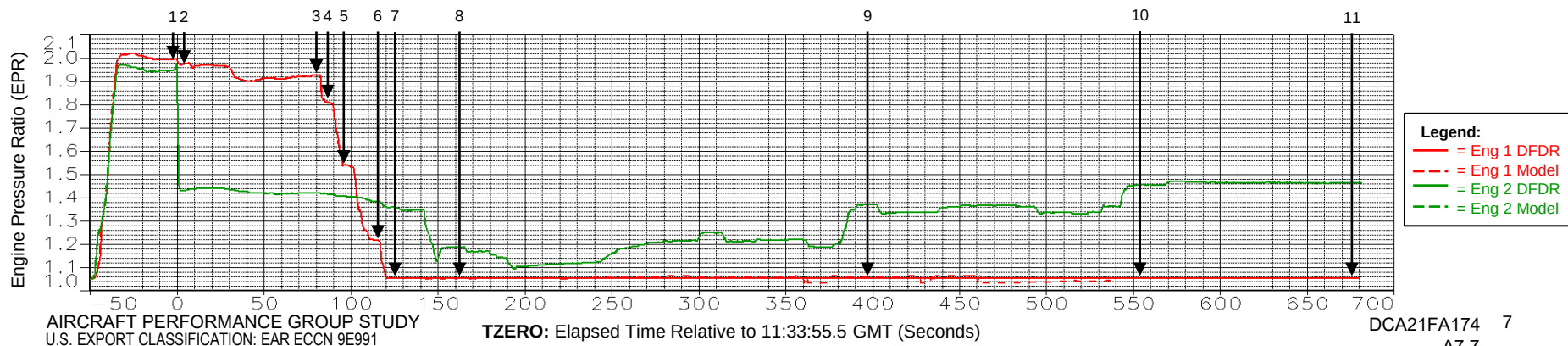
Point	TZERO (s)	Air Speed (kts)	Altitude (ft)	EPR	Net Thrust (lbs)	Ram Drag (lbs)	Gross Thrust (lbs)	PLA (Degrees)	N1 Speed (RPM)	N2 Speed (RPM)	Fuel Flow (lb/hr)	EGT (Deg F)
1	-1.0	158	298	1.947	11849	2646	14495	120	7891	11258	7926	950
2	3.0	150	524	1.429	5923	1941	7864	90	6380	10187	3942	722
3	80.5	208	2094	1.417	5329	2679	8008	89	6408	10185	3842	713
4	85.6	218	2082	1.415	5295	2835	8130	90	6420	10195	3871	714
5	96.7	242	1921	1.403	5188	3202	8390	89	6429	10208	3924	715
6	115.8	249	2025	1.381	4924	3245	8169	89	6357	10155	3784	705
7	125.9	248	2034	1.357	4644	3159	7803	87	6256	10081	3601	693
8	161.1	246	1797	1.185	2755	2616	5371	80	5316	9417	2428	620
9	397.8	170	634	1.366	5072	2131	7203	87	6150	10026	3543	694
10	553.9	142	261	1.452	6304	1910	8214	91	6469	10256	4145	734
11	676.7	122	27	1.462	6581	1614	8195	92	6481	10267	4184	738



ENG #1 JT8D-9 W/ HUSH KIT SIMULATION ANALYSIS

Simulation includes effects of AvAero Hush Kit. This increases Thrust, N1, N2, and Fuel Flow to base JT8D-9 simulation

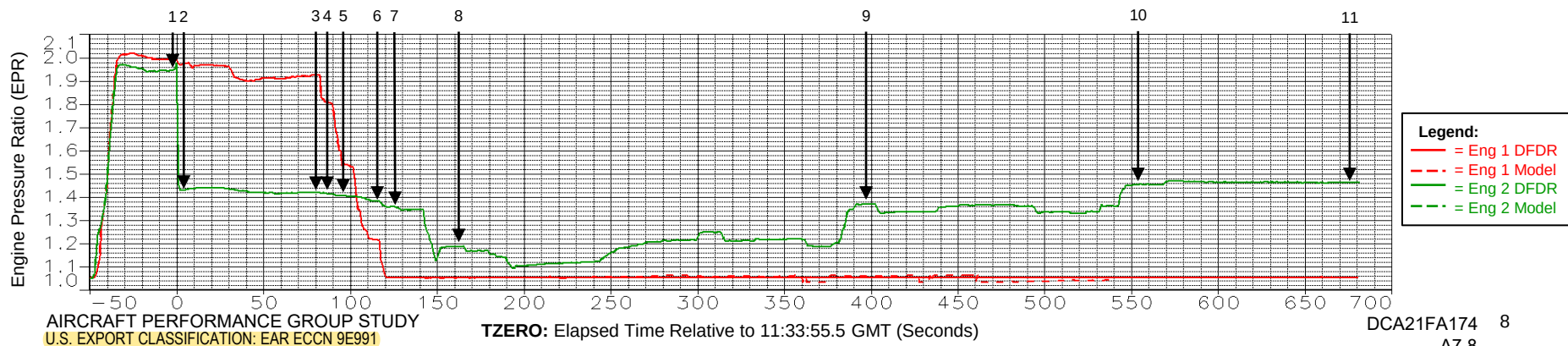
Point	TZERO (s)	Air Speed (kts)	Altitude (ft)	EPR	Net Thrust (lbs)	PLA (Degrees)	N1 Speed (RPM)	N2 Speed (RPM)	Fuel Flow (lb/hr)	EGT (Deg F)
1	-1.0	158	298	1.994	12639	125	8197	11439	8694	986
2	3.0	150	524	1.970	12309	123	8116	11382	8346	967
3	80.5	208	2094	1.928	10973	121	8002	11297	7788	941
4	85.6	218	2082	1.811	9773	114	7692	11101	6913	891
5	96.7	242	1921	1.542	6956	100	6971	10632	5086	779
6	115.8	249	2025	1.214	3166	82	5638	9651	2726	628
7	125.9	248	2034	1.051	1263	77	4171	8533	1806	672
8	161.1	246	1797	1.051	1258	77	4150	8515	1804	673
9	397.8	170	634	1.051	1132	75	3656	7999	1553	682
10	553.9	142	261	1.052	1004	74	3378	7648	1437	694
11	676.7	122	27	1.052	972	73	3231	7461	1368	701



ENG #2 JT8D-9 W/ HUSH KIT SIMULATION ANALYSIS

Simulation includes effects of AvAero Hush Kit. This increases Thrust, N1, N2, and Fuel Flow to base JT8D-9 simulation

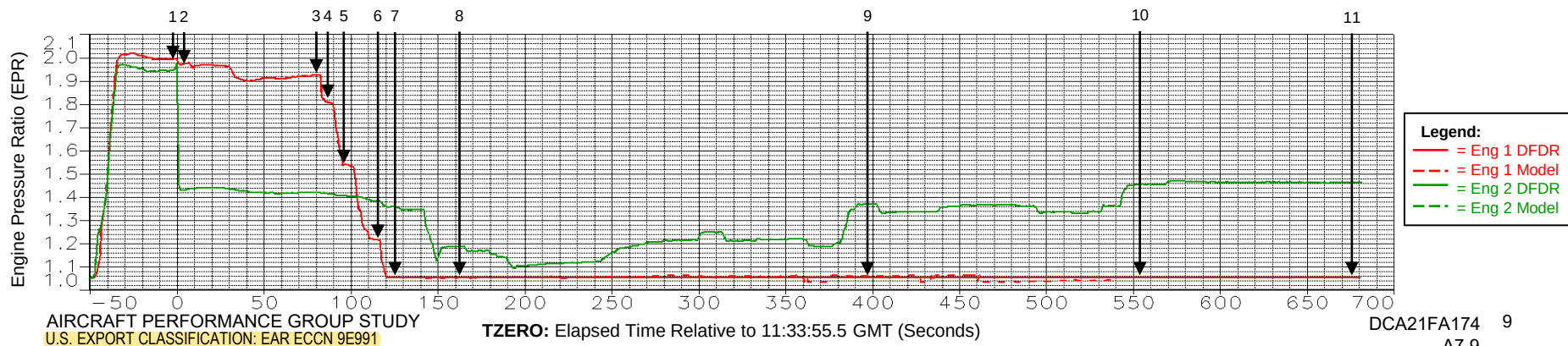
Point	TZERO (s)	Air Speed (kts)	Altitude (ft)	EPR	Net Thrust (lbs)	PLA (Degrees)	N1 Speed (RPM)	N2 Speed (RPM)	Fuel Flow (lb/hr)	EGT (Deg F)
1	-1.0	158	298	1.947	12121	123	8060	11352	8240	957
2	3.0	150	524	1.429	6117	91	6472	10272	4077	718
3	80.5	208	2094	1.417	5513	90	6503	10268	3980	710
4	85.6	218	2082	1.415	5481	91	6515	10279	4012	711
5	96.7	242	1921	1.403	5372	91	6526	10294	4067	711
6	115.8	249	2025	1.381	5099	90	6456	10248	3924	702
7	125.9	248	2034	1.357	4809	88	6355	10179	3736	690
8	161.1	246	1797	1.185	2864	81	5437	9492	2535	620
9	397.8	170	634	1.366	5241	88	6242	10110	3672	692
10	553.9	142	261	1.452	6513	92	6559	10343	4284	730
11	676.7	122	27	1.462	6796	93	6569	10354	4322	733



ENG #1 JT8D-9 W/ HUSH KIT AND DETERIORATION SIMULATION ANALYSIS

Simulation includes effects of AvAero Hush Kit and deterioration.

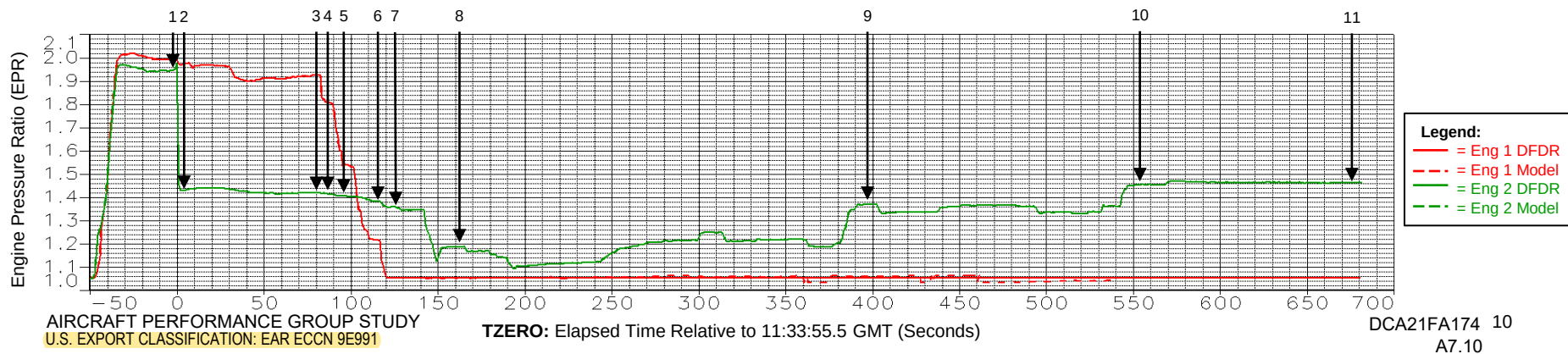
Point	TZERO (s)	Air Speed (kts)	Altitude (ft)	EPR	Net Thrust (lbs)	PLA (Degrees)	N1 Speed (RPM)	N2 Speed (RPM)	Fuel Flow (lb/hr)	EGT (Deg F)
1	-1.0	158	298	1.994	12682	130	8142	11437	8998	1046
2	3.0	150	524	1.970	12349	128	8066	11383	8644	1027
3	80.5	208	2094	1.928	11036	126	7960	11317	8100	1005
4	85.6	218	2082	1.811	9831	122	7667	11159	7232	959
5	96.7	242	1921	1.542	6993	106	6973	10693	5350	842
6	115.8	249	2025	1.214	3211	84	5643	9676	2927	695
7	125.9	248	2034	1.051	1291	78	4176	8562	1928	727
8	161.1	246	1797	1.051	1285	78	4154	8543	1926	728
9	397.8	170	634	1.051	1143	76	3654	8023	1648	736
10	553.9	142	261	1.052	996	75	3359	7641	1514	753
11	676.7	122	27	1.052	962	74	3212	7461	1441	758



ENG #2 JT8D-9 W/ HUSH KIT AND DETERIORATION SIMULATION ANALYSIS

Simulation includes effects of AvAero Hush Kit and deterioration.

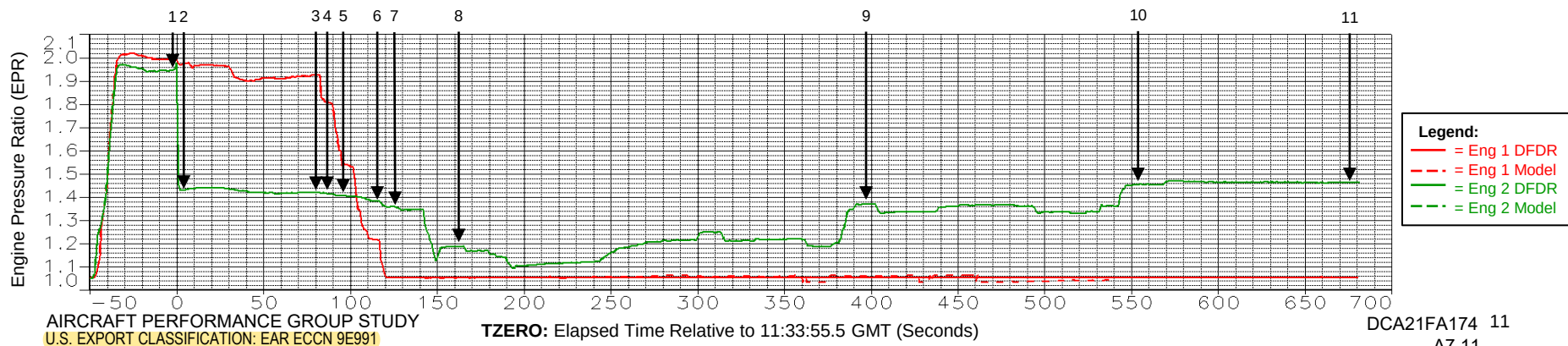
Point	TZERO (s)	Air Speed (kts)	Altitude (ft)	EPR	Net Thrust (lbs)	PLA (Degrees)	N1 Speed (RPM)	N2 Speed (RPM)	Fuel Flow (lb/hr)	EGT (Deg F)
1	-1.0	158	298	1.947	12163	128	8014	11358	8527	1014
2	3.0	150	524	1.429	6135	96	6478	10308	4297	778
3	80.5	208	2094	1.417	5542	95	6508	10310	4194	768
4	85.6	218	2082	1.415	5512	96	6521	10321	4228	769
5	96.7	242	1921	1.403	5408	95	6531	10335	4287	770
6	115.8	249	2025	1.381	5137	94	6462	10285	4143	761
7	125.9	248	2034	1.357	4846	92	6359	10209	3949	749
8	161.1	246	1797	1.185	2907	82	5439	9512	2718	684
9	397.8	170	634	1.366	5267	92	6248	10138	3882	753
10	553.9	142	261	1.452	6527	97	6566	10386	4506	789
11	676.7	122	27	1.462	6807	98	6576	10398	4546	792



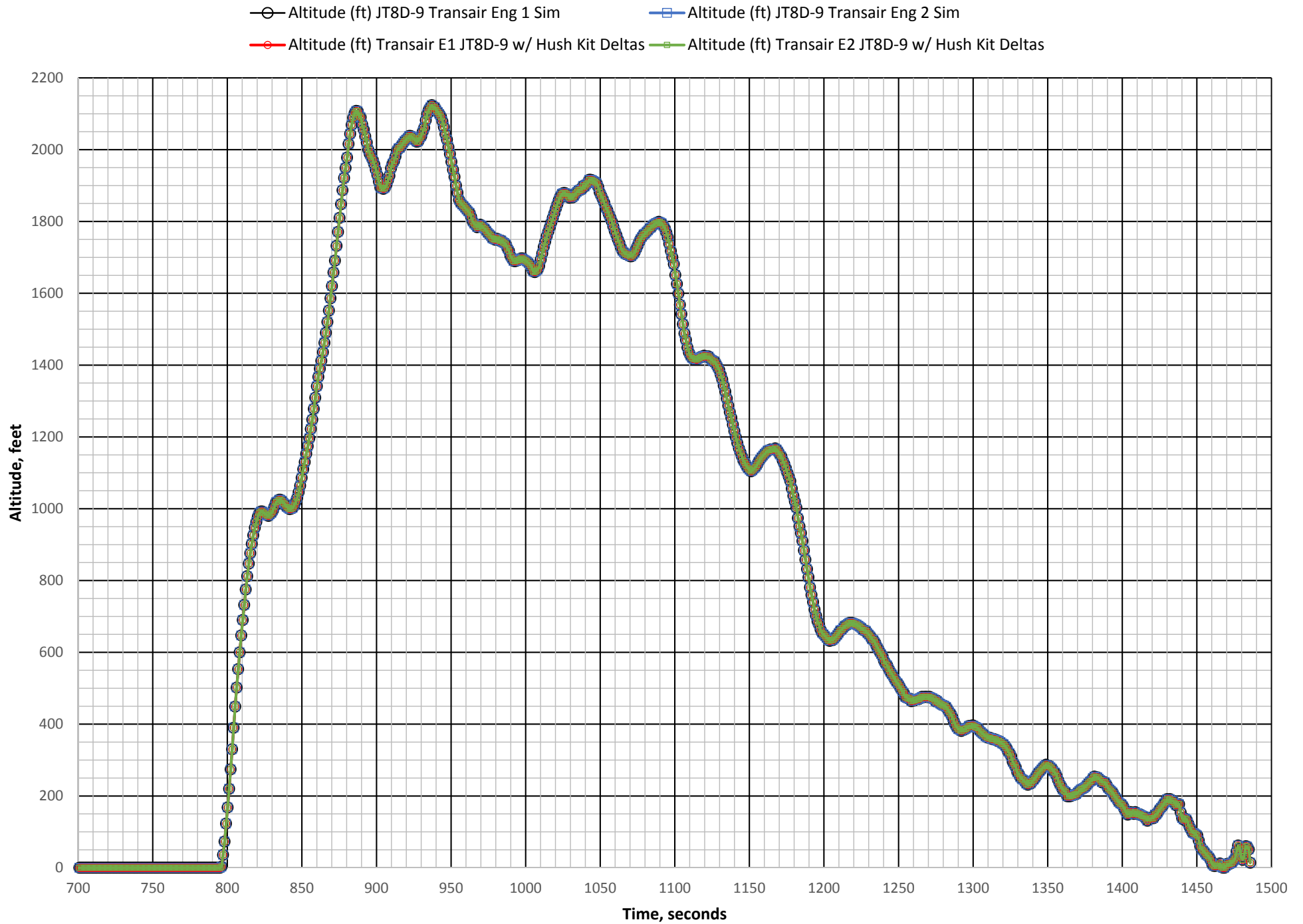
ENG #2 JT8D-9 W/ HUSH KIT, DETERIORATION, & LPT DAMAGE SIMULATION ANALYSIS

Simulation includes effects of AvAero Hush Kit, deterioration, and LPT damage. The damage is added at Tzero.

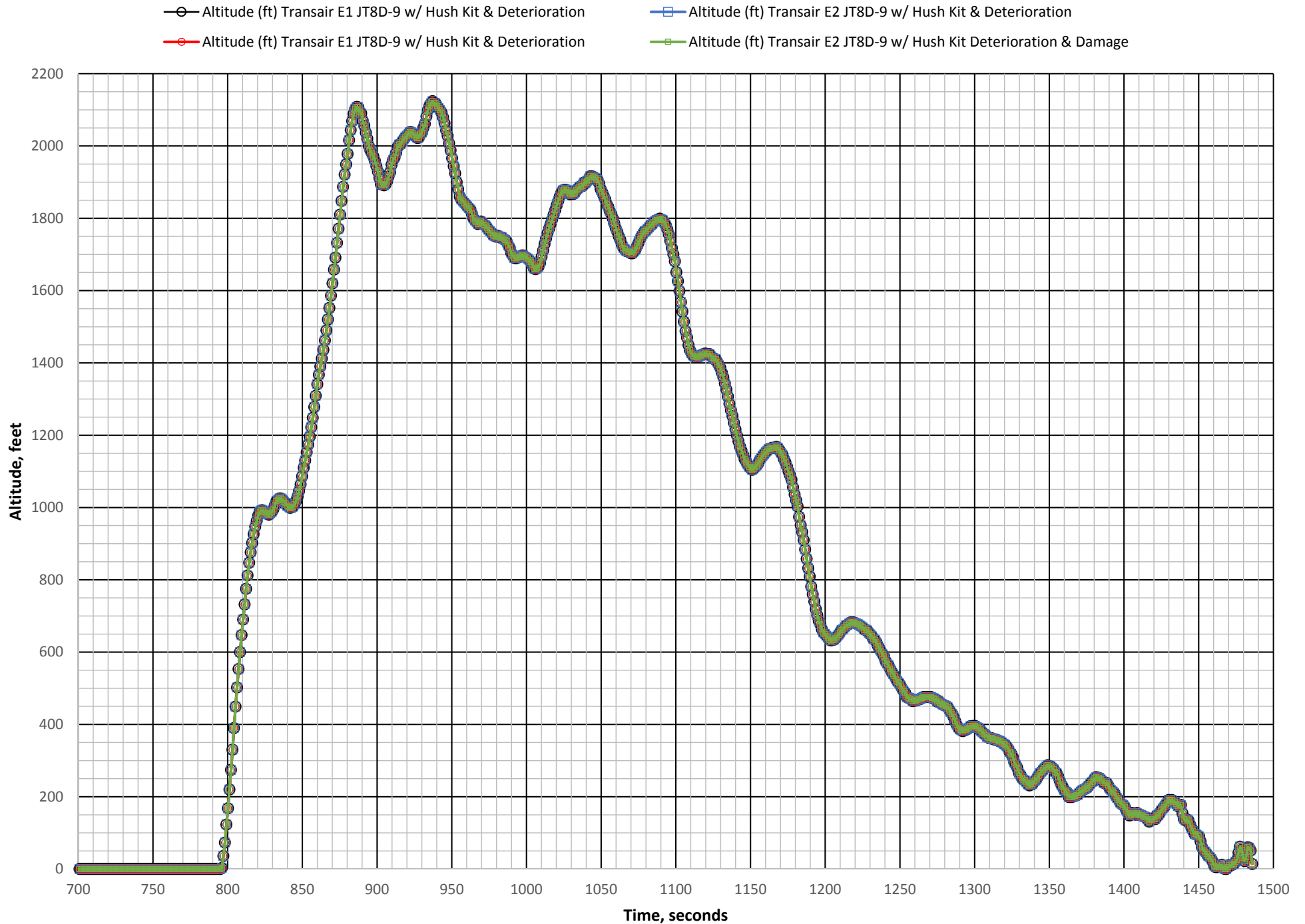
Point	TZERO (s)	Air Speed (kts)	Altitude (ft)	EPR	Net Thrust (lbs)	PLA (Degrees)	N1 Speed (RPM)	N2 Speed (RPM)	Fuel Flow (lb/hr)	EGT (Deg F)
1	-1.0	158	298	1.947	12163	128	8014	11358	8527	1014
2	3.0	150	524	1.429	5480	122	5947	11395	4862	952
3	80.5	208	2094	1.417	4956	121	5980	11381	4744	941
4	85.6	218	2082	1.415	4930	122	5992	11386	4784	943
5	96.7	242	1921	1.403	4838	121	6000	11389	4850	944
6	115.8	249	2025	1.381	4580	120	5928	11347	4664	926
7	125.9	248	2034	1.357	4299	117	5823	11288	4419	904
8	161.1	246	1797	1.185	2468	96	4773	10421	2979	807
9	397.8	170	634	1.366	4674	117	5700	11254	4336	907
10	553.9	142	261	1.452	5844	124	6039	11470	5126	973
11	676.7	122	27	1.462	6093	125	6051	11487	5177	978



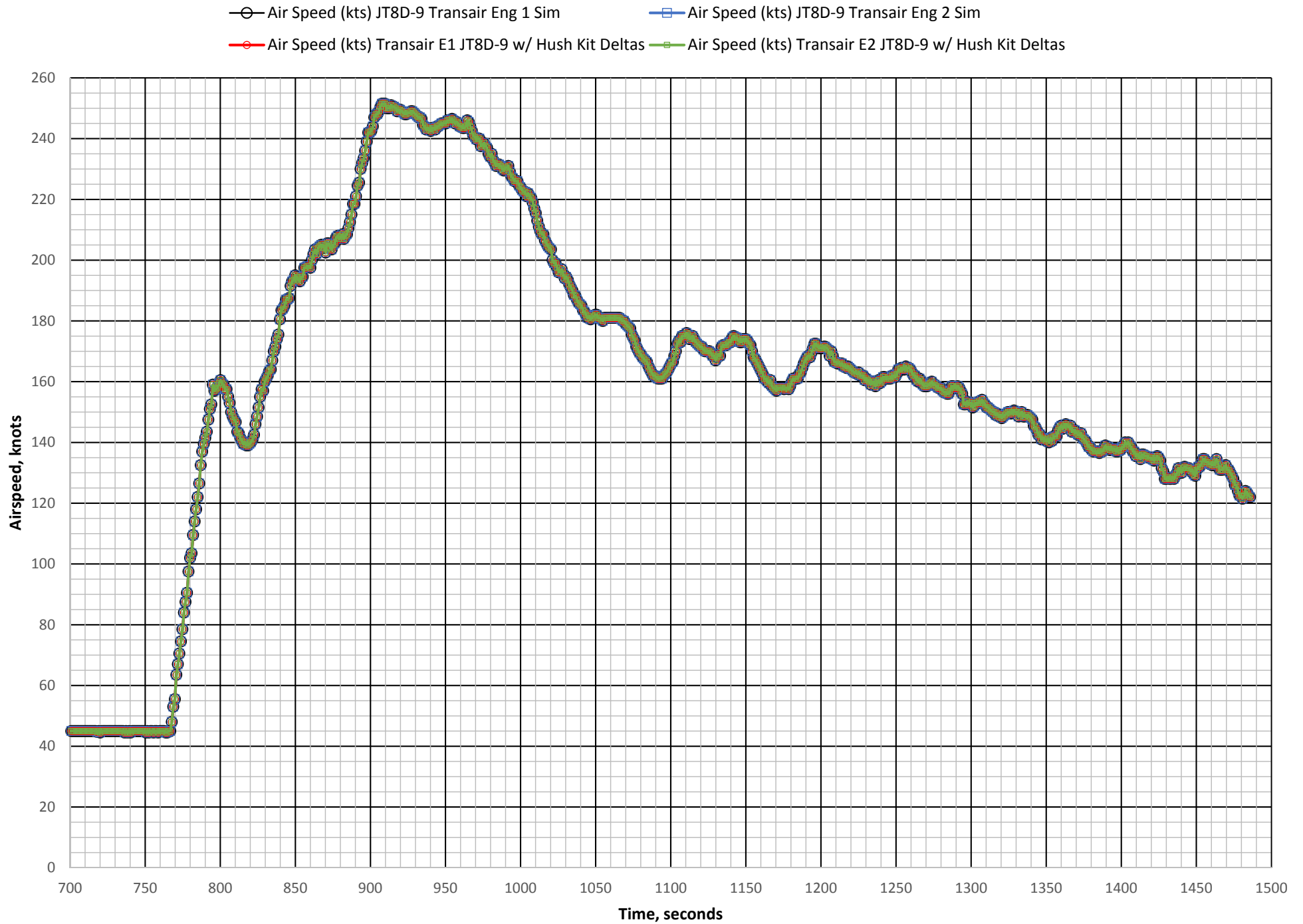
Engine Model Data



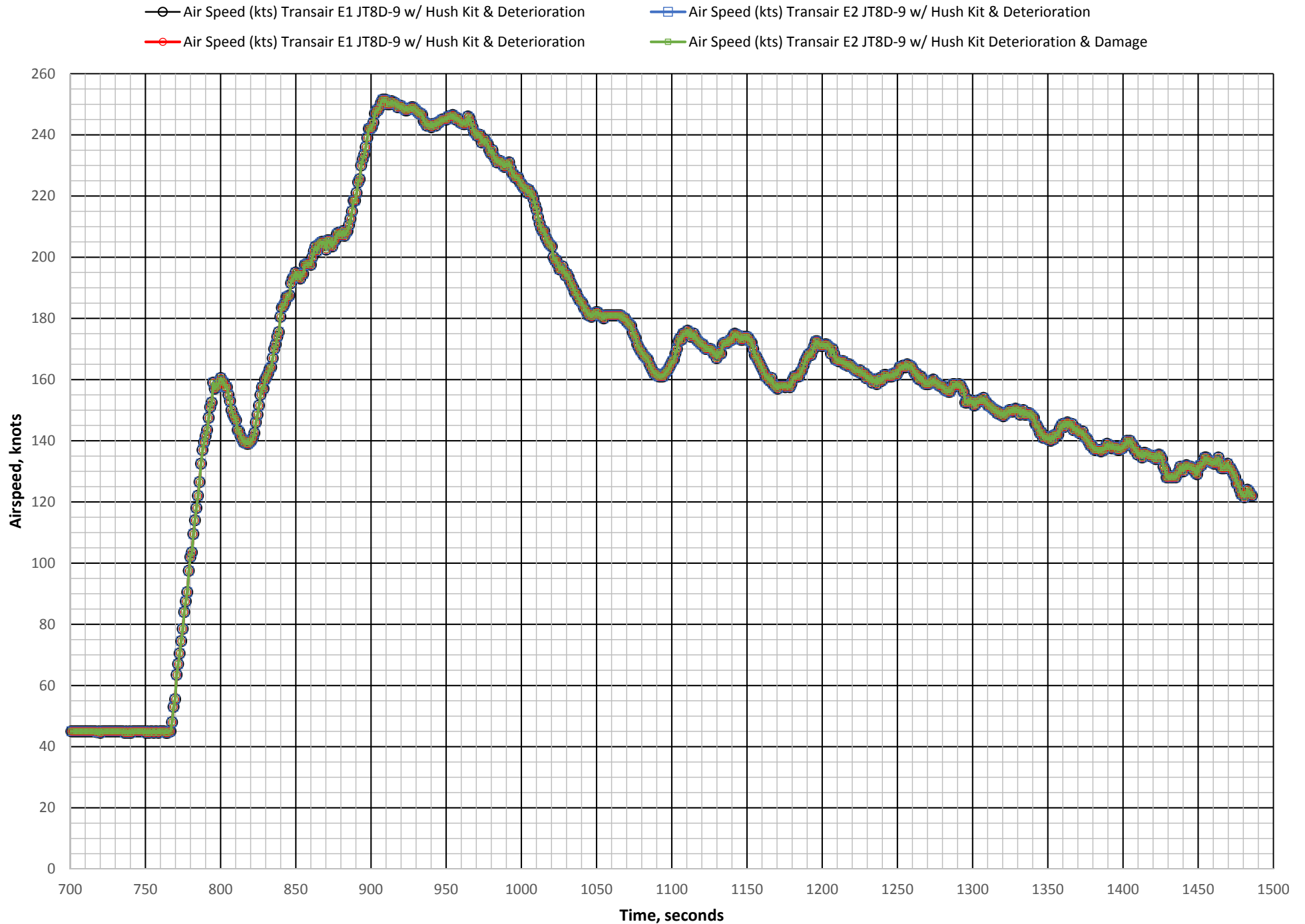
Engine Model Data



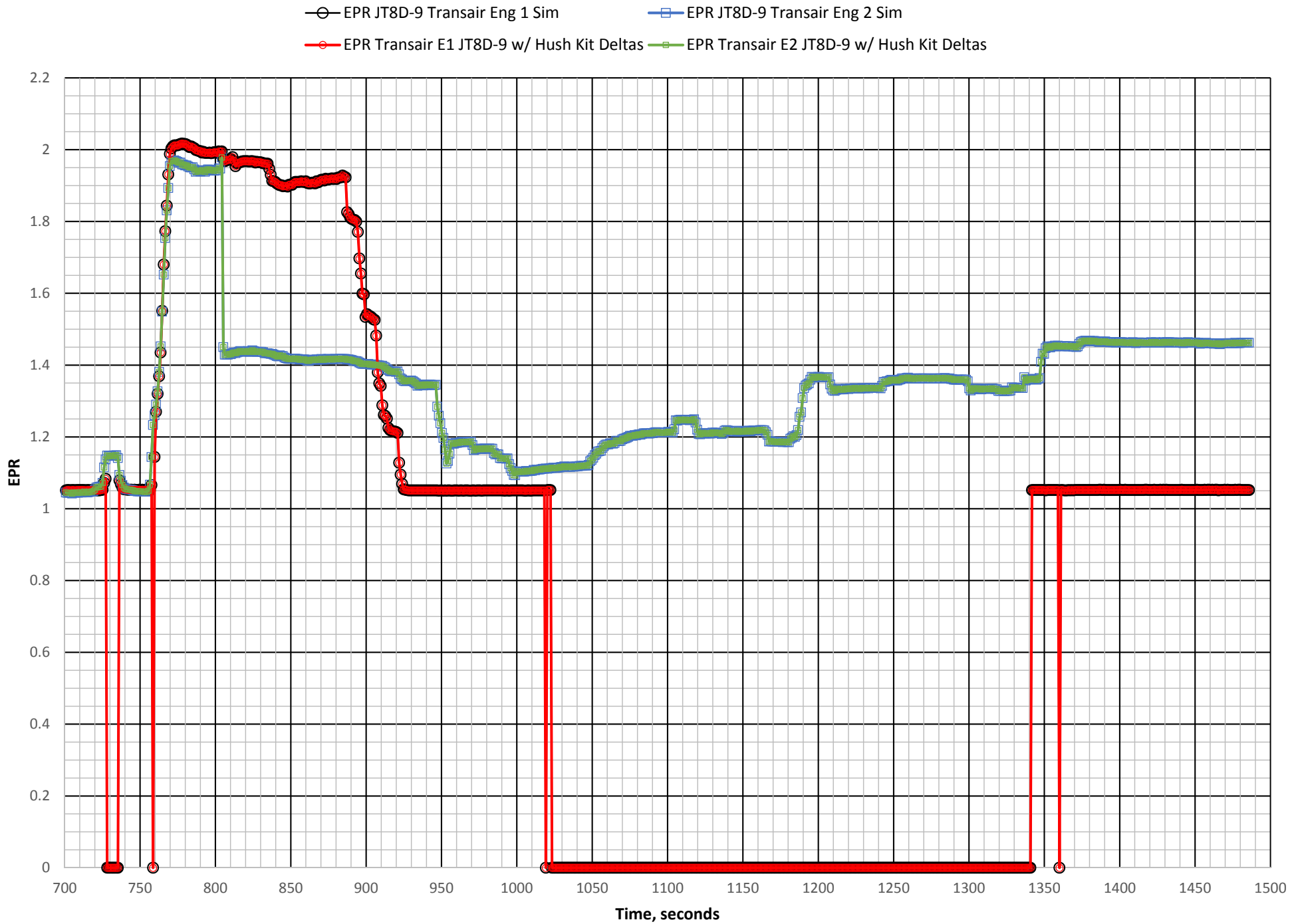
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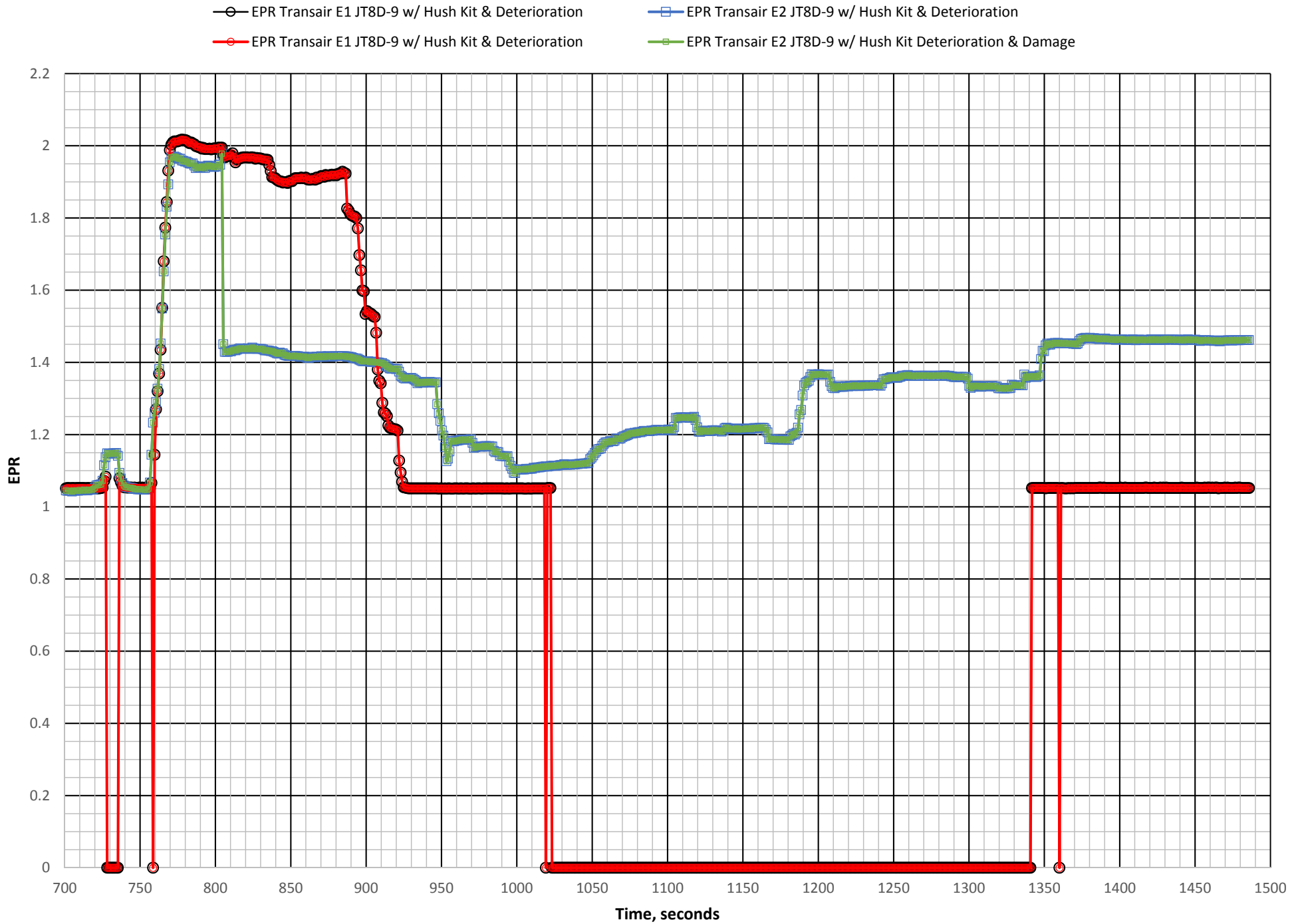
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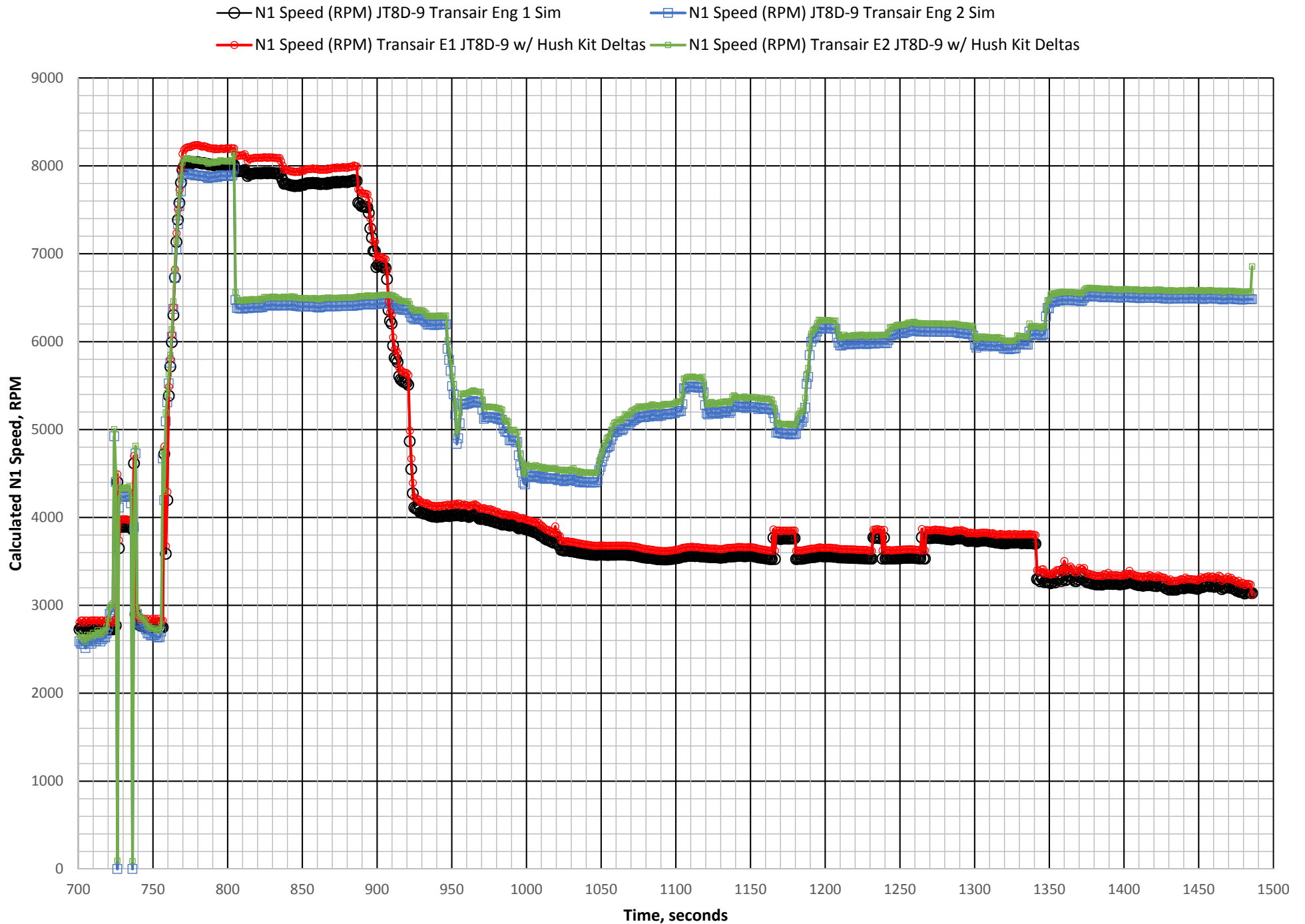
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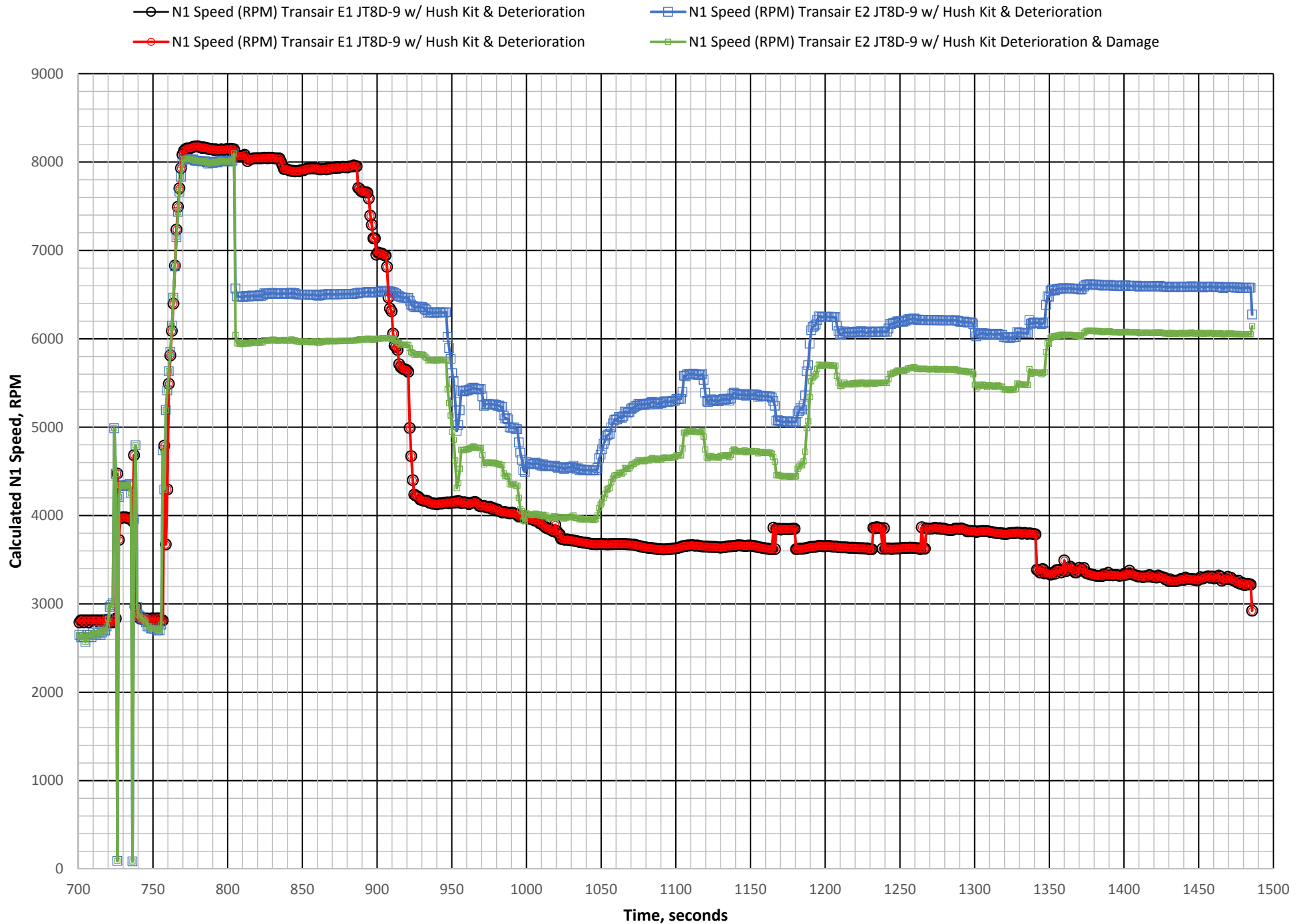
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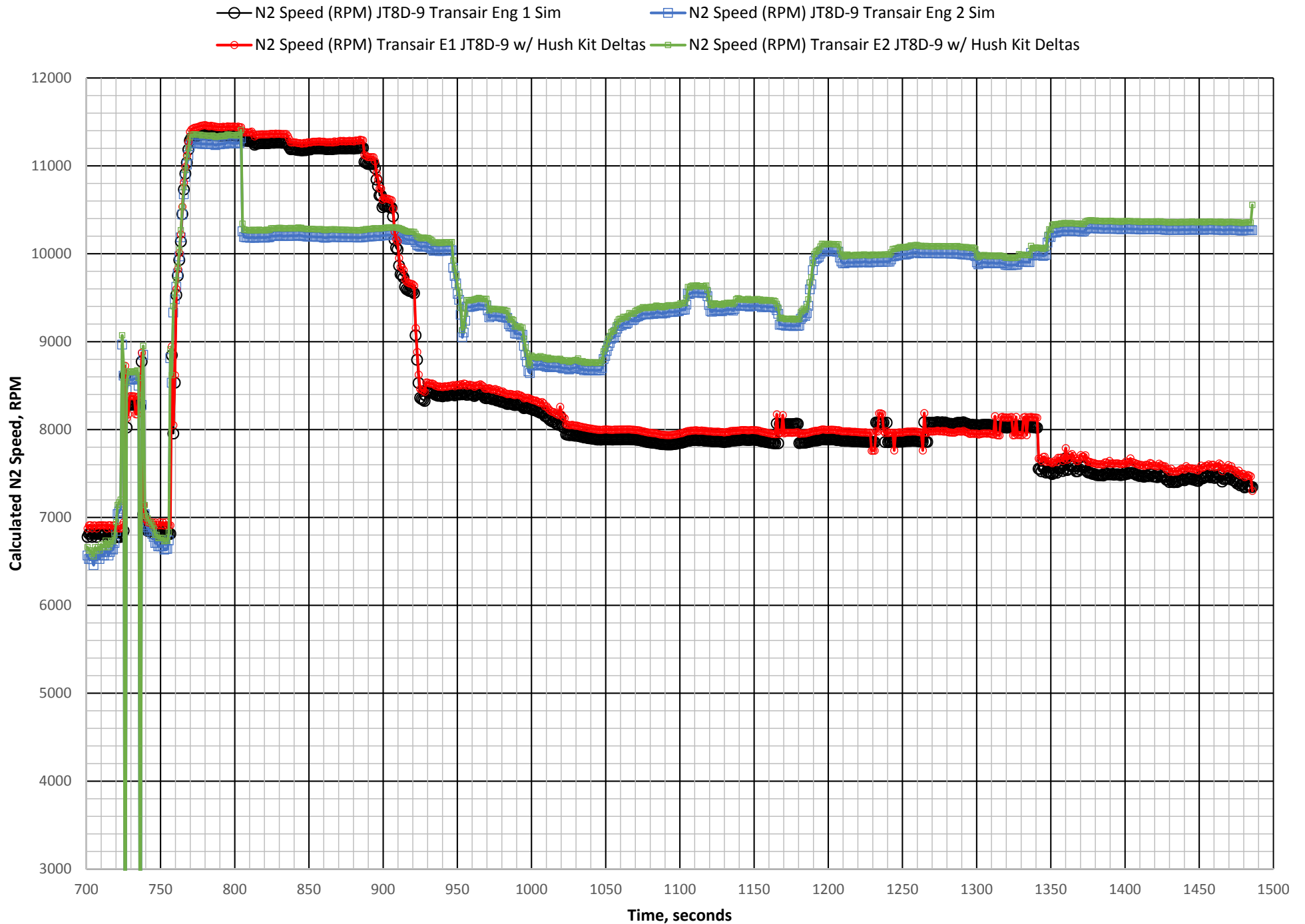
Engine Model Data



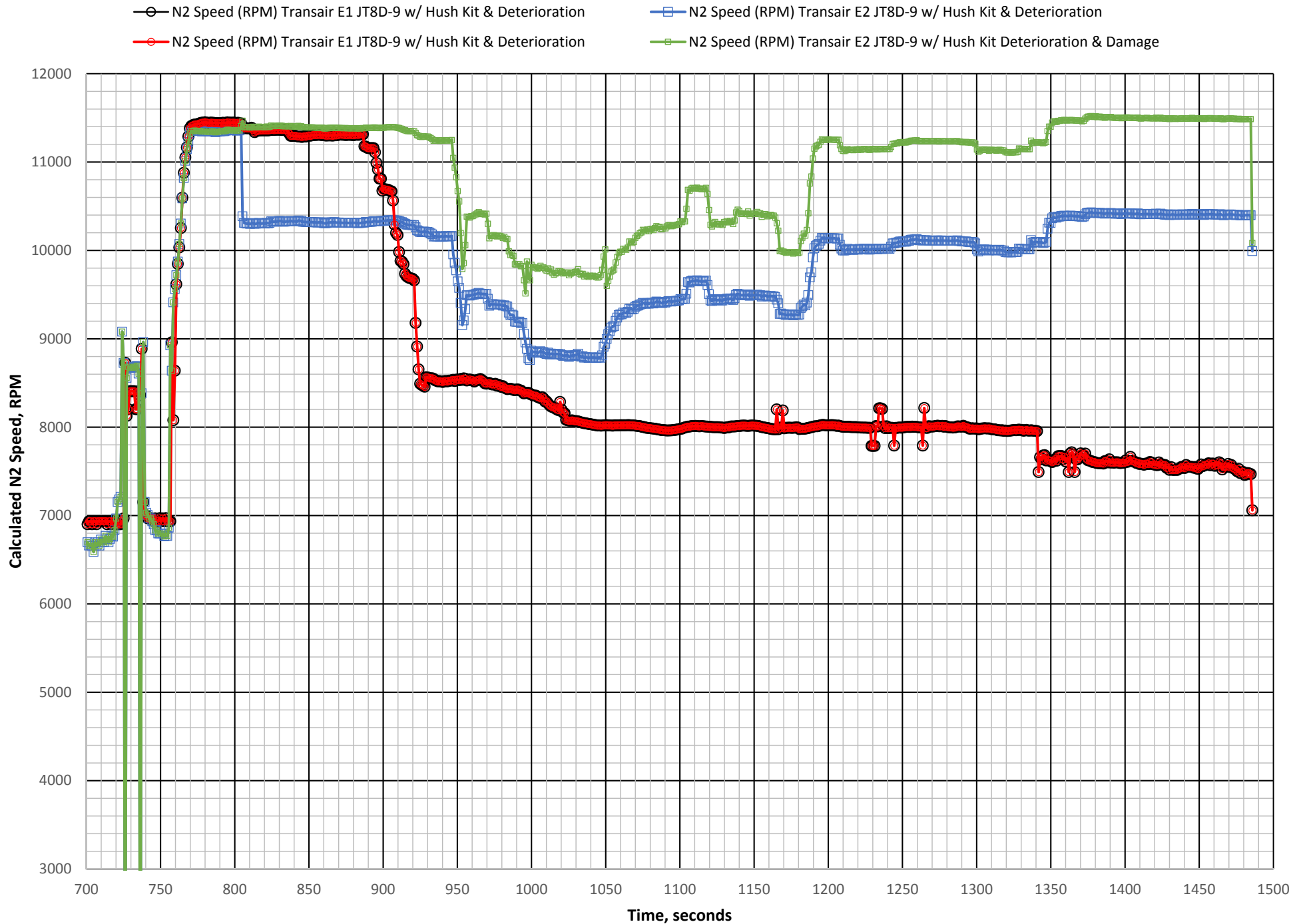
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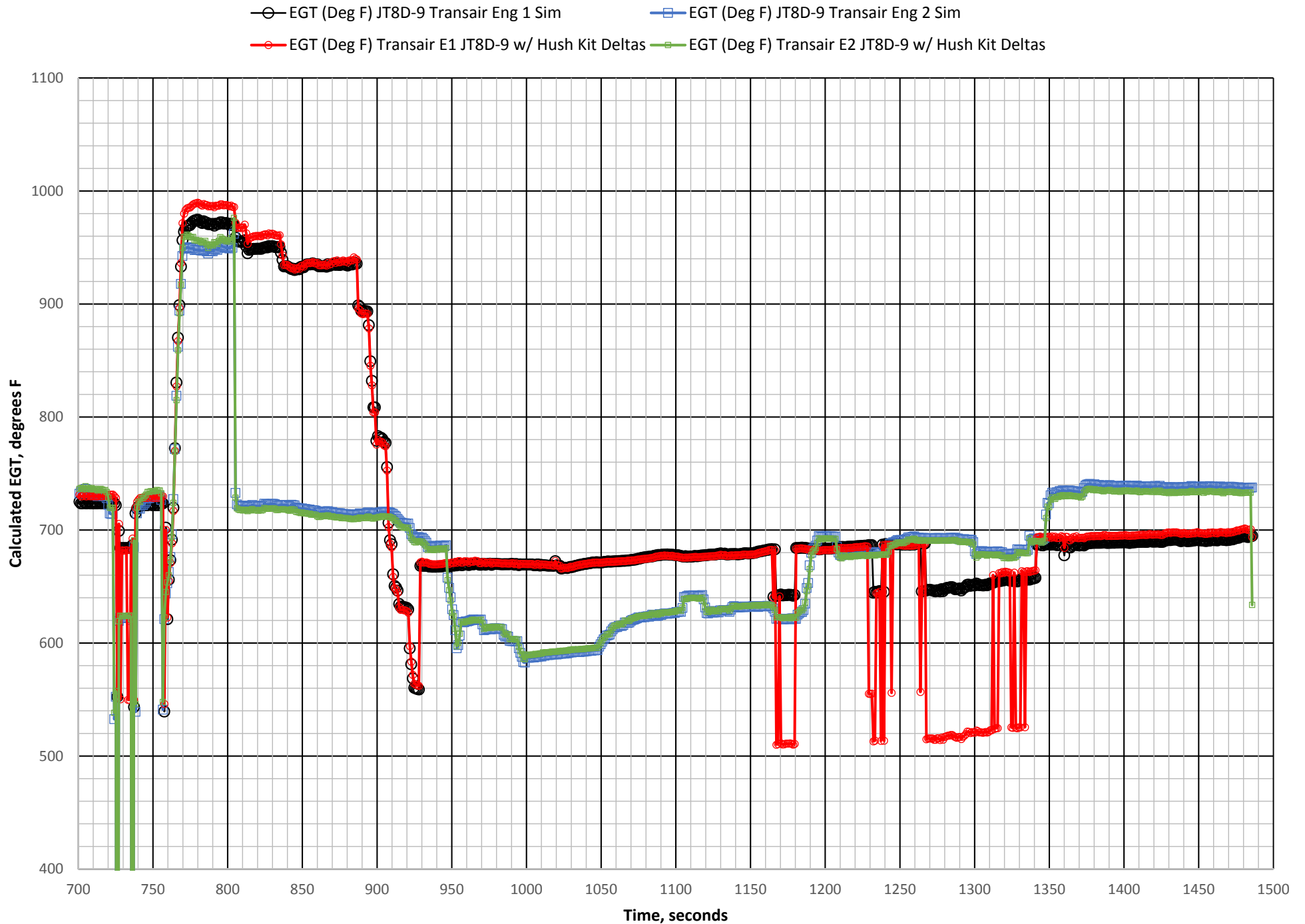
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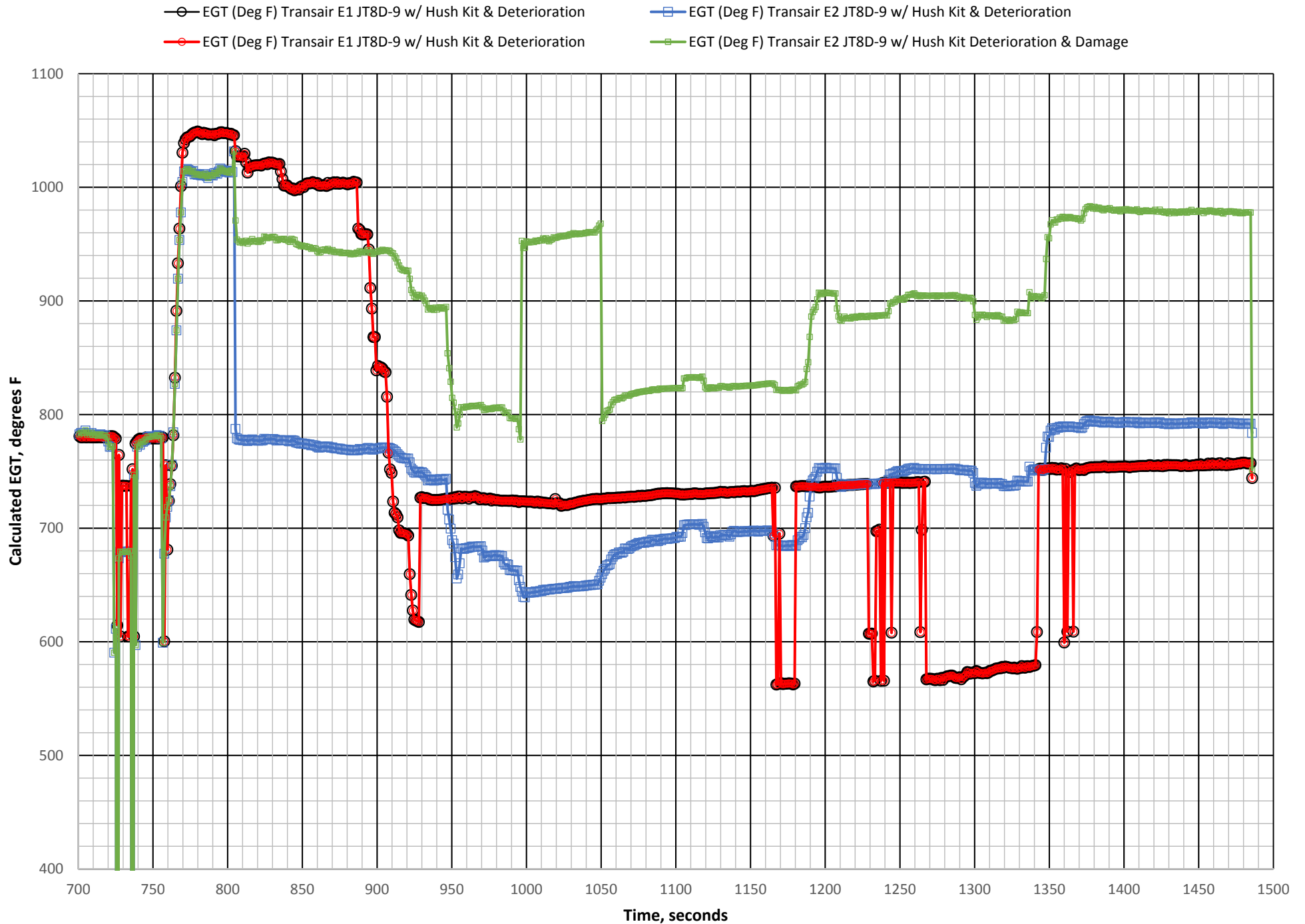
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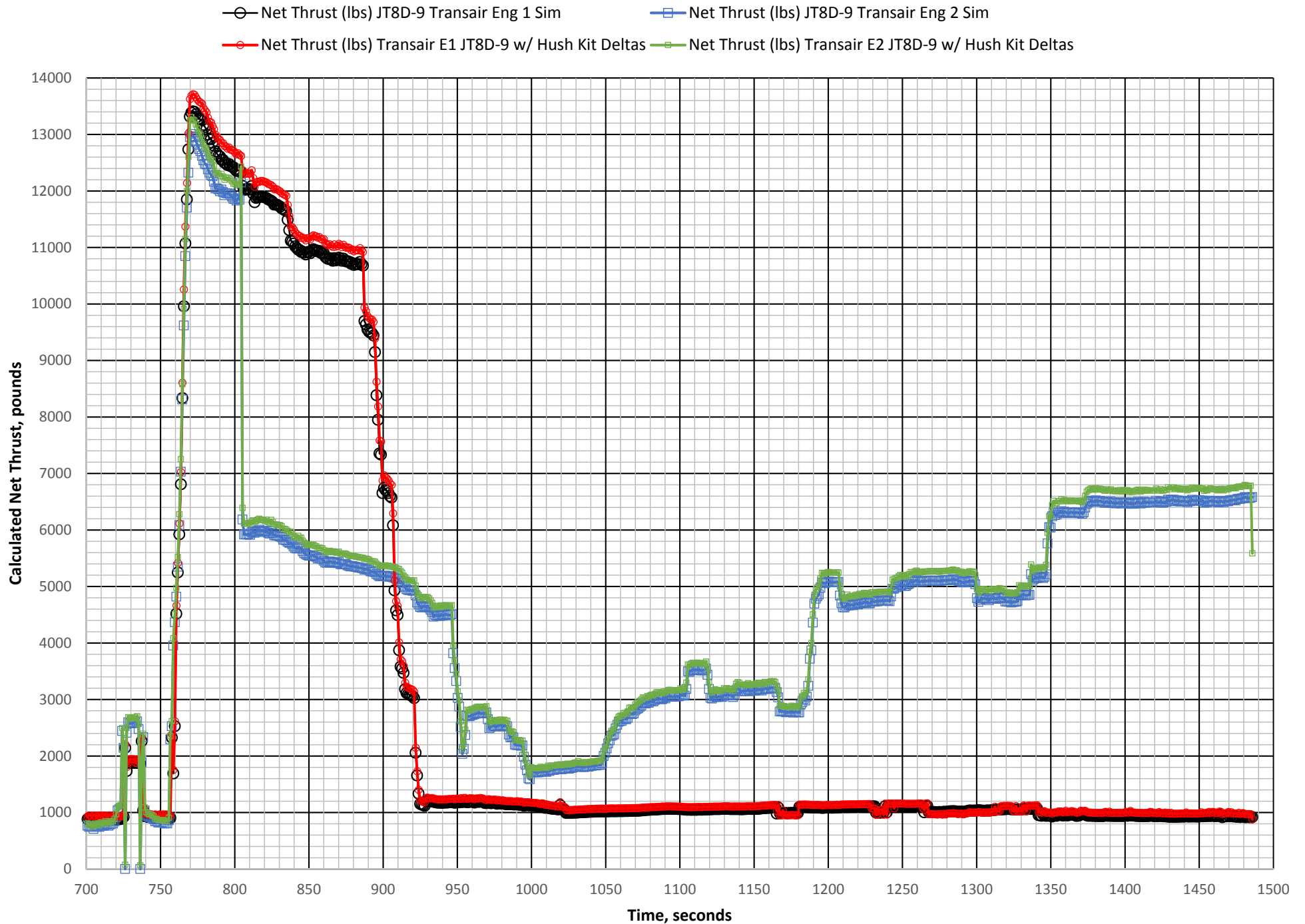
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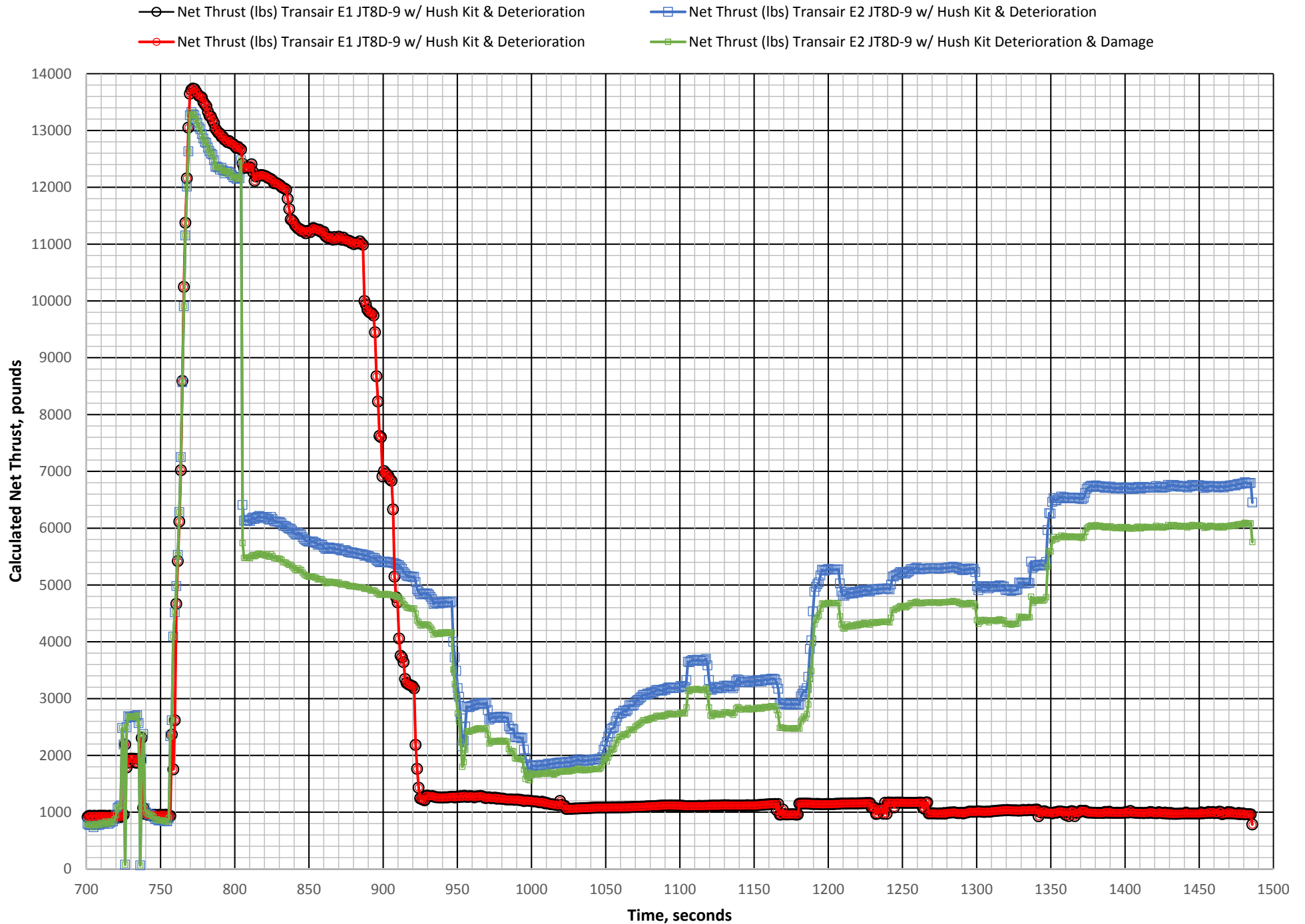
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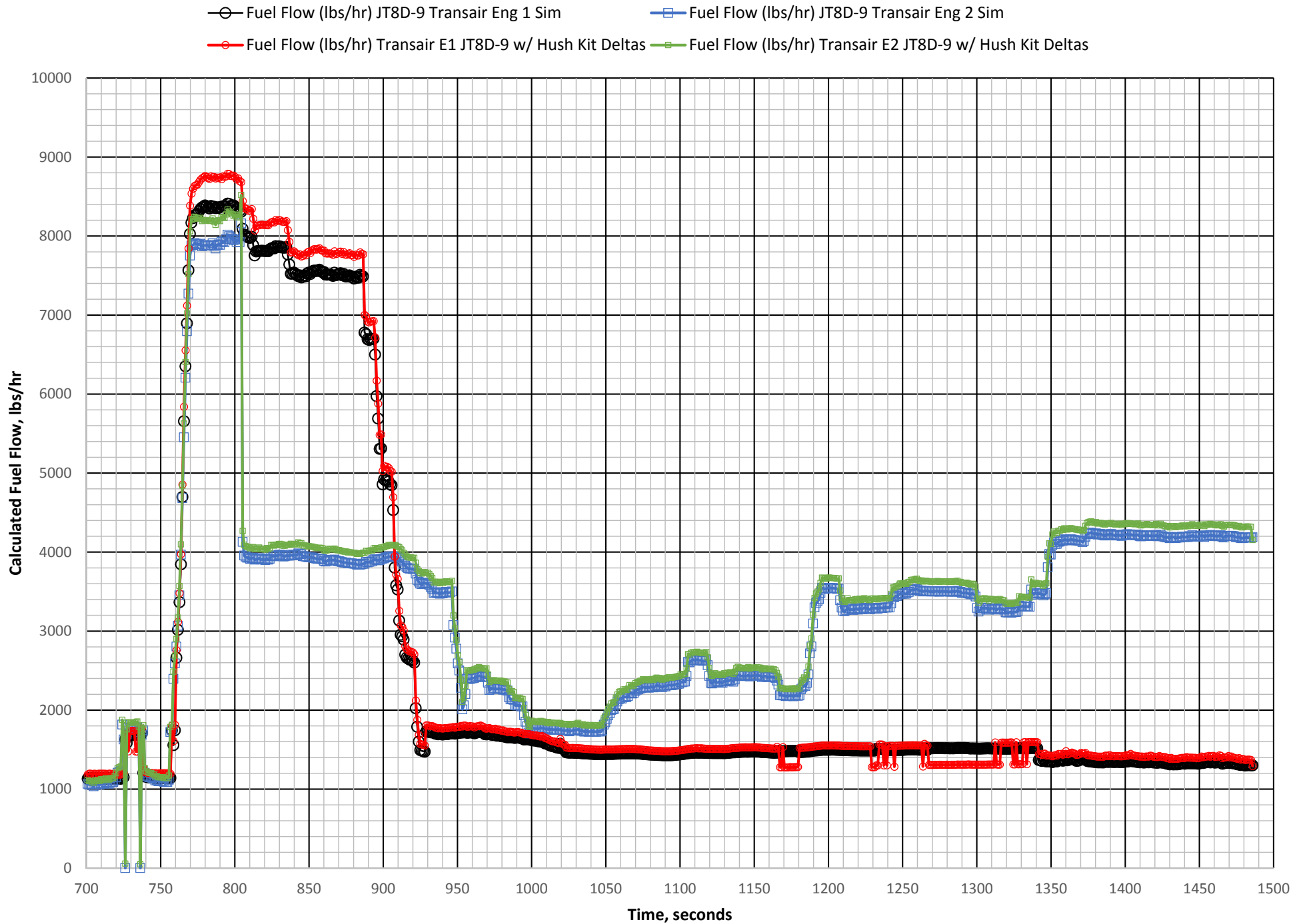
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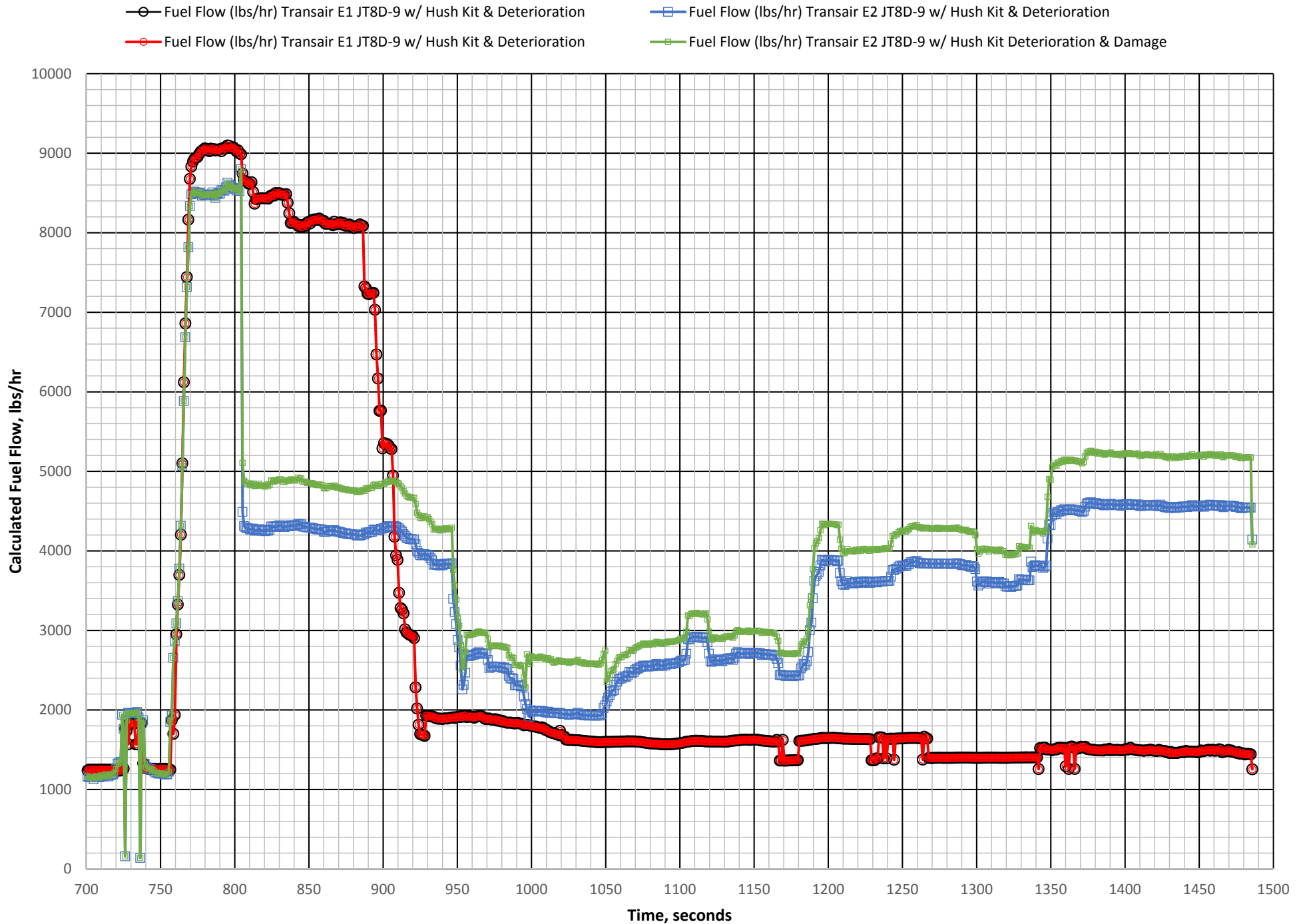
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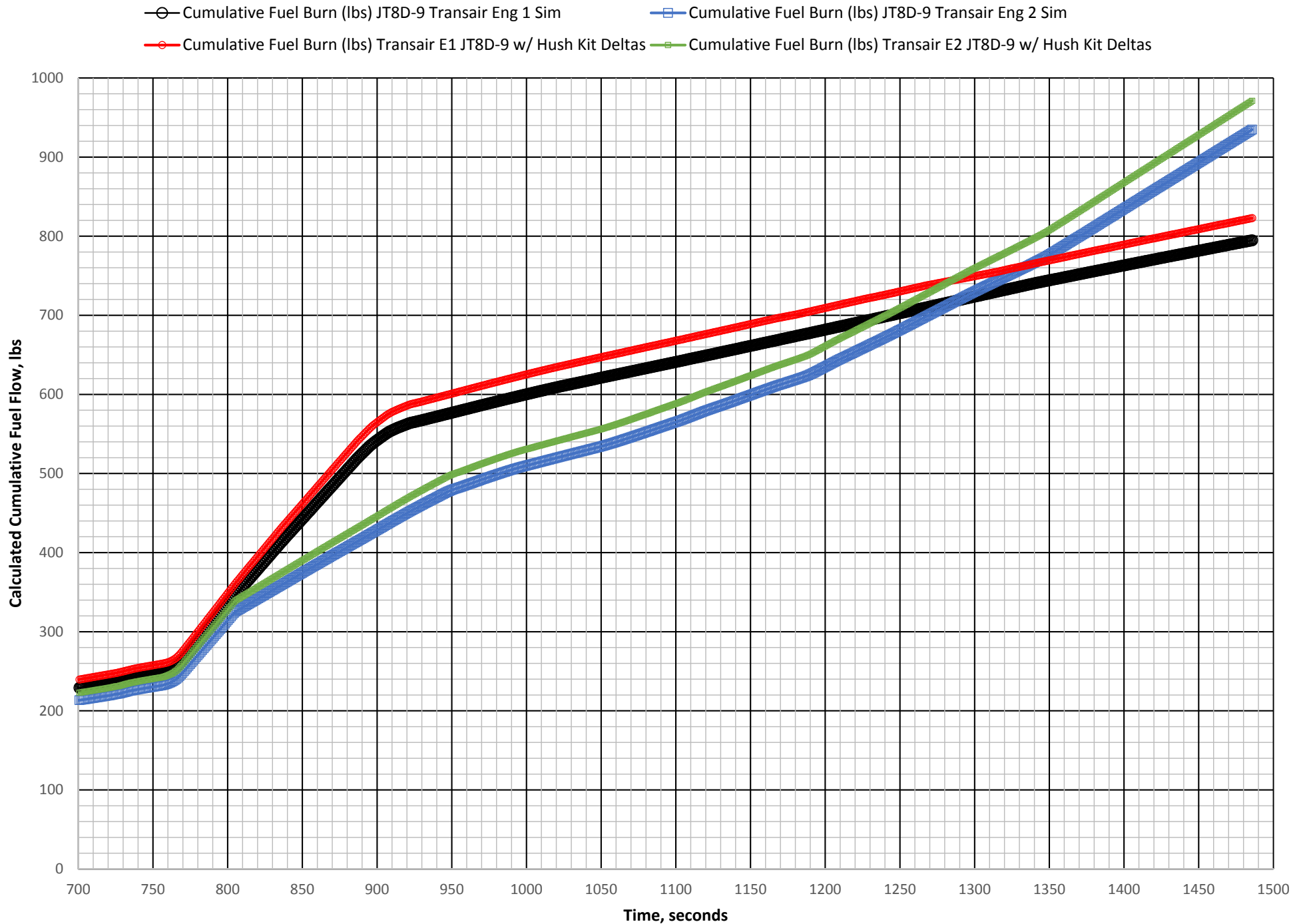
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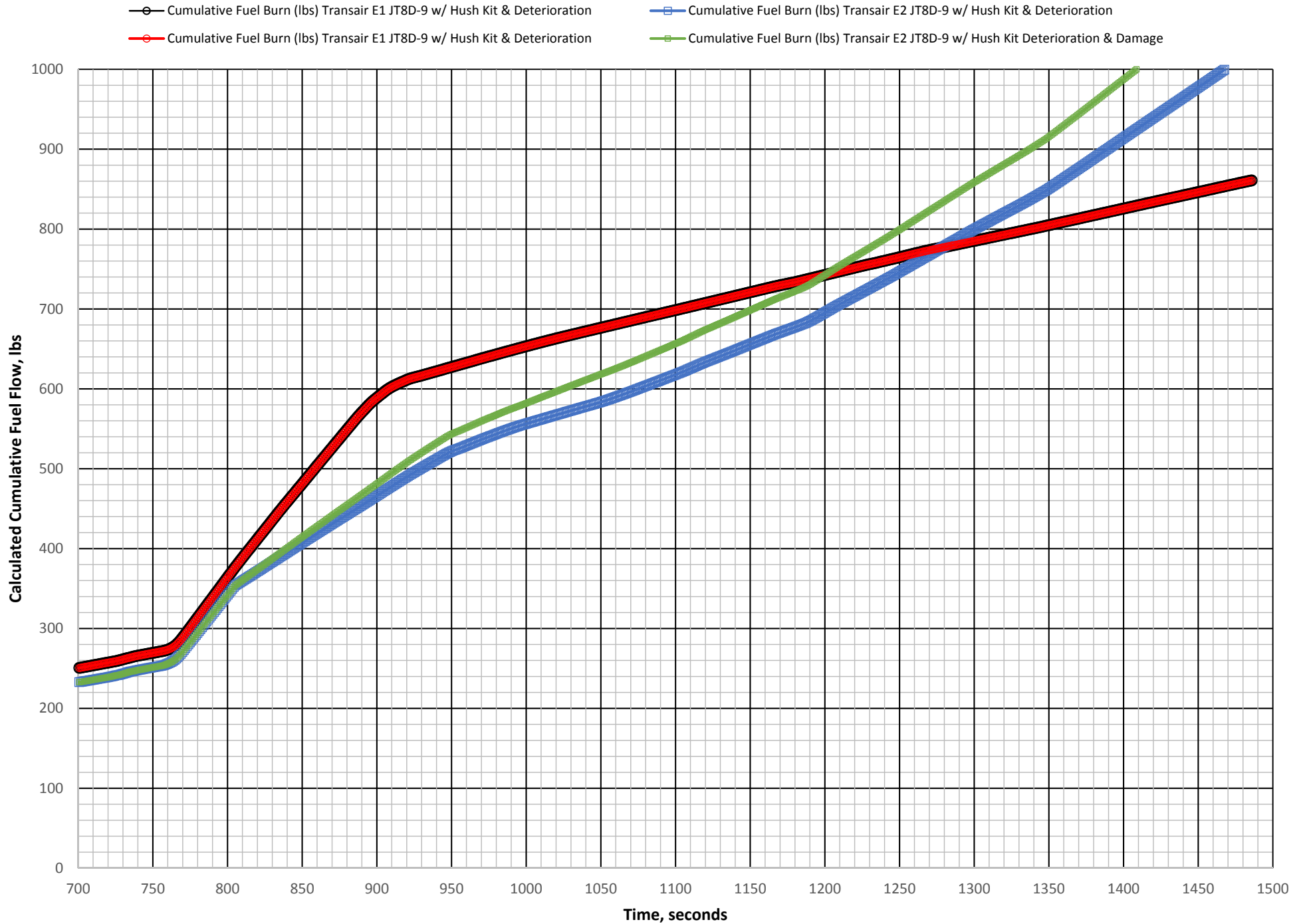
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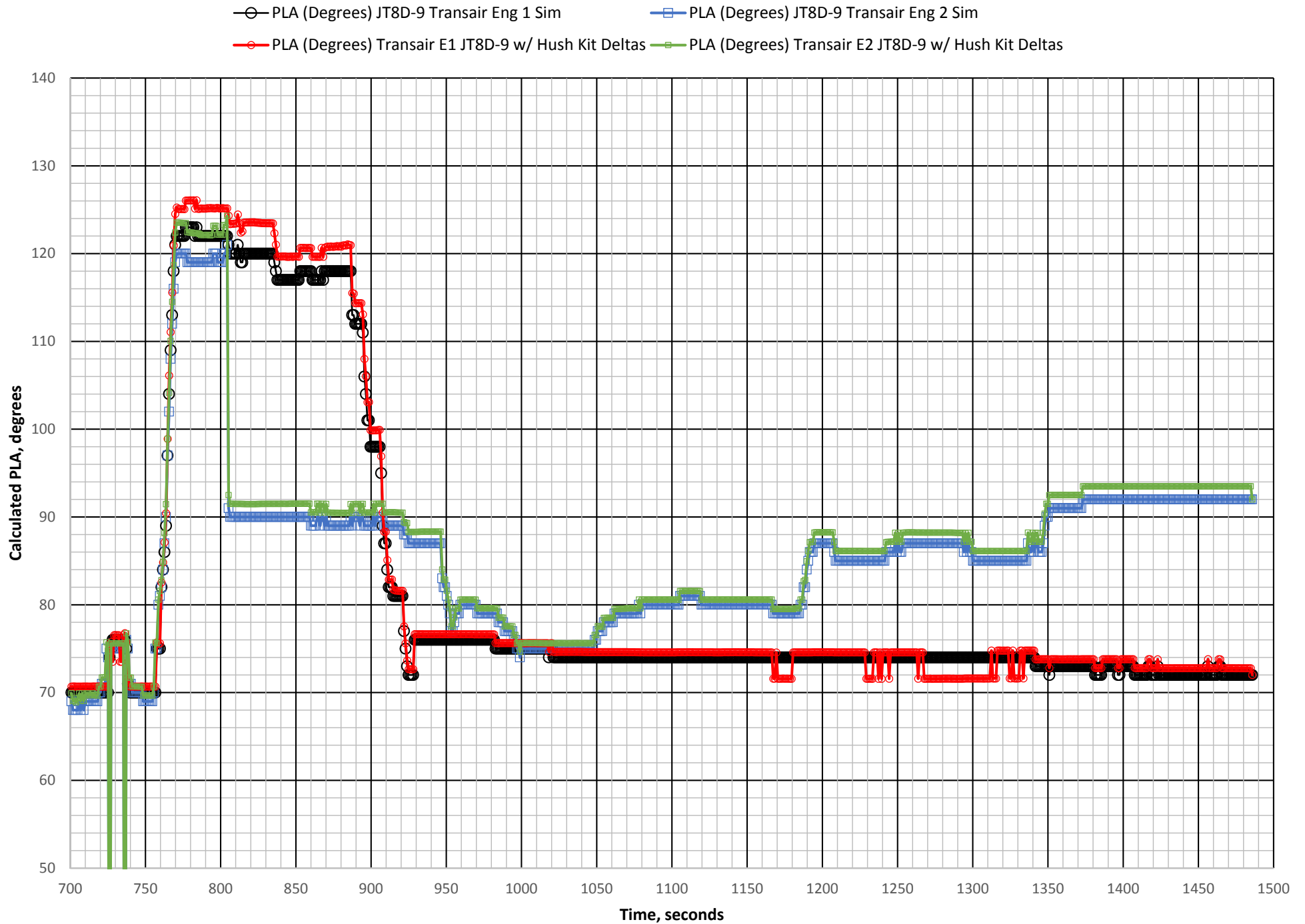
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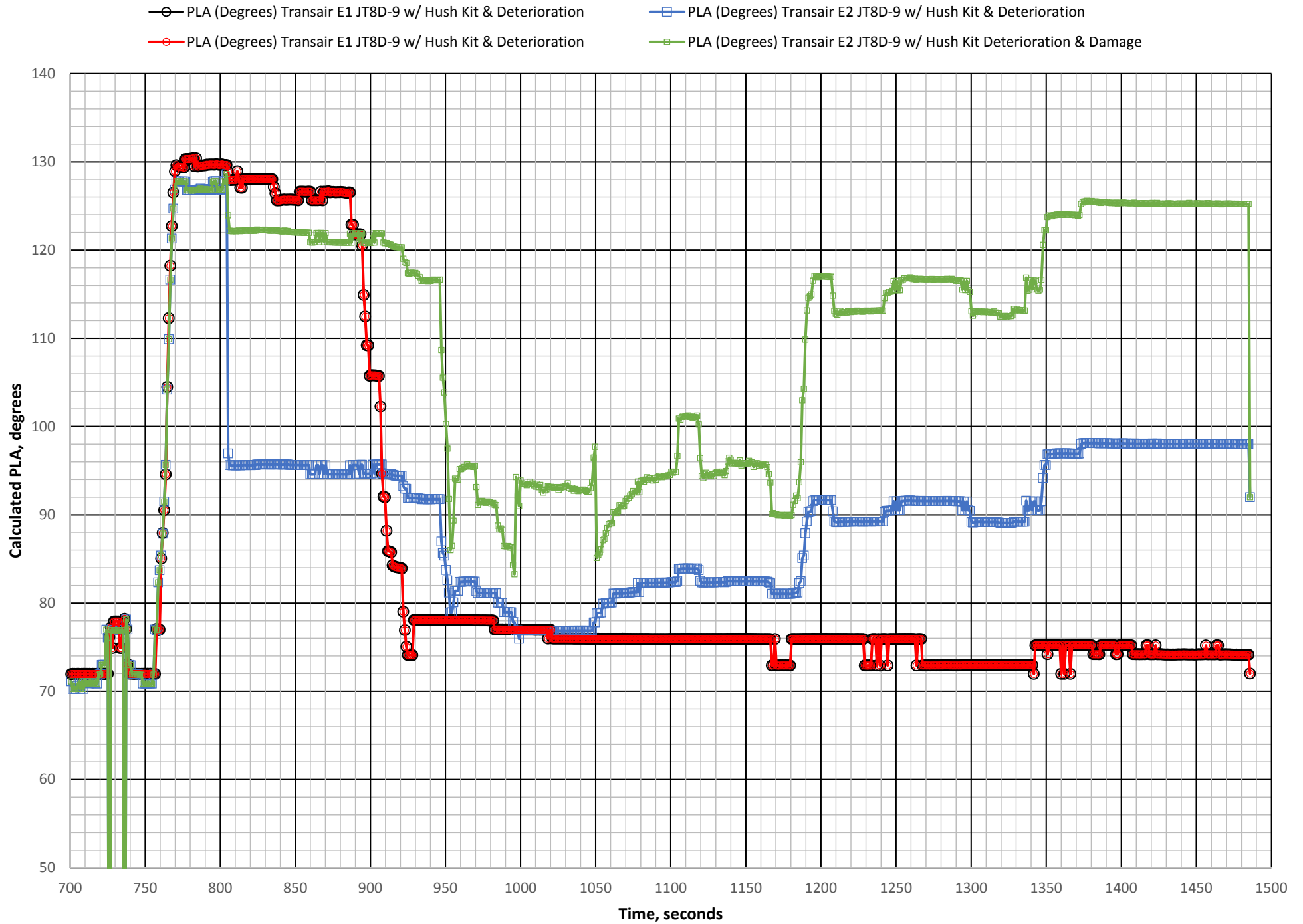
Engine Model Data



Engine Model Data



Engine Model Data



ATTACHMENT 8: B737-200 CLIMB PERFORMANCE

Based on Data Used to Develop the Airplane Flight Manual (AFM)

- All engines operating (AEO) thrust
- One engine inoperative (OEI) thrust and climb performance
- N810TA flight 810 thrust and climb performance

Figure 14. Performance Assessment of Climb Capability During Event Flight

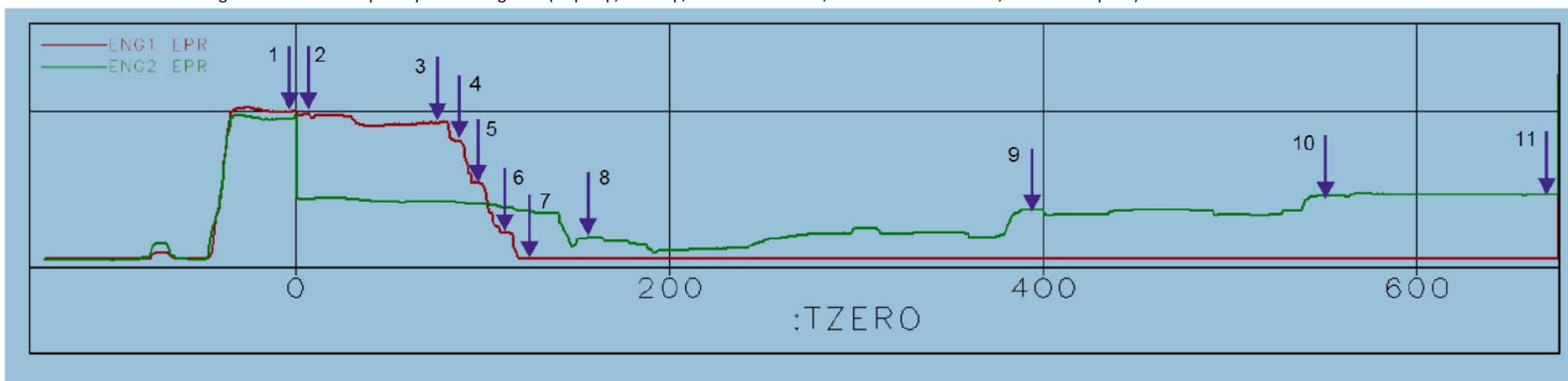
Point	TZERO (s)	Air Speed (kts)	Altitude (ft)	EPR #1	*Actual Engine #1 Thrust (lbs)	**AFM Assumed Max Takeoff Thrust (lbs)	EPR #2	*Actual Engine #2 Thrust (lbs)	**AFM Assumed Max Takeoff Thrust (lbs)	Actual Airplane-Level Thrust (lbs)	All-Engine AFM Thrust (lbs)	Engine Out AFM Thrust (lbs)
1	-1	158	298	1.994	12682	12375	1.947	12163	12375	24845	24750	12375
2	3	150	524	1.970	12349	12295	1.429	5480	12295	17829	24590	12295
3	80.5	208	2094	1.928	11036	11001	1.417	4956	11001	15992	22002	11001
4	85.6	218	2082	1.811	9831	10955	1.415	4930	10955	14761	21910	10955
5	96.7	242	1921	1.542	6993	10916	1.403	4838	10916	11831	21832	10916
6	115.8	249	2025	1.214	3211	10828	1.381	4580	10828	7791	21655	10828
7	125.9	248	2034	1.051	1291	10829	1.357	4299	10829	5590	21657	10829
8	161.1	246	1797	1.051	1285	10971	1.185	2468	10971	3753	21942	10971
9	397.8	170	634	1.051	1143	12084	1.366	4674	12084	5817	24168	12084
10	553.9	142	261	1.052	996	12525	1.452	5844	12525	6840	25050	12525
11	676.7	122	27	1.052	962	12375	1.462	6093	12375	7055	24750	12375

Assumed Flap	Event Climb Capability at Event Speed and Altitude with Actual Thrust		AFM EO Climb Capability at Event Speed and Altitude	
	Gradient (%)	Rate of Climb (feet per minute)	Gradient (%)	Rate of Climb (feet per minute)
5	19.2	3550	5.4	1000
5	11.4	2010	5.1	900
0	11.2	2770	5.4	1350
0	9.8	2550	5.3	1380
0	6.4	1830	4.9	1410
0	1.9	570	4.6	1380
0	-0.9	-270	4.7	1380
0	-2.9	-830	4.9	1420
0	-0.8	-150	5.8	1160
1	-0.4	-70	5.4	890
1	-2.5	-360	3.1	440

Relevant AFM Dispatch Requirements:

2.4% Minimum Engine Out Gradient Capability in Second Segment (Takeoff Flap, Gear Up Point, Takeoff Thrust, V2 Speed)

1.2% Minimum Engine Out Gradient Capability in Final Segment (Flaps Up, Gear Up, 1500 Feet Altitude, Max Continuous Thrust, Final Climb Speed)



* Pratt and Whitney Thrust Simulation considering hushkit, deterioration, and LPT damage on Engine #2

** Maximum Takeoff Thrust used to develop Airplane Flight Manual

ATTACHMENT 9: BOEING 737-200 ADV SIMULATION STUDY

To: NTSB Performance Group Chair

Subject: **Performance Observations of Transair (TEW) 737-200C (PY151/N810TA) Water Landing after Air Turn Back on July 2, 2021 in Support of NTSB Aircraft Performance Group Study**

Reference: *Service Request, TEW 737-200C N810TA Water Landing After Air Turn Back - Honolulu, Hawaii 02 July 2021, dated July 2, 2021*

Enclosure:	Enclosure Description:	Number of Pages:
A	Figures	34

Discussion:

Event Report

In the Reference Service Request (SR), Boeing Air Safety Investigation (ASI) reported that a Transair (TEW) 737-200C (PY151/N810TA) experienced a water landing after air turn back (ATB) shortly after takeoff from Honolulu International Airport (HNL), Hawaii on July 2, 2021. The SR stated the following:

The US NTSB has initiated an investigation into the subject event.

Date: 02 July 2021

Time: 01:45 HST

Location: HNL (Honolulu)

Model: 737-200C

Registry: N810TA

Narrative: A Transair 737-200C N810TA (JT8D P&W engines), cargo flight number 810, from Honolulu, HI to Kahului, HI landed in the water shortly after takeoff 3NM off the coast southwest of HNL airport after attempting to return to the airport. According to initial reports an engine problem was reported after takeoff.

Persons on Board: Unknown

Injuries: Unknown, 2 pilots reportedly rescued by Coast Guard

Damage: Unknown, suspected to be substantial damage or hull loss

The flight data recorder (FDR), cockpit voice recorder (CVR), and the airframe itself were recovered from the sea floor in the Pacific Ocean off the coast of Honolulu, Hawaii in October 2021, several months after the accident. The event is under investigation by the National Transportation Safety Board (NTSB) with assistance from Boeing and Pratt & Whitney (P&W). Collecting the airplane wreckage required a significant recovery effort.

Supporting Data

The following anecdotal and paraphrased information was provided from the investigation:

- Based on pilot interviews shortly after the accident, both pilots stated that:
 - Shortly after takeoff, the airplane experienced a sudden thrust change, and the crew identified an engine failure through a drop in engine pressure ratio (EPR) and exhaust gas temperature (EGT). Shortly after the engine event, there was an initial yaw to the right and the airplane was controllable.
 - There was no recollection of engine fire warnings.
 - Airspeed and altitude could not be maintained in level flight.

- The airplane remained controllable in all three axes.
- The right engine continued operating until water impact with high EGT and an unknown EPR at the time of water impact.
- The event airplane was equipped with P&W JT8D-9A engines.
- The water ditching was accomplished with Flaps 1 and the landing gear retracted based on pilot interviews, paraphrased CVR content, and post-event airframe inspection.
- Post-event airframe wreckage inspection showed the following:¹
 - Engine 1 thrust lever was near the forward stop.
 - Engine 2 thrust lever was near the aft stop, with the thrust reverser handle in full reverse.
 - Both fuel control switches were in the RUN position.
 - Both engine fire handles were stowed.
 - Engine 1 EPR gauge read approximately 1.02.
 - Engine 2 EPR gauge read approximately 1.6.
 - Other engine gauges were unreadable for various reasons.
- Post-event detailed engine inspections included the following:
 - The left engine (also referred to as 'engine #1' within this report) showed signs of damage consistent with impact with the water at a comparatively low engine rotation speed. Engine teardown by the investigation revealed no significant evidence of pre-impact mechanical damage to the compressor, turbine sections, the accessory systems, or fuel systems.
 - The right engine (also referred to as 'engine #2' within this report) showed signs of damage consistent with impact with the water at a comparatively high engine rotation speed. Engine teardown by the investigation revealed that two turbine blades were found fractured in the T1 section. The teardown revealed no significant evidence of pre-impact mechanical damage to the accessory systems or fuel systems.

The following data were provided to the Boeing Aerodynamics Post-Certification Support (PCS) group for evaluation:

- FDR data for the event flight were obtained by the Boeing ASI group and translated to engineering units based on a custom data frame owned by a third party (AACO Incorporated). ASI provided the PCS group an initial version (November 2021) of FDR data for the event flight and 4 prior flights and an April 2022 version for the event flight only. The Boeing April 2022 version of processed FDR data includes the time vector being lengthened by a factor of 1.00697, based on a finding that the FDR device recorded slightly less than 1 second of data within 1 actual second. The event flight lasted approximately 13 minutes from takeoff to the end of the data recording. The FDR data contain 18 parameters, which are listed below. The time vector is an artifact of NTSB data processing. The FDR data does not include date information for year, month, or day.
 - Pressure altitude
 - Computed airspeed
 - Body-axis accelerations (longitudinal, vertical, and lateral)
 - Euler angles (pitch, roll, magnetic heading)
 - EPR for left and right engines
 - Column and left elevator deflection
 - Left seat control wheel and left aileron deflection
 - Rudder pedal and rudder deflection
 - VHF Keying discrete
 - Autopilot Pitch Engage discrete
- Automatic Dependent Surveillance-Broadcast (ADS-B) data from the event flight was obtained by ASI to support the event flight investigation. Parameters in the ADS-B data include latitude, longitude, pressure altitude, ground speed, ground track heading, and more. Parameter values are

¹ Engine controls on the 737-200 are generally handled by physical cables. Impact damage to the fuselage can pull the cables and alter the thrust control positions after impact.

tabulated in comma separated value (CSV) format with a recording rate of approximately 1 sample per second.

- A paraphrased CVR transcript was made available for the sole purpose of the event flight investigation, shared by the NTSB Aircraft Performance Group chair on March 8, 2022 and updated on April 19, 2022 in advance of the CVR transcript becoming publicly available. Specific terms of use for data sharing, retention and access restrictions were imposed by the NTSB to enable the paraphrased CVR transcript information to be used for event evaluation.
- A flight load manifest was provided by TEW for the planned flight. A paraphrased subset of information indicated that the airplane was scheduled to depart from HNL with a gross weight of 93,557 pounds, a center of gravity (CG) of 19.1% mean aerodynamic chord (MAC), a stabilizer trim setting of 5.2 units, and a flap setting of 5 degrees.
- P&W provided the NTSB Aircraft Performance Group calculations of a variety of engine parameters for the duration of the event flight. Data were provided in CSV format. Calculated parameters were generated for each engine using the following models:
 - baseline JT8D-9A engines without a hush kit
 - JT8D-9A engines equipped with a hush kit per Supplemental Type Certification (STC)
 - JT8D-9A engines equipped with a hush kit per STC and an estimation of deterioration
 - JT8D-9A engines equipped with a hush kit per STC, an estimation of deterioration, and an estimation of the right engine damage

Weather Report

A publicly available Aviation Routine Weather Report (METAR) was posted at 11:53 Greenwich Mean Time (GMT)/1:53 AM local time. The water ditching event occurred 8 minutes before the posted METAR at 11:45 GMT/1:45 AM local time. The METAR stated the following:

*PHNL 021153Z 06010G21KT 10SM FEW025 SCT050 26/17 A3003 RMK AO2 SLP169 60000
T02560172 10267 20256 56008*

The METAR indicated winds were from 60 degrees at 10 knots with gusts up to 21 knots. Based on the HNL Runway 08R true heading of 90 degrees, the airplane would have experienced a headwind of approximately 9 knots and a crosswind from the left of 5 knots. Sea-level pressure was 30.03 inches and outside air temperature was 26 degrees Celsius. Minimum horizontal visibility was 10 statute miles.

Paraphrased Subset of CVR Findings

The following are pertinent times reported on the paraphrased CVR transcript that support event data evaluation. All time values listed in Table 1 include a time shift (subtraction) of 32,159.35 seconds² to translate from the CVR transcript estimated values to equivalent Boeing FDR time values. The time values were estimated based on paraphrased CVR transcript time history charts which use a different time array than the time array for the Boeing FDR data. The Boeing April 2022 version of FDR data shows the right engine peak EPR just prior to a rapid reduction evident at elapsed time 9,480.15 seconds, which aligns to the paraphrased CVR transcript elapsed time of 41,639.5 seconds³. The level of precision reflected in the time values tabulated in Table 1 is the result of estimating time values from the paraphrased CVR to the nearest 0.1 seconds and then applying the time shift. Paraphrased CVR transcript information was used to inform assumptions for landing gear retraction and flap retraction during the event flight. Figures 6A through 6H contain event markers (shown with a blue filled circle and a label "CVR Item...") based on paraphrased CVR transcript statements for awareness.

² Boeing used the March 8, 2022 version of the paraphrased CVR transcript when calculating a time shift of 32,159.35 seconds. The April 19, 2022 version of the paraphrased CVR transcript was adjusted by 4 seconds total based on the findings outlined in Flight Data Observations, below. The effect of this difference in this text is negligible due to Boeing aligning the paraphrased CVR content to the FDR content manually, but would result in a final time shift of 32,155.35 seconds.

³ Based on the April 19, 2022 version of the paraphrased CVR transcript, this value would be 41,635.5 seconds.

Table 1. Subset of Paraphrased CVR Statements from Event Flight

Paraphrased CVR Item	Boeing FDR Elapsed Time (seconds)	Paraphrased CVR Statement/Description
1	9,446.15	Set reduced thrust call
2	9,451.15	80 knot call
3	9,460.65	V1 call
4	9,462.65	Rotate call
5	9,463.65	V2 call
6	9,470.25	Positive rate call
7	9,470.85	Gear up call
8	9,477.65	A thud sound was recorded
9	9,480.15	A low frequency vibration sound was recorded decreasing in pitch from ~115 Hz to ~105 Hz
10	9,481.15	Crew reacted to loss of power
11	9,486.15	"Crew's initial identification of anomaly as engine 2"
12	9,491.15	CA called '500' and '800'
13	9,506.65	Call of flaps coming up
14	9,556.25	Level at 2,000 comment
15	9,578.05	The crew discussed a 210 degree heading
16	9,639.15	The crew discussed a 240 degree heading
17	9,678.45	Transfer of control from FO to CA
18	9,713.55	Ambiguous question from CA about EGT. FO reported engine 1 is failed
19	9,722.25	FO reported engine 2 still functioning
20	9,791.45	FO mentioned engine 2 running hot
21	9,848.15	CA confirmed the aircraft is clean
22	9,856.25	Sounds possibly consistent with a momentary stick shaker.
23	9,858.25	"CA mentioned they're in a descent"
24	9,862.45	Sounds of increasing pitch, consistent with increasing engine thrust
25	9,877.35	FO confirmed aircraft is clean (specifically flaps and speedbrakes)
26	9,886.75	"CA confirmed they're struggling to hold altitude and instructed FO to finish as much of the checklist as possible"
27	9,915.65	"FO commented that they're in a descent"
28	9,959.15	Flaps 1 call
29	9,963.55	"EGPWS 500' callout"
30	9,964.85	EGPWS Too Low Gear callout
31	10,001.45	EGPWS Too Low Gear callout
32	10,003.15	EGPWS Too Low Terrain callout

Paraphrased CVR Item	Boeing FDR Elapsed Time (seconds)	Paraphrased CVR Statement/Description
33	10,006.15	EGPWS Too Low Gear callout
34	10,009.05	EGPWS Too Low Terrain callout
35	10,011.15	EGPWS Pull Up callout
36	10,012.95	EGPWS Pull Up callout
37	10,014.15	EGPWS Pull Up callout
38	10,042.95	FO called out a heading of 60 degrees
39	10,113.15	Sound similar to stick shaker, approximately 1.7 seconds
40	10,124.65	Sound similar to stick shaker, approximately 1.6 seconds

List of Figures

Table 2 provides a list of figures pertaining to the event flight data.

Table 2. List of Figures

Figure	Description
1	Event flight ground track overview
2	Event flight ground track takeoff close-up
3	Control column vs elevator deflection
4	Control wheel vs aileron deflection
5	Rudder pedal vs rudder deflection
6	Overview for duration of event flight FDR data, time 9,300 to 10,161 seconds
6A	Overview of event flight FDR data, time 9,410 to 9,510 seconds
6B	Overview of event flight FDR data, time 9,510 to 9,610 seconds
6C	Overview of event flight FDR data, time 9,610 to 9,710 seconds
6D	Overview of event flight FDR data, time 9,710 to 9,810 seconds
6E	Overview of event flight FDR data, time 9,810 to 9,910 seconds
6F	Overview of event flight FDR data, time 9,910 to 10,010 seconds
6G	Overview of event flight FDR data, time 10,010 to 10,110 seconds
6H	Overview of event flight FDR data, time 10,110 to 10,161 seconds
7A	Event flight data vs simulation for takeoff, longitudinal parameters, FDR data time 9,425 to 9,525 seconds
7B	Event flight data vs simulation for takeoff, lateral/directional parameters, FDR data time 9,425 to 9,525 seconds
7C	Event flight data vs simulation for takeoff, engine parameters, FDR data time 9,425 to 9,525 seconds
8A	Event flight data vs simulation for initial engine #2 EPR reduction, longitudinal parameters, FDR data time 9,470 to 9,570 seconds
8B	Event flight data vs simulation for initial engine #2 EPR reduction, lateral/directional parameters, FDR data time 9,470 to 9,570 seconds
8C	Event flight data vs simulation for initial engine #2 EPR reduction, engine parameters, FDR data time 9,470 to 9,570 seconds
9A	Event flight data vs simulation engine #1 EPR reduction flight data, longitudinal parameters, FDR data time 9,550 to 9,650 seconds
9B	Event flight data vs simulation engine #1 EPR reduction flight data, lateral/directional parameters, FDR data time 9,550 to 9,650 seconds

Figure	Description
9C	Event flight data vs simulation engine #1 EPR reduction flight data, engine parameters, FDR data time 9,550 to 9,650 seconds
10A	Event flight data vs simulation for in-air turn, longitudinal parameters, FDR data time 9,700 to 9,800 seconds
10B	Event flight data vs simulation for in-air turn, lateral/directional parameters, FDR data time 9,700 to 9,800 seconds
10C	Event flight data vs simulation for in-air turn, engine parameters, FDR data time 9,700 to 9,800 seconds
11A	Event flight data vs. simulation for flaps up deceleration, longitudinal parameters, FDR data time 9,800 to 9,900 seconds
11B	Event flight data vs. simulation for flaps up deceleration, lateral/directional parameters, FDR data time 9,800 to 9,900 seconds
11C	Event flight data vs. simulation for flaps up deceleration, engine parameters, FDR data time 9,800 to 9,900 seconds
12A	Event flight data vs. simulation for flaps 1 deceleration, longitudinal parameters, FDR data time 10,070 to 10,161 seconds
12B	Event flight data vs. simulation for flaps 1 deceleration, lateral/directional parameters, FDR data time 10,070 to 10,161 seconds
12C	Event flight data vs. simulation for flaps 1 deceleration, engine parameters, FDR data time 10,070 to 10,161 seconds
13	Performance Assessment of Event Flight Takeoff Ground Roll Acceleration
14	Performance Assessment of Climb Capability During Event Flight

Flight Data Observations

Due to the limited number of parameters recorded by the FDR, ADS-B flight data were used to supplement FDR data. ADS-B data for pressure altitude, latitude, longitude, ground speed, ground track heading, and vertical speed were used for event flight data evaluation. ADS-B data were converted from CSV format to engineering scientific binary (ESB), and the ADS-B time values were shifted to align with the FDR data based solely on pressure altitude for the event flight takeoff. A constant time-shift of 8,787.90 seconds was added to the ADS-B time values to empirically align with the April 2022 Boeing version of event flight FDR data for pressure altitude. The event flight ADS-B data for latitude and longitude showed good agreement when checking points with Google Earth overlays on the departure runway (HNL 08R) for taxi and takeoff (Figures 1 and 2).

Issues were discovered with the FDR data for certain flight control parameters, which are described in the section, "Evaluation of Flight Control Parameters," below.

Evaluation of Flight Control Parameters

Control sweeps for column deflection vs. elevator deflection, control wheel deflection vs. left aileron deflection, and rudder pedal deflection vs. rudder deflection are presented in Figures 3, 4, and 5, respectively. The FDR data presented in Figures 3, 4, and 5 were linearly interpolated versus time to align with timestamps for vertical acceleration to enable cross-plots at the same value of time, which may introduce errors and/or uncertainty. Using FDR data from a sister ship, N809TA, with the same supplemental type certificate (STC) installation as N810TA, Boeing confirmed that similar flight control behavior was observed on both airplanes (data not shown in this report). For the accident flight of N810TA and sister ship N809TA, no reports of flight control anomalies were identified. Boeing therefore concluded that the accident airplane's flight controls were properly rigged and operated near nominal.

Column deflection vs elevator deflection for the event flight FDR data and the Boeing simulation expected nominal relationship is attached as Figure 3. The control column vs. elevator deflection relationship of the event flight FDR data exhibits similar behavior to the nominal airplane relationship.

Control wheel deflection vs left aileron deflection for the event flight FDR data and the Boeing simulation expected nominal relationship is attached as Figure 4. The control wheel vs. left aileron deflection relationship of the event flight FDR data exhibits significantly different behavior relative to the nominal airplane relationship. The FDR data for the left aileron show values of approximately ± 21 degrees, which is consistent with the expected travel limits for the airplane. The FDR data for control wheel reaches approximately ± 125 degrees during on-ground control sweeps and in flight. The FDR data for control wheel exceeds the no-load travel limit of 87.5 degrees (corresponding to full aileron travel) and the mechanical stop of 107.5 degrees. For recorded control wheel deflections less than approximately ± 100 degrees, control wheel vs. left aileron generally exhibits a linear relationship and appears to be scaled incorrectly. The expected relationship between recorded control wheel deflection and left aileron deflection appears non-linear beyond recorded control wheel deflections of ± 100 degrees. Boeing concluded that the FDR control wheel deflection data are erroneous. The event flight control wheel deflection was estimated in lieu of FDR control wheel deflection based on FDR aileron deflection and the (expected) simulation model nominal relationship of control wheel to aileron.

Rudder pedal deflection vs rudder deflection for the event flight, pre-takeoff on-ground pedal sweep FDR data and the Boeing simulation expected nominal relationship is attached as Figure 5. The rudder pedal vs. rudder deflection relationship of the event flight FDR data exhibits significantly different behavior than the nominal airplane relationship. The FDR data for rudder pedal deflection reaches approximately ± 15 degrees, which exceeds the expected travel limits of ± 12.6 degrees. Boeing applied an empirically derived factor of $(12.6/15) = 0.84$ to the recorded rudder pedal deflection values as an adjustment to the recorded data. The FDR data for rudder deflection show only positive values between 0 and 100 degrees during pre-flight control sweeps and in flight, which exceeds the expected travel limits of ± 26 degrees. Boeing concluded that the FDR rudder deflection data are erroneous. An estimated rudder deflection was calculated based on recorded (and adjusted, as above) rudder pedal deflection, pressure altitude, and computed airspeed and the simulation model nominal relationship of rudder pedal to rudder as a function of dynamic pressure (lbs/ft^2). The estimated rudder deflection does not account for yaw damper activity.

Data Observations

Time history plots of the pertinent event flight parameters are attached as Figures 6, 6A, 6B, 6C, 6D, 6E, 6F, 6G, and 6H. Figure 6 provides FDR data for the duration of the event flight from taxi on-ground to the end of the FDR recording time. Figures 6A, 6B, 6C, 6D, 6E, 6F, 6G, and 6H provide close-ups of 100-second duration with the same parameters as Figure 6. The "Time (Seconds)" parameter along the x-axis of these figures represents the elapsed time from an arbitrary point initialized prior to takeoff and was created during the processing of the FDR data. FDR data presented in Figures 6 and 6A through 6H are directly from the Boeing translation to engineering units, with the exception of control wheel deflection and rudder pedal deflection which are described further in the section "Evaluation of Flight Control Parameters" above.

Several time segments of event flight data show that when the adjusted rudder pedal deflection indicated approximately zero for sustained periods of time, there were high frequency fluctuations of near ± 0.7 degrees (Figure 6). This adjusted rudder pedal characteristic appeared to be at a frequency much higher than a pilot-in-the-loop could command. The source of the recorded rudder pedal deflection fluctuations could not be determined with the available data but may be associated with signal noise or slack in the rudder pedals without a manual force application.

Below are observations based on the Boeing April 2022 version of FDR data supplemented with ADS-B data to accompany the attached Figures 1, 2, 6, and 6A through 6H. Observations are noted starting with the FDR data time stamp in elapsed seconds.

- **Time (seconds) - flight data observation (Reference Figure #)**
- 9,433 to 9446 – initial thrust application for takeoff based on EPR increase from near 1.05 towards 2.0 (Figure 6A). On average, the left engine reached near an EPR of 2.0, and the right engine reached near an EPR of 1.95 during the takeoff and initial climb.

- 9,461– takeoff rotation was initiated with the column deflected aft at a computed airspeed near 122 knots as evidenced by the increase in column and trailing-edge-up elevator deflection (Figure 6A).
- 9,467 – estimated liftoff from HNL Runway 08R occurred near this time at a computed airspeed near 144 knots as evidenced by acceleration parameters (Figure 6A).
- 9,481.2 – the right engine EPR reduced rapidly from near 1.98 to 1.45 within one second while the left engine EPR remained near 2.0 (the resulting thrust asymmetry would tend to yaw the airplane to the right with the left EPR higher than the right EPR), resulting in a significant thrust asymmetry (Figure 6A). Based on event flight ADS-B data aligned with the event flight FDR data, the airplane was located near latitude 21.3064 degrees North and longitude -157.92398 degrees East (approximately 7,451 feet from the Runway 08R threshold) [Figure 2]. At the time of the right engine EPR reduction, magnetic heading was approximately 80 degrees, ground track angle (aligned to true north) was approximately 90 degrees, pitch attitude was near 18 degrees, bank angle was near zero, adjusted rudder pedal deflection was near zero, pressure altitude was near 400 feet, vertical speed was around 3,600 feet per minute (fpm) and computed airspeed was near 160 knots (Figure 6A). Shortly after the right engine rapid EPR reduction, the calculated control wheel deflection moved to the left up to approximately -35 degrees rapidly and then reduced towards zero while the rudder pedal deflection quickly increased from near zero to near -4.5 degrees. The adjusted rudder pedal deflection of near -4.5 degrees was assumed to be a left rudder pedal deflection to oppose the thrust asymmetry. The sign convention for rudder pedal deflection could not be determined definitively due, in part, to the absence of valid rudder deflection. Issues with FDR rudder deflection data are described in the section, “Evaluation of Flight Control Parameters.”
- 9,497 to 9,515 – The pitch attitude gradually reduced to near 7 degrees, on average, and the airplane leveled off near a pressure altitude of 1,000 feet, resulting in computed airspeed gradually increasing from 140 knots to 185 knots (Figure 6A). Near the same time, a right turn was initiated starting with wings near level, calculated control wheel deflections of up to 35 degrees (right), followed by a right bank angle of 18-20 degrees and a gradual magnetic heading increase from near 80 degrees to around 115 degrees (Figures 6A and 6B). The left engine EPR remained near 1.9 and the right engine EPR remained near 1.4, resulting in a thrust asymmetry that would tend to yaw the airplane nose-right. A left adjusted rudder pedal deflection was sustained near -4 degrees on average in opposition to the nose-right thrust asymmetry (left EPR higher than the right EPR).
- 9,520 to 9,555 – Pitch attitude was increased to 10-12 degrees, vertical speed increased to a peak of approximately 2,400 fpm, computed airspeed increased gradually from near 185 knots to around 205 knots, and the airplane climbed up to a pressure altitude of approximately 2,000 feet (Figure 6B). The left engine EPR remained near 1.9 and the right engine EPR remained near 1.4, resulting in a thrust asymmetry that would tend to yaw the airplane nose-right. Adjusted rudder pedal deflection remained between -3 and -3.5 degrees (left) in opposition of the nose-right thrust asymmetry (the left engine at a higher EPR than the right engine). The airplane remained in a right bank of near 18 degrees, on average, with an average right calculated control wheel deflection near 20 degrees, and the magnetic heading increased gradually from near 115 degrees to around 155 degrees.
- 9,558 to 9,576 – Pressure altitude initially increased from near 2,050 feet up to slightly above 2,100 feet and then slowly reduced to around 1,900 feet as the computed airspeed continued to increase and the left engine EPR started to decrease (Figure 6B). Adjusted rudder pedal deflection was reduced to near -2.7 degrees (left) while the airplane remained in a right bank of near 20 degrees, on average, with an average right calculated control wheel deflection of approximately 15 degrees, and the magnetic heading continued to slowly increase from around 160 degrees to near 185 degrees. Pitch attitude decreased from about 12 degrees to near 4 degrees, computed airspeed increased gradually from near 205 knots to around 245 knots, and the left engine EPR reduced from around 1.9 to near 1.5.
- 9,580 to 9,610 – Computed airspeed remained near 250 knots while the airplane gradually climbed from a pressure altitude of 1,900 feet up to near 2,080 feet (Figure 6B). During this time, the left engine EPR decreased from near 1.5 to about 1.05 over a duration of approximately 20 seconds, the right engine EPR remained near 1.4, the direction of thrust asymmetry transitioned from nose-right to nose-left (the right engine at a higher EPR than the left engine), the adjusted rudder pedal

deflection remained approximately -2 degrees (left), and the average calculated control wheel deflection was near 20 degrees to the right. The adjusted rudder pedal deflection to the left was maintained with a thrust asymmetry that would also tend to yaw the airplane nose-left. The airplane remained in a right bank near 15 degrees, on average, with variations between 18 degrees and 3 degrees, and magnetic heading increased gradually from near 190 degrees to around 210 degrees. The time-rate-of-change of magnetic heading reduced to near zero during this time. The observed variations in bank angle are commensurate with corresponding calculated control wheel deflections. The left engine EPR remained near 1.05 for the remainder of the FDR data.

- 9,614 – The airplane reached the highest recorded pressure altitude during the event flight of approximately 2,120 feet with vertical speed momentarily near zero, computed airspeed near 245 knots, the left engine EPR near 1.05, the right engine EPR near 1.35, pitch attitude near 5 degrees, bank angle near 13 degrees (right), adjusted rudder pedal deflection of around -2 degrees (left), and a right calculated control wheel deflection of approximately 20 degrees (Figure 6C). The thrust asymmetry would tend to yaw the airplane nose-left (right EPR higher than left EPR), and the rudder pedal deflection also remained to the left.
- 9,615 to 9,635 – Computed airspeed remained at approximately 245 knots while pressure altitude reduced from near 2,120 feet to approximately 1,840 feet, the left engine EPR remained near 1.05, the right engine EPR reduced from near 1.35 to around 1.18, and adjusted rudder pedal deflection was near -2 degrees (left) [Figure 6C]. An adjusted rudder pedal deflection to the left was maintained with the thrust asymmetry (right EPR higher than left EPR) that would also tend to yaw the airplane nose-left. A calculated control wheel deflection between approximately 15 and 25 degrees was maintained to the right.
- 9,635 to 9,680 – The right engine EPR reduced from around 1.18 to approximately 1.1 between time 9,635 and 9,678 seconds and pressure altitude slowly reduced from around 1,840 feet to near 1,680 feet with vertical speed fluctuations between zero and -600 fpm while computed airspeed reduced from approximately 245 knots to near 225 knots (Figure 6C). Between time 9,667 and 9,680 seconds, the adjusted rudder pedal deflection reduced from approximately -1.5 degrees (left) to approximately zero with high frequency fluctuations of near ± 0.7 degrees. The fluctuations observed in the recorded rudder pedal deflection are discussed further in the beginning of this section (“Data Observations”). Bank angle was reduced from near 14 degrees (right) to approximately wings level in response to a calculated control wheel deflection to the left, and magnetic heading stabilized near 242 degrees.
- 9,680 to 9,700 – The column deflection moved aft (airplane-nose-up) to near 1.5 degrees, resulting in an increase in pitch attitude from near 5 degrees to approximately 9 degrees, an increase in vertical speed from near zero to around 1,000 fpm, a gradual increase in pressure altitude from about 1,680 feet to 1,880 feet, and a reduction in computed airspeed from near 225 knots to approximately 200 knots (Figure 6C). During this time, EPR remained constant near 1.05 for the left engine and 1.1 for the right engine.
- 9,710 to 9,720 – The pitch attitude remained near 9 degrees and the airplane began to climb, as the computed airspeed continued to decrease at a faster rate (Figure 6D). The pressure altitude increased from near 1,880 feet up to approximately 1,915 feet and computed airspeed reduced from approximately 190 knots to near 182 knots. During this time, the bank angle was near -2 degrees (left), the calculated control wheel deflection was approximately zero, on average, and the magnetic heading gradually increased to the left.
- 9,725 – EPR for the right engine began to gradually increase from near 1.1. Column deflection increased from near zero to approximately 2 degrees (aft) at this time and varied between approximately 2 and 3 degrees (aft) for the remainder of the flight. Stabilizer position could not be determined from the available data because stabilizer position was not recorded.⁴
- 9,727 to 9,752 – Beginning with the wings near level around time 9,727 seconds and a magnetic heading near 234 degrees, the calculated control wheel deflection was increased to the right with variations between about 5 degrees and 35 degrees, and the airplane rolled to the right in response

⁴ Stabilizer trim is used to alleviate control column forces in flight. Typically, multiple trim inputs are made over the course of a regular flight.

(Figure 6D). A peak bank angle of approximately 17 degrees (right) was reached near time 9,752 seconds.

- 9,752 to 9,754 – The calculated control wheel deflection was briefly reduced from approximately 20 degrees (right) to near zero (centered) and maintained between time 9,752 seconds and 9,754 seconds while bank angle began to reduce to the left (towards wings level) [Figure 6D]. During this time, EPR for the left engine was near 1.05 and EPR for the right engine was near 1.2, which would tend to roll the airplane left-wing-down based on the thrust asymmetry alone.
- 9,754 to 9,758 – Calculated control wheel deflection moved to approximately -20 degrees (left) that resulted in an increased roll rate to the left, and bank angle reduced gradually from near 13 degrees (right) to about 4 degrees (right) [Figure 6D].
- 9,760 to 9,768 – The airplane rolled to the left while the calculated control wheel was near zero, on average, passing through wings-level near time 9,761 seconds (Figure 6D). During this time, EPR for the left engine remained near 1.05, and EPR for the right engine was near 1.2 and continuing to increase, which would tend to roll the airplane left-wing-down based on the thrust asymmetry alone.
- 9,770 to 9,795 – The calculated control wheel deflection moved to the right near time 9,770 seconds, and the trend of bank angle reversed direction from moving left, reaching a peak of near -13 degrees (left), before moving to the right in response (Figure 6D). Around the time of reaching a peak bank angle to the left, the pitch attitude was reduced to near 3 degrees due to a reduction in column deflection, resulting in a significant reduction in vertical speed and a descent. The airplane continued to roll to the right from near -13 degrees (left) to near 20 degrees (right) with an average calculated control wheel deflection of approximately 25 degrees (right). Near time 9,787 seconds, the pitch attitude had increased to approximately 9 degrees, and in response, the airplane leveled off at a pressure altitude near 1,420 feet.
- 9,797 to 9,805 – The airplane sustained a right bank angle of around 20-25 degrees while an average calculated control wheel deflection of approximately 20 degrees was maintained (Figure 6D). The airplane remained near a pressure altitude of 1,400 feet and a computed airspeed of approximately 170 knots.
- 9,825 to 9,846 – Beginning with computed airspeed near 175 knots, pressure altitude near 1,100 feet, and pitch attitude around 8 degrees, the column deflection increased further aft, resulting in an increased pitch attitude and a gradual reduction in computed airspeed to a minimum of approximately 157 knots (Figure 6E). During this time, on average, vertical speed remained near zero, bank angle remained near 10-12 degrees (right), calculated control wheel deflection remained near 20 degrees (right), adjusted rudder pedal deflection remained near zero, the left engine EPR remained around 1.05, and the right engine EPR was near 1.2. The combination of right control wheel deflection, right wing down bank angle, and near zero rudder pedal deflection is consistent with a thrust asymmetry that would tend to yaw the airplane nose-left. Fluctuations are observed in the adjusted rudder pedal deflection while indicating near zero and are discussed further in the beginning of this section.
- 9,846 to 9,870 – The pitch attitude was reduced following a sharp reduction in the column deflection, and in response, the computed airspeed gradually increased from near 157 knots to 172 knots, pressure altitude reduced gradually from near 1,100 feet to approximately 700 feet, and vertical speed reduced to near -1,400 fpm (Figure 6E). During this time, on average, vertical speed remained near -1,000 fpm, bank angle remained near 10-14 degrees (right), calculated control wheel deflection remained near 15-20 degrees (right), adjusted rudder pedal deflection remained near zero, and the left engine EPR was around 1.05. The right engine EPR gradually increased from near 1.2 to around 1.3. The combination of right control wheel deflection and near zero rudder pedal deflection is consistent with a thrust asymmetry that would tend to yaw the airplane nose-left. Fluctuations are observed in the adjusted rudder pedal deflection while indicating near zero and are discussed further in the beginning of this section.
- 9,930 to 9,950 – The pressure altitude reduced and was maintained near 480 feet, computed airspeed reduced and was maintained near 160 knots, and calculated control wheel deflection remained near 20 degrees (right), on average, with near zero adjusted rudder pedal deflection in the presence of a thrust asymmetry that would tend to yaw the airplane nose-left (Figure 6F).

- 10,060 to 10,080 – The computed airspeed remained near 140 knots, on average, and pitch attitude remained around 10 degrees while pressure altitude gradually decreased from around 250 feet to around 150 feet (Figure 6G). Bank angle slowly reduced from near 8-10 degrees (right) to around 3 degrees (right). Calculated control wheel deflection remained near 20 degrees on average (right), adjusted rudder pedal deflection was moved to near 1 degree (right), the left engine EPR remained around 1.05, and the right engine EPR was near 1.47. Rudder pedal deflection to the right is consistent with a thrust asymmetry that would tend to yaw the airplane nose-left.
- 10,090 to 10,100 – Computed airspeed remained near 135 knots, on average, and pressure altitude remained near 150 feet (Figure 6G). Column deflection increased further aft resulting in an increased pitch attitude from near 12 degrees to near 15 degrees, and vertical speed increased slowly from near zero (level flight) to near 400 fpm. Bank angle was near zero (wings level), calculated control wheel deflection remained near 20 degrees, on average (right), adjusted rudder pedal deflection remained near 1 degree (right), the left engine EPR remained around 1.05, and the right engine EPR remained near 1.47.
- 10,100 to 10,110 – Computed airspeed reduced gradually from near 135 knots to a minimum of approximately 128 knots, pressure altitude increased from near 150 feet to around 190 feet, and pitch attitude gradually reduced from near 15 degrees to approximately 12 degrees (Figure 6G).
- 10,110 to 10,145 – Computed airspeed remained near 130-135 knots while pressure altitude slowly reduced from around 180 feet to near 0 feet (Figure 6H). The airplane rolled into a bank angle of around -14 to -8 degrees (left), and magnetic heading gradually reduced from near 60 degrees to around 25 degrees.
- 10,161 – estimated time of initial impact for a water landing (Figure 6H). Based on event flight ADS-B data aligned with the event flight FDR data, the airplane was located near latitude 21.276 degrees North and longitude -158.026 degrees East approximately 5 nmi from HNL Runway 08R (Figure 1). At the time of initial impact with the water, pitch attitude was near 12 degrees, bank angle was near -12 degrees (left), ground speed was near 114 knots, computed airspeed was near 122 knots, and magnetic heading was near 6 degrees (Figure 6H).

Evaluation of Airplane Configuration

The following parameters are necessary to support flight data evaluation, were not recorded in the event flight data (FDR or other sources), and were estimated using other available information:

- Flap position
- Gear position
- Gross weight
- Center of gravity (%MAC)
- Stabilizer position

For the purpose of data evaluation, the Boeing FDR data end time of nose gear retraction shortly after takeoff was assumed to be 9,477.65 seconds based on the paraphrased CVR transcript Item 8 noted in Table 1. Boeing's expectation for normal nose gear retraction time is 1.0 seconds from the start of gear handle movement to the start of gear movement, 4.5 seconds of actual nose gear retraction time, and 1.0 seconds for uplock and flight deck indication based on Boeing flight test data.

It was also assumed the Boeing FDR data start time of flap retraction shortly after takeoff was time 9,506.65 seconds, based on the paraphrased CVR transcript Item 13 noted in Table 1. It was assumed that takeoff occurred with Flap Detent 5 based on the takeoff Load Manifest. It was also assumed that flaps were retracted from Detent 5 to UP based on the paraphrased CVR transcript. Boeing's expectation for normal flap retraction time from Flap Detent 5 to 0 is 21.7 seconds based on Boeing flight test data.

Kinematic Consistency Evaluation

In addition to an evaluation of the recorded parameters captured in the section "Data Observations," a kinematic consistency (KinCon) evaluation was conducted on the provided FDR and ADS-B data. KinCon is used to correct inherent inconsistencies often present in recorded data from different sensors because

of the presence of instrumentation biases due to misalignment in inertial measurements, contamination of pressure and altitude measurements due to flow separation, and sample rate differences. The KinCon process uses integrated acceleration data to ensure basic inertial parameters such as altitude, ground speed, and drift angle are compatible and comparable. The output is a kinematically consistent set of data with acceleration biases removed, allowing calculations of angle of attack (AOA), sideslip angle, wind data, ground track information and other parameters.

Winds are calculated by taking the difference between body-axis inertial speeds and body-axis airspeeds and then rotating these components to the earth axis. This is a multi-step process performed within KinCon. First, the body-axis inertial speed components are calculated based on the KinCon acceleration data and the three Euler angles (pitch attitude, bank angle, and heading angle).

Then, the body-axis airspeed components are calculated based on true airspeed, AOA, and sideslip, which are calculated using the KinCon process. The true airspeed is calculated based on the recorded airspeed, recorded pressure altitude, and static outside air temperature (OAT) [estimated to be 11.0 degrees Celsius above standard day temperature based on METAR weather reporting]. Airplane body AOA is calculated based on an aerodynamics lift model extracted from the simulation in lieu of calculation based on vane AOA, which was not recorded. The sideslip angle is calculated based on the recorded lateral acceleration, calculated rudder surface deflection, calculated control wheel deflection, and airplane configuration information. The derived body-axis wind speed components are the difference between the body-axis inertial speeds and the body-axis airspeeds. The earth-axis horizontal and vertical winds are calculated based on the derived body-axis wind components and the Euler angles. The calculated winds are invalid while the airplane is on ground due to the lack of ground interaction modeling.

The calculated horizontal wind speed and direction for the time segments analyzed varied between 10 and 30 knots and from 40 to 80 degrees, respectively. The calculated horizontal wind speeds in-air are higher than the METAR-reported wind speed, which is expected because reported winds near the runway are typically lower than winds aloft. The calculated wind direction is generally consistent with the METAR-reported wind direction.

Simulation Study

The 737-200ADV Boeing desktop engineering simulation was used to re-create event flight segments of interest to the NTSB Aircraft Performance Group. The primary intent of a simulation study is to provide a data set from a model representative of nominal airplane characteristics for comparison with available FDR data. The simulation offers flexibility in being able to drive the simulation control positions with recorded data or use mathematical pilot models to target the recorded/calculated airplane state and/or flight path. The simulation is a six-degrees-of-freedom non-linear model that has been updated to match flight test data. A mathematical pilot calculates and applies flight control or control surface inputs to track specified parameter(s) (e.g. heading) in an attempt to minimize the error between the flight data and simulation. The simulation was set up with similar initial conditions (e.g. weight, speed, etc.), control inputs, and thrust (EPR) as documented by the FDR and other provided data sources.

All simulation data used the following setup:

- Engine model: P&W JT8D-9. The event airplane was reported to have P&W JT8D-9A engines. The closest available Boeing simulation engine model was P&W JT8D-9 representing nominal engine thrust. The simulation reflects a nominal operating set of engines in the absence of any engine failure(s) or deterioration.
- Engine thrust was calculated using FDR EPR values for each engine, with a small bias applied to EPR as required to minimize the error between kinematically corrected flight and simulation parameters for longitudinal acceleration, computed airspeed, and pressure altitude. The Boeing simulation model represents nominal behavior for each engine and calculates net thrust based on EPR, Mach number, and static OAT.

- Airplane gross weight was assumed to be 93,557 pounds, and the CG position was assumed to be 19.1% MAC, based on the Load Manifest. These assumptions were made considering the event flight was approximately 13 minutes (relatively short). Effects of fuel burn and associated gross weight reduction and/or CG movement were considered negligible and were therefore excluded.
- Speedbrakes were assumed to be retracted throughout the event flight.
- The static OAT was set to 11.0 degrees Celsius above standard day temperature, based on METAR weather information for the event flight takeoff.
- Simulation wind speed and direction were set based on the calculated winds in-air. More information regarding the calculated winds is in the section, "Kinematic Consistency Evaluation."

Findings from Simulation Study Matches

The simulation output, which is based on an airplane with near nominal behavior, reflects the FDR and calculated data reasonably well. For all simulation matches other than the event flight takeoff, the simulation rudder pedal deflection was biased a small amount to the right relative to the adjusted FDR rudder pedal deflection such that the resulting simulation aileron deflection generally aligned with the FDR left aileron deflection.

Simulation Time History Matches Discussion

Simulation vs FDR Match #1: Event Flight Takeoff (Figures: 7A, 7B, and 7C)

Setup Notes

Parameter	Notes
Flap Detent	Flaps 5 based on the Load Manifest
Gear	Down initially with retraction based on the paraphrased CVR transcript
Stabilizer Position	set to 5.2 units on-ground based on the Load Manifest
Wind Speed and Direction	Horizontal wind speed and direction were set to reflect an approximate average of the in-air calculated values from the kinematic consistency evaluation.

- Simulation data start at time 9,433.5 seconds and end at time 9,478.5 seconds.
- The equations of motion were applied within the simulation in the presence of control inputs and atmospheric, but the resulting lateral/directional motion was not calculated (the lateral/directional integrators were disabled). This setup was included in the simulation to focus the match on longitudinal parameters for the takeoff segment of flight data only.
- A mathematical pilot was applied to the simulation control column deflection to target the kinematically corrected pitch attitude, pressure altitude, and computed airspeed. Rudder pedal deflection inputs were driven by the adjusted FDR values. Control wheel inputs were driven by the calculated values based on the FDR left aileron.
- A bias of -0.02 was applied to each engine EPR relative to FDR values to improve the match of longitudinal acceleration, computed airspeed, and pressure altitude. A symmetric EPR bias was applied in this segment due to the time segment being prior to the right engine decrease.

Simulation Match Observations

The simulation output reflects the FDR and calculated data reasonably well (Figures 7A and 7B).

The simulation net thrust for the left and right engines are each below the P&W calculated thrust with a hushkit and deterioration by approximately 500 pounds (Figure 7C).

Simulation vs FDR Match #2: Initial Right Engine EPR Reduction (Figures: 8A, 8B, and 8C)

Setup Notes

Parameter	Notes
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Flap Detent	Flaps 5 initially based on the Load Manifest followed by a retraction to UP based on the paraphrased CVR transcript
Gear	Gear UP based on the paraphrased CVR transcript
Stabilizer Position	Stabilizer was trimmed in-flight, aligning with near zero control column deflection indicated by the FDR data and held constant for the duration of the match.
Wind Speed and Direction	Horizontal wind speed and direction were set to the calculated values from the kinematic consistency evaluation.

- Simulation data start at time 9,479 seconds and end at time 9,563 seconds.
- Mathematical pilots were applied to simulation control column deflection and control wheel deflection to target the recorded Euler angles, pressure altitude, and computed airspeed. The simulation rudder pedal deflection was set to the adjusted FDR values with the addition of a bias of 0.85 degrees to the right for the duration of the time segment analyzed. The simulation rudder pedal bias in relation to the adjusted FDR values was determined empirically such that the resulting simulation aileron deflection generally aligned with the FDR left aileron deflection.
- No biases were applied to engine EPR values relative to FDR values.

Simulation Match Observations

The simulation output reflects the FDR and calculated data reasonably well (Figures 8A and 8B).

The simulation net thrust for the left engine is below the P&W calculated thrust with a hushkit and deterioration by approximately 400 pounds (Figure 8C). The simulation net thrust for the right engine is above the P&W calculated thrust with a hushkit, deterioration, and damage by approximately 400 pounds.

Simulation vs FDR Match # 3: Left Engine EPR Reduction (Figures: 9A, 9B, and 9C)

Setup Notes

Parameter	Notes
Flap Detent	Flaps UP based on the paraphrased CVR transcript
Gear	Gear UP based on the paraphrased CVR transcript
Stabilizer Position	Stabilizer was trimmed in-flight, aligning with near zero control column deflection indicated by the FDR data and held constant for the duration of the match.
Wind Speed and Direction	Horizontal wind speed and direction were set to the calculated values from the kinematic consistency evaluation.

- Simulation data start at time 9,567 seconds and end at time 9,662 seconds.
- Mathematical pilots were applied to control column deflection and control wheel deflection to target the recorded Euler angles, pressure altitude, and computed airspeed. The simulation rudder pedal deflection was set to the adjusted FDR values with the addition of a bias of 0.7 degrees to the right for the duration of the time segment analyzed. The simulation rudder pedal bias in relation to the adjusted FDR values was determined empirically such that the resulting simulation aileron deflection generally aligned with the FDR left aileron deflection.
- A bias of 0.05 was applied to the left and right engine EPR values relative to FDR values to improve the match of longitudinal acceleration, computed airspeed, and pressure altitude.

Simulation Match Observations

The simulation output reflects the FDR and calculated data reasonably well (Figures 9A and 9B).

The simulation net thrust for the left engine is above the P&W calculated thrust with a hushkit and deterioration by approximately 200 to 400 pounds (Figure 9C). The simulation net thrust for the right engine is above the P&W calculated thrust with a hushkit, deterioration, and damage by approximately 800 pounds.

The simulation data suggests that the effects of the right engine damage and/or thrust asymmetry may not be modeled correctly due to the significant error evident in the thrust required to achieve a reasonable match of longitudinal acceleration, computed airspeed, and pressure altitude.

Simulation vs FDR Match # 4: In-Air Turn (Figures: 10A, 10B, and 10C)

Setup Notes

Parameter	Notes
Flap Detent	Flaps UP based on the paraphrased CVR transcript
Gear	Gear UP based on the paraphrased CVR transcript
Stabilizer Position	Stabilizer was set in-flight as required to yield a simulation non-zero column trim similar to FDR data and held constant for the duration of the match.
Wind Speed and Direction	Horizontal wind speed and direction were set to the calculated values from the kinematic consistency evaluation.

- Simulation data start at time 9,724.2 seconds and end at time 9,780 seconds.
- Mathematical pilots were applied to control column deflection and control wheel deflection to target the recorded Euler angles, pressure altitude, and computed airspeed. Simulation rudder pedal deflection was set to 0.5 degrees to the right for the duration of this time history match. The adjusted FDR rudder pedal deflection appeared to be near zero, on average. The simulation rudder pedal was determined empirically such that the resulting simulation aileron deflection generally aligned with the FDR left aileron deflection.
- A bias of -0.02 was applied to the left and right engine EPR values relative to FDR values to improve the match of longitudinal acceleration, computed airspeed, and pressure altitude.

Simulation Match Observations

The simulation output reflects the FDR and calculated data reasonably well (Figures 10A and 10B). In particular, the simulation left aileron deflection is similar to the FDR left aileron deflection throughout the time history.

The simulation net thrust for the left engine is below the P&W calculated thrust with a hushkit and deterioration by approximately 400 pounds (Figure 10C). The simulation net thrust for the right engine is approximately the same as the P&W calculated thrust with a hushkit, deterioration, and damage.

Simulation vs FDR Match # 5: Deceleration with Flaps UP (Figures: 11A, 11B, and 11C)

Setup Notes

Parameter	Notes
Flap Detent	Flaps UP based on the paraphrased CVR transcript
Gear	Gear UP based on the paraphrased CVR transcript
Stabilizer Position	Stabilizer was set in-flight as required to yield a simulation non-zero column trim similar to FDR data and held constant for the duration of the match.
Wind Speed and Direction	Horizontal wind speed and direction were set to the calculated values from the kinematic consistency evaluation.

- Simulation data start at time 9,813 seconds and end at time 9,875 seconds.
- Mathematical pilots were applied to control column deflection and control wheel deflection. Rudder pedal deflection was set to 0.6 degrees to the right for the duration of this time history match. The FDR pedal deflection appeared to be near zero, on average. The simulation rudder pedal was determined empirically such that the resulting simulation aileron deflection generally aligned with the FDR left aileron deflection.

- A bias of 0.03 was applied to the left and right engine EPR values relative to FDR values to improve the match of longitudinal acceleration, computed airspeed, and pressure altitude.

Simulation Match Observations

The simulation output reflects the FDR and calculated data reasonably well (Figures 11A and 11B).

Figure 11A presents calculated body AOA, described in the section, “Kinematic Consistency Evaluation,” for FDR time 9,810 to 9,880 seconds. The calculated body AOA reached a maximum of approximately 12 degrees. The expected stick shaker activation angle is approximately 12.0 degrees wing AOA for Flap Detent 0, which is equivalent to 11.0 degrees body AOA (noted on Figure 11A). The body AOA data calculated from the FDR suggest that stick shaker may have been active at least momentarily for up to 4 occurrences. Simulation data indicate intermittent stick shaker activation between time 9,840 seconds and time 9,875 seconds due to a higher AOA required to maintain the targeted vertical flight path and airspeed.

The simulation net thrust for the left engine is above the P&W calculated thrust with a hushkit and deterioration by approximately 250 pounds (Figure 11C). The simulation net thrust for the right engine is above the P&W calculated thrust with a hushkit, deterioration, and damage by approximately 600 pounds.

Simulation vs FDR Match # 6: Deceleration with Flaps 1 (Figures: 12A, 12B, and 12C)

Setup Notes

Parameter	Notes
Flap Detent	Flaps 1 was assumed based on the paraphrased CVR transcript
Gear	Gear UP was assumed based on the paraphrased CVR transcript
Stabilizer Position	Stabilizer was set in-flight as required to yield a simulation non-zero column trim similar to FDR data and held constant for the duration of the match.
Wind Speed and Direction	Horizontal wind speed and direction were set to the calculated values from the kinematic consistency evaluation.

- Simulation data start at time 10,085 seconds and end at time 10,130 seconds.
- Mathematical pilots were applied to control column deflection and control wheel deflection. The simulation rudder pedal deflection was set to the adjusted FDR values with the addition of a bias of 1.0 degree to the right for the duration of the time segment analyzed. The simulation rudder pedal bias in relation to the adjusted FDR values was determined empirically such that the resulting simulation aileron deflection generally aligned with the FDR left aileron deflection.
- A bias of -0.03 was applied to the left and right engine EPR values relative to FDR values to improve the match of longitudinal acceleration, computed airspeed, and pressure altitude.

Simulation Match Observations

The simulation output reflects the FDR and calculated data reasonably well (Figures 12A and 12B).

Figure 12A presents calculated body AOA, described in the section, “Kinematic Consistency Evaluation,” for FDR time 10,070 to 10,161 seconds. The calculated body AOA reached a maximum of approximately 16 degrees. The expected stick shaker activation angle is approximately 16.6 degrees wing AOA for Flap Detent 1, which is equivalent to 15.6 degrees body AOA (noted on Figure 12A). The body AOA data calculated from the FDR suggest that stick shaker may have been active at least momentarily for up to 2 occurrences between time 10,110 and time 10,155 seconds. Simulation data indicate intermittent stick shaker activation between time 10,110 seconds and time 10,130 seconds due to a higher AOA required to maintain the targeted vertical flight path and airspeed.

The simulation net thrust for the left engine is below the P&W calculated thrust with a hushkit and deterioration by approximately 500 pounds (Figure 12C). The simulation net thrust for the right engine is above the P&W calculated thrust with a hushkit, deterioration, and damage by approximately 100 pounds.

Performance Evaluation

Two performance evaluations were conducted by the Boeing Aerodynamics Performance group to establish expected airplane performance in terms of both acceleration during ground roll and climb capability during flight. These data are provided to evaluate the actual airplane performance relative to the expected airplane performance at the time of dispatch. The expected airplane performance is based on parameters and calculation methods consistent with the development of the dispatch performance data contained in the Airplane Flight Manual (AFM) and the operational data contained in the Flight Crew Operations Manual (FCOM). These parameters include engine thrust and airplane drag and were established during the 737-200 flight test program.

The first evaluation that was conducted was an on-ground acceleration assessment for the event flight takeoff. For this assessment, the kinematically-corrected FDR acceleration data were compared against the expected all-engine acceleration calculated using the same performance parameters and database that was used to develop the performance data contained in the AFM. This evaluation assumed that the initial thrust setting used by the flight crew is consistent with a full thrust (no derate) takeoff for the entire ground roll. Additionally, wind was determined for this assessment by comparing the FDR computed airspeed with the ADS-B ground speed data. The difference between the FDR computed airspeed (converted to true airspeed) and ADS-B ground speed was used to estimate the wind speed and resulted in about a 17 knot headwind between the ground speeds of 50 and 110 knots. Figure 13 provides the acceleration comparison and shows that the acceleration during the ground roll of the actual airplane was slightly greater than the acceleration assumed to build the performance data in the AFM. This difference in accelerations is expected as the parameters used to develop the AFM are conservatively set such that actual airplane performance exceeds the published AFM performance.

The second evaluation that was conducted assessed the climb capability at various points during the event flight. Comparisons were made between the expected climb capability for the event EPR settings considering engine damage and the potential climb capability assuming one engine inoperative and the other engine at maximum takeoff thrust to compare against AFM dispatch requirements. These assessments were conducted for various speeds and pressure altitudes throughout the event flight. The climb capability for the event EPR settings used net thrust values provided by P&W and considered the installed hush kit, engine deterioration, and low pressure turbine damage from the event. For the climb capability assuming maximum takeoff thrust, the thrust values used are consistent with the takeoff thrust assumed for AFM takeoff performance data development. Specifically, it is minimum takeoff thrust expected when EPR is set to the maximum takeoff thrust setting.

This comparison is provided in Figure 14 and shows that with one engine inoperative the airplane would always have sufficient climb capability assuming the other engine remained at takeoff thrust. The x-axis in Figure 14 represents elapsed time (TZERO, seconds) in relation to the first engine event (right engine EPR reduction) where a value of zero is used as a reference. This comparison is valid for the pressure altitudes, speeds, and configurations achieved during the event flight. The data also show that positive climb capability was unobtainable for the recorded engine EPR values beyond time TZERO plus 120 seconds (between points 6 and 7).

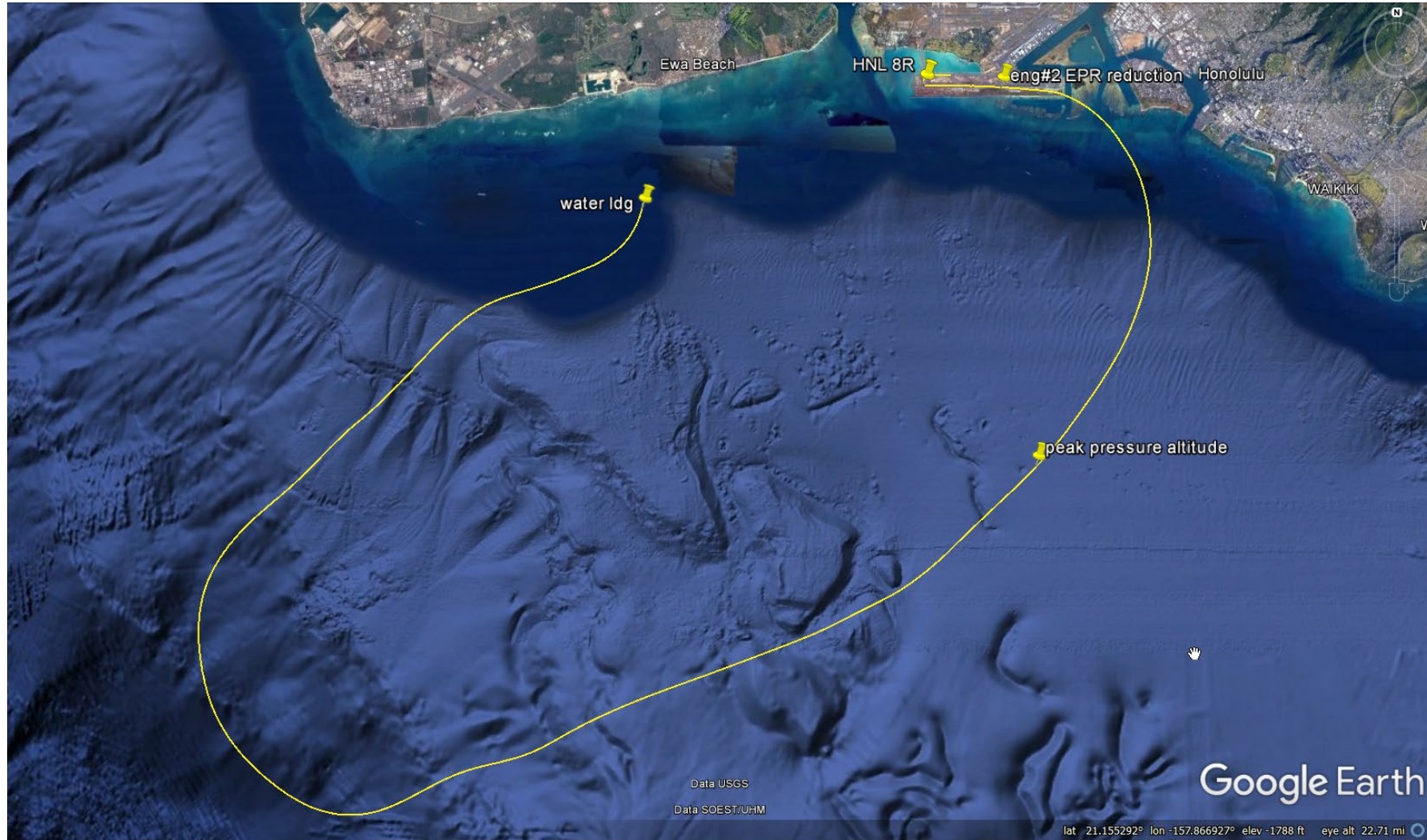
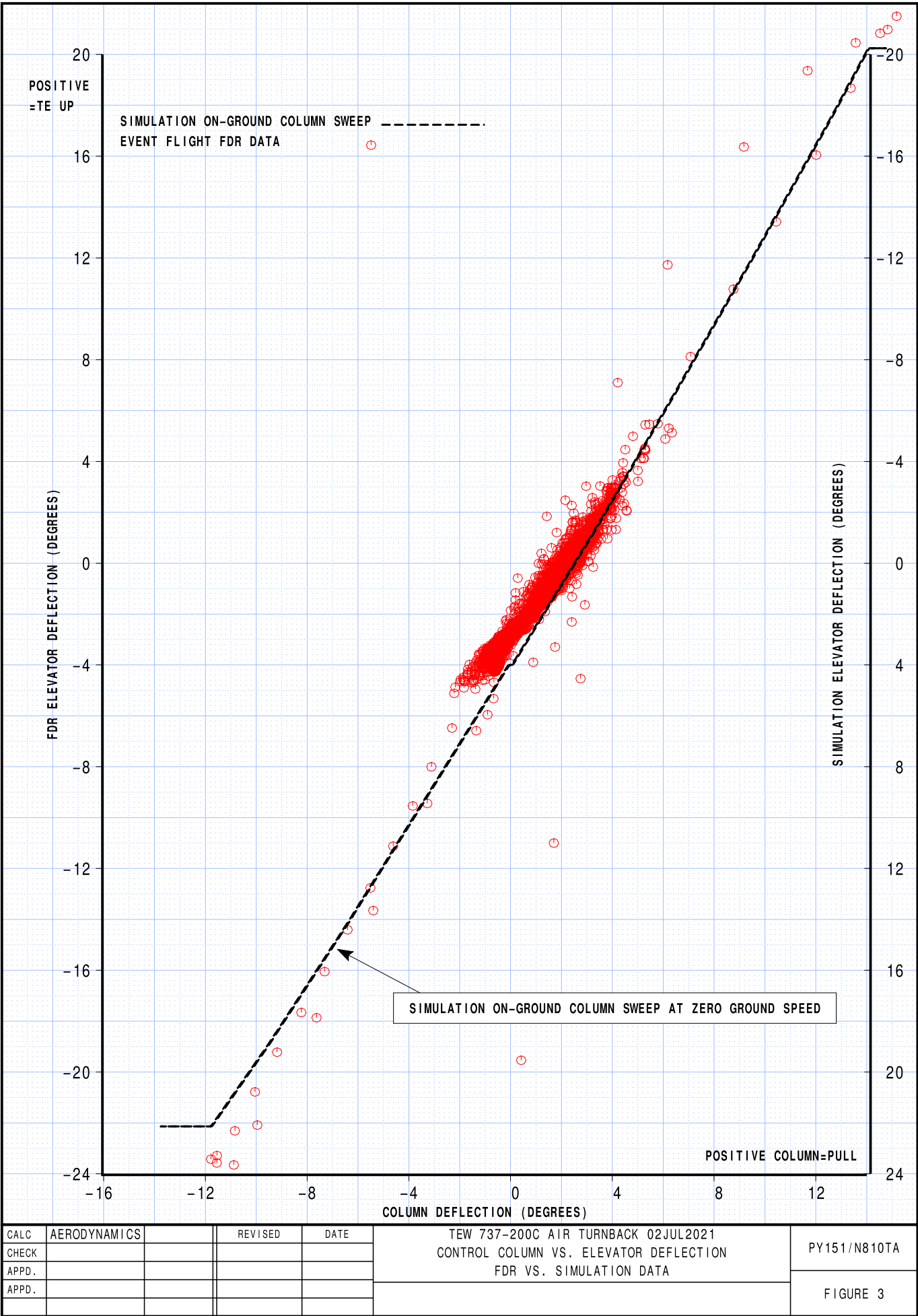
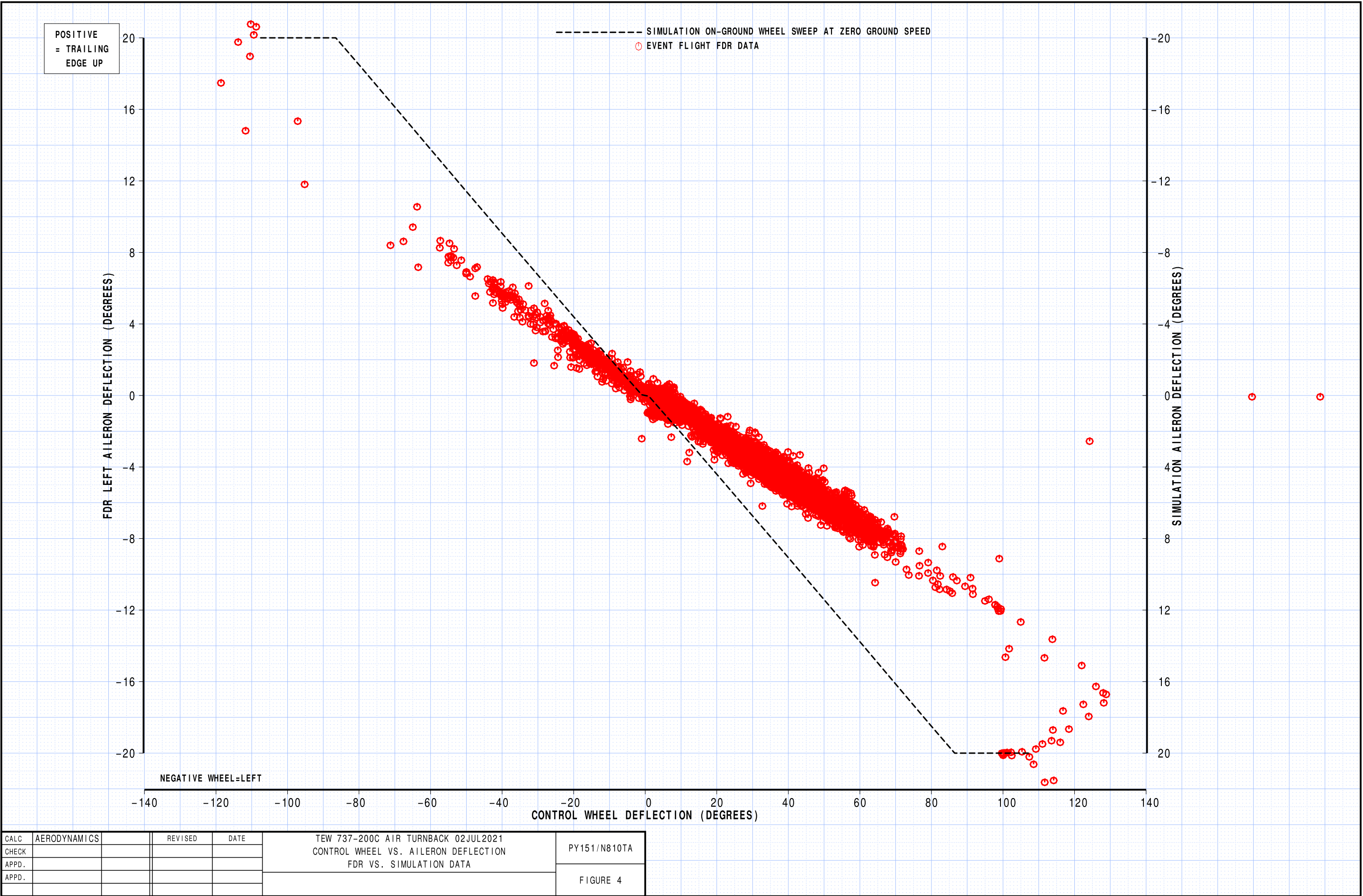


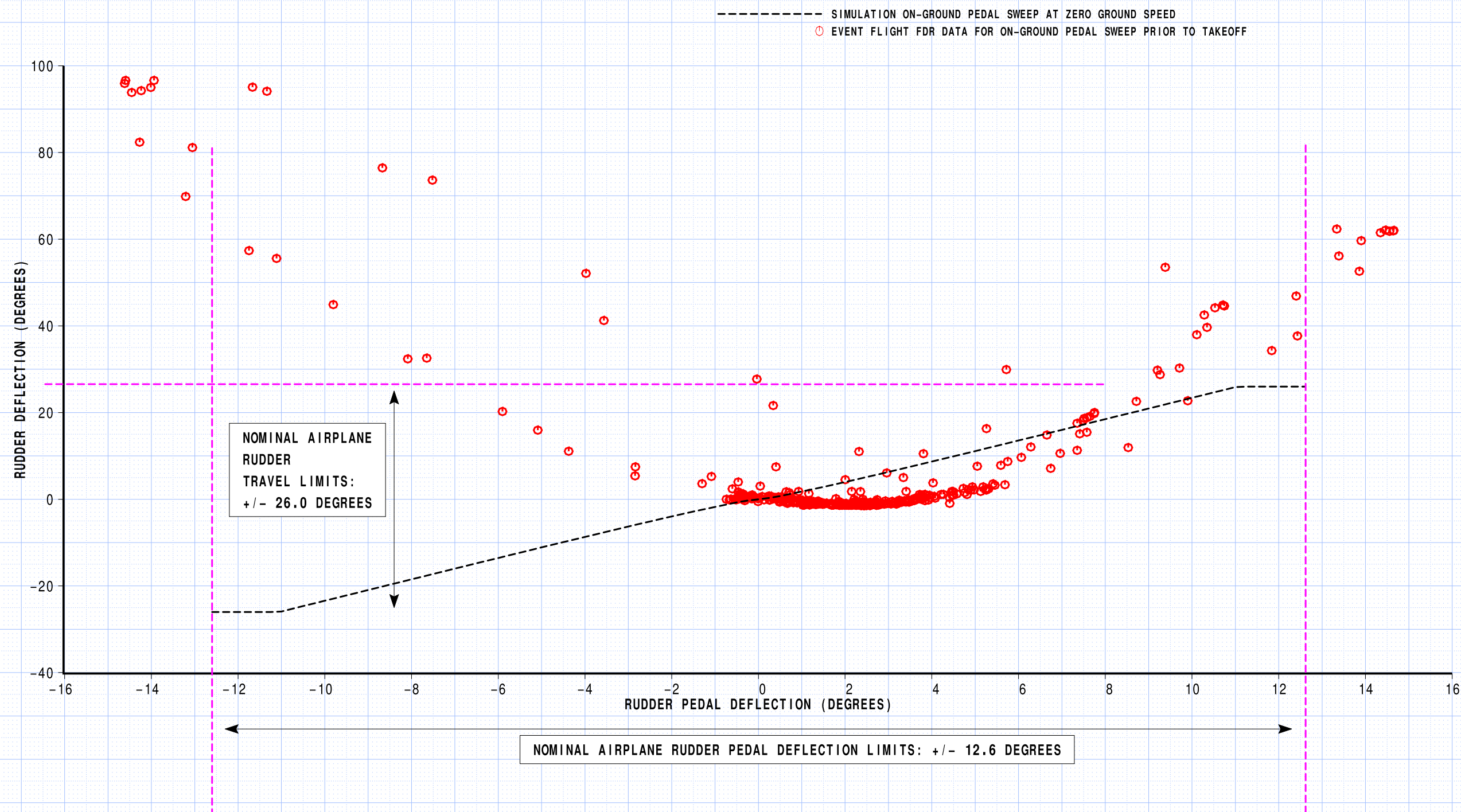
FIGURE 1. TEW 737-200C (PY151/N810TA) 02JUL2021 AIR TURNBACK AND WATER LANDING
EVENT FLIGHT GROUND TRACK OVERVIEW



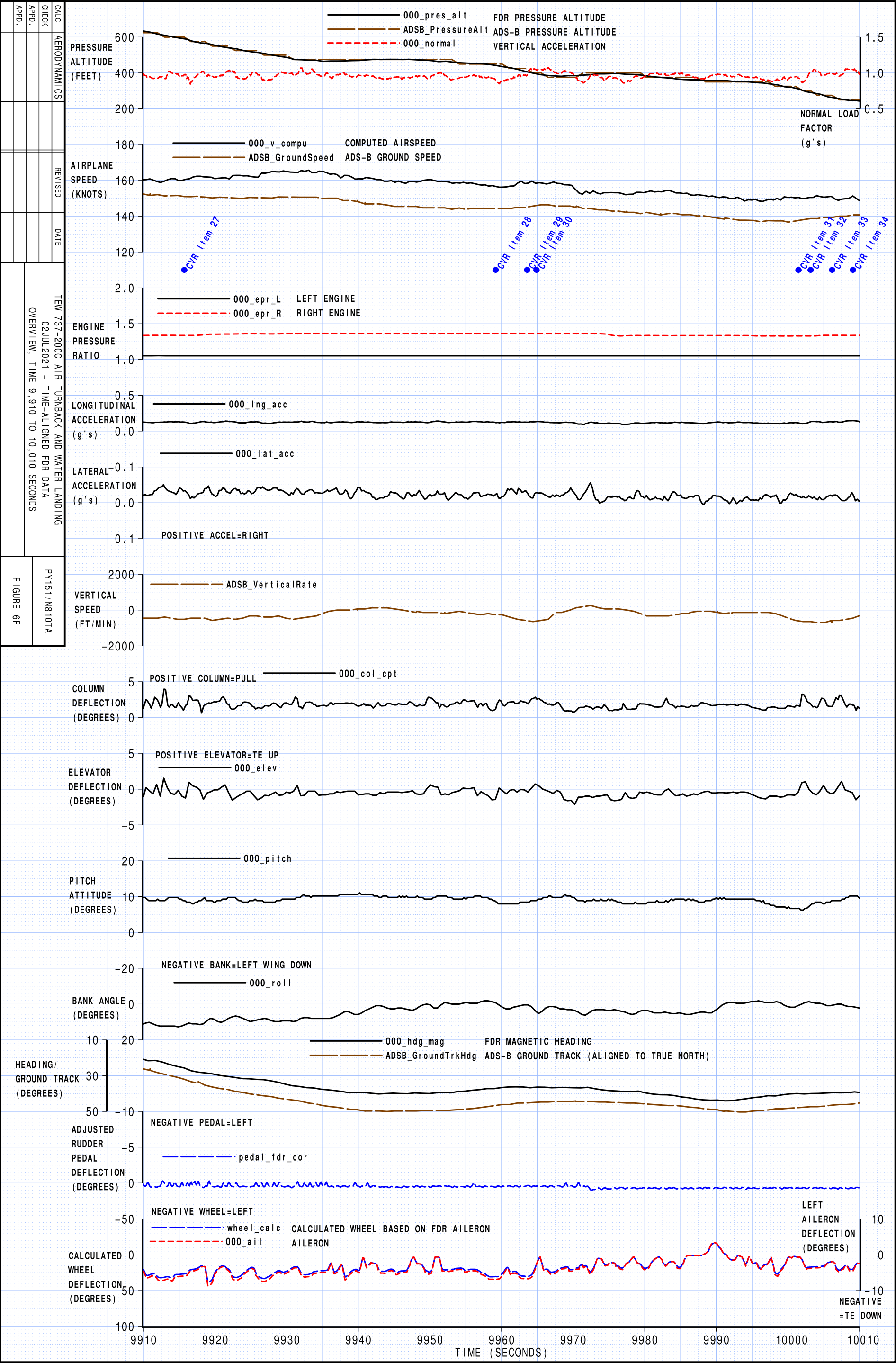
FIGURE 2. TEW 737-200C (PY151/N810TA) 02JUL2021 AIR TURNBACK AND WATER LANDING
EVENT FLIGHT GROUND TRACK TAKEOFF CLOSE-UP

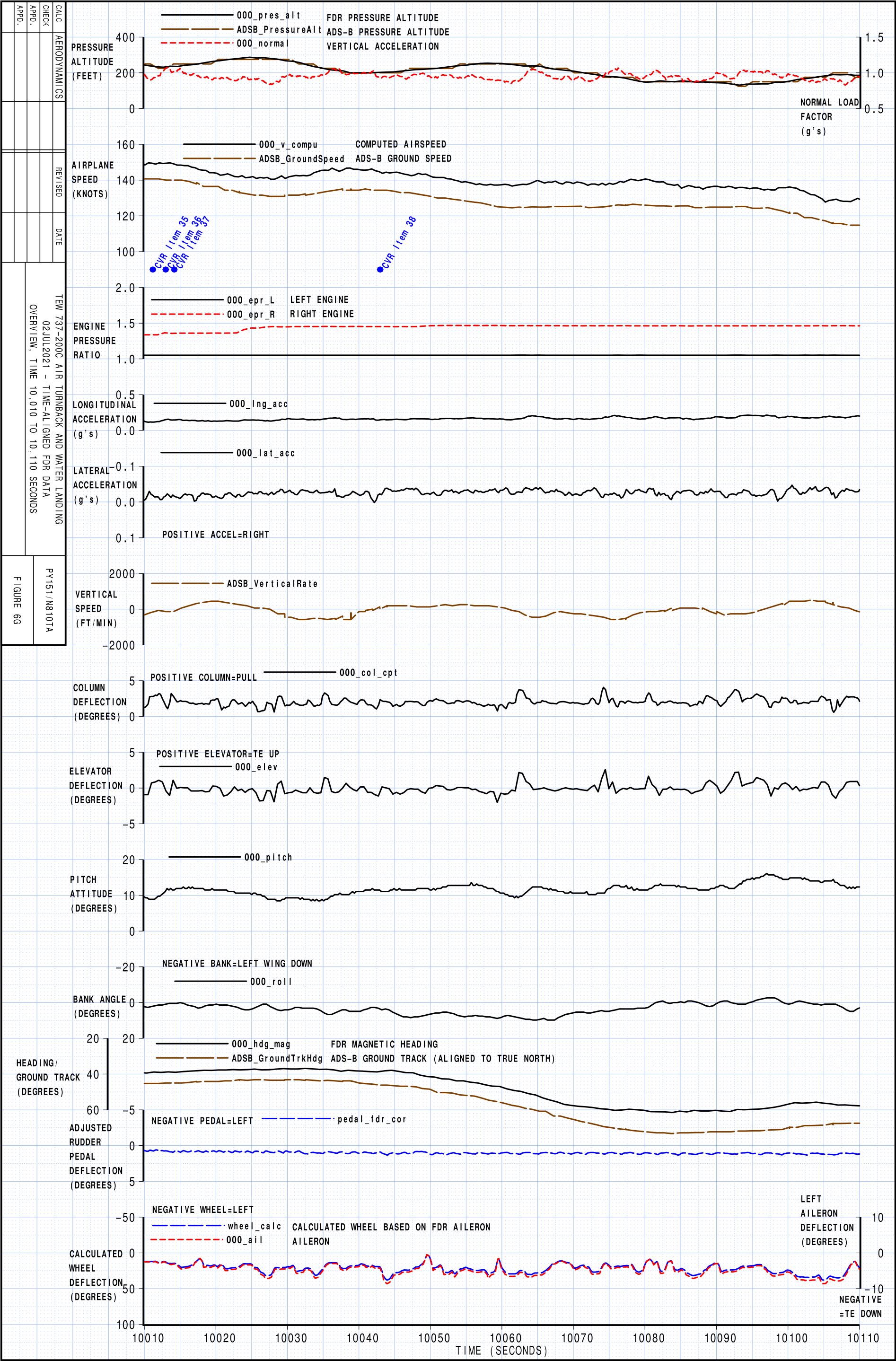


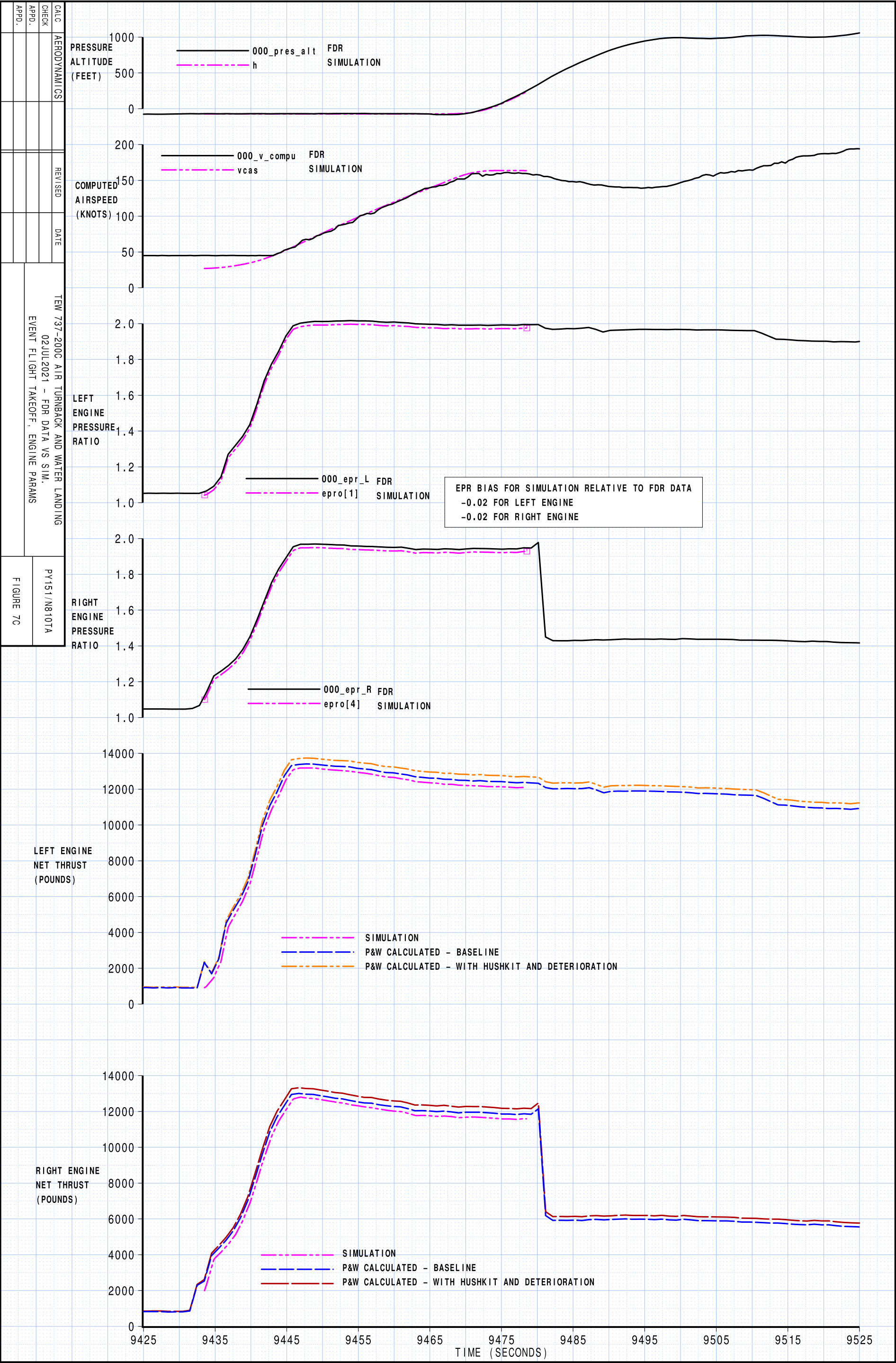


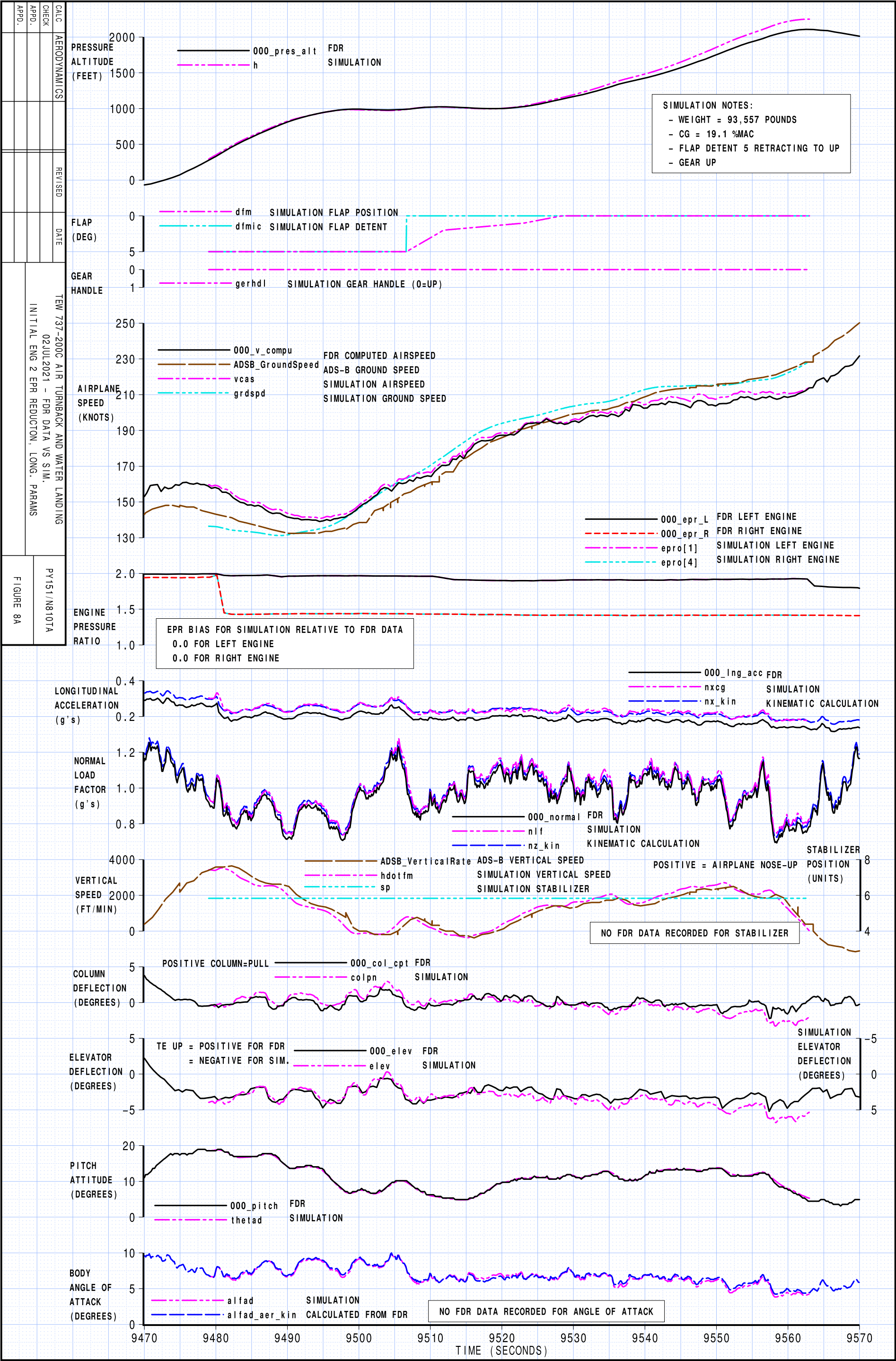


CALC	AERODYNAMICS		REVISED	DATE	TEW 737-200C AIR TURNBACK 02JUL2021 RUDDER PEDAL VS. RUDDER DEFLECTION FDR VS. SIMULATION DATA	PY151/N810TA
CHECK						
APPD.						
APPD.						FIGURE 5

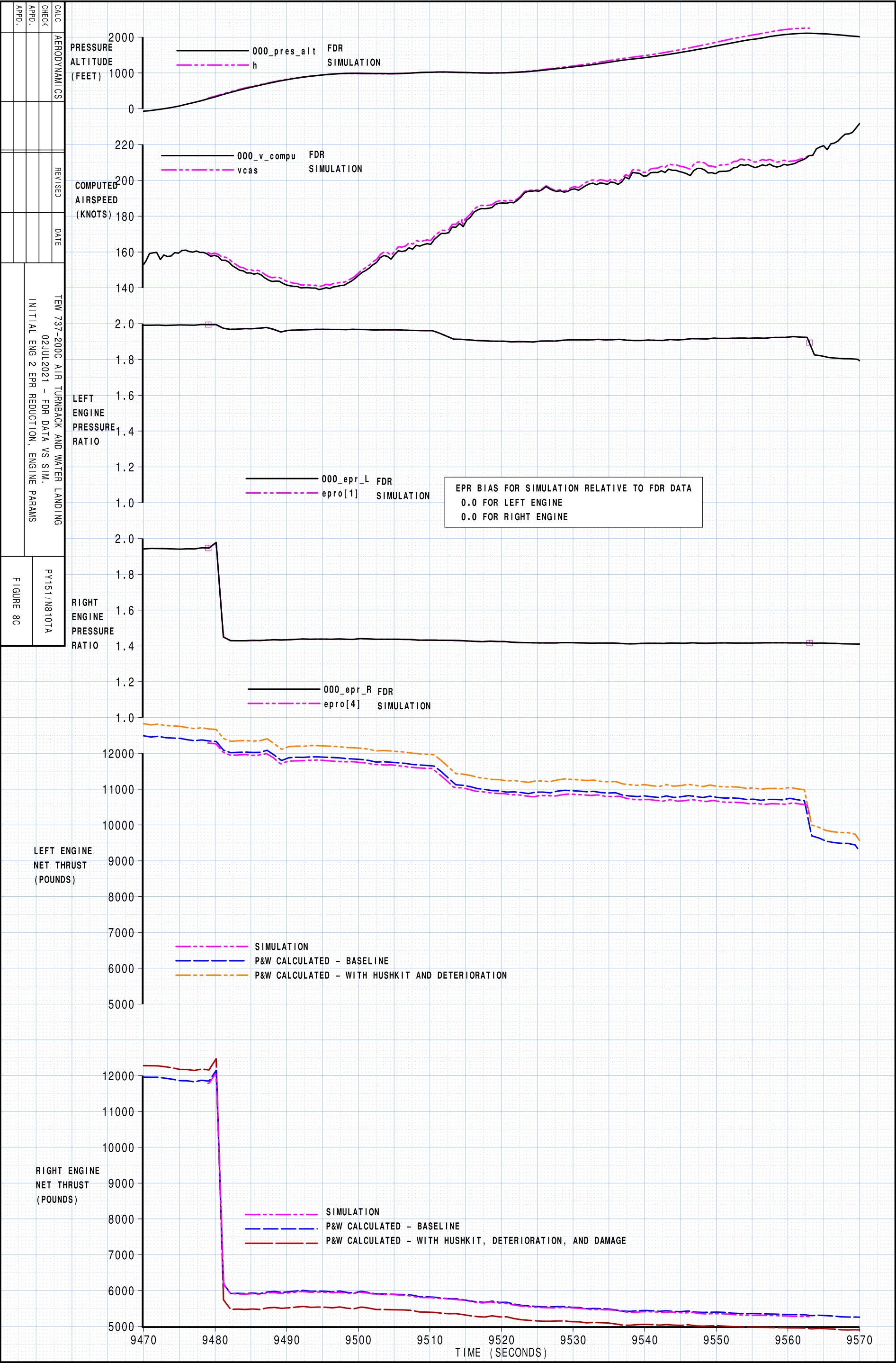


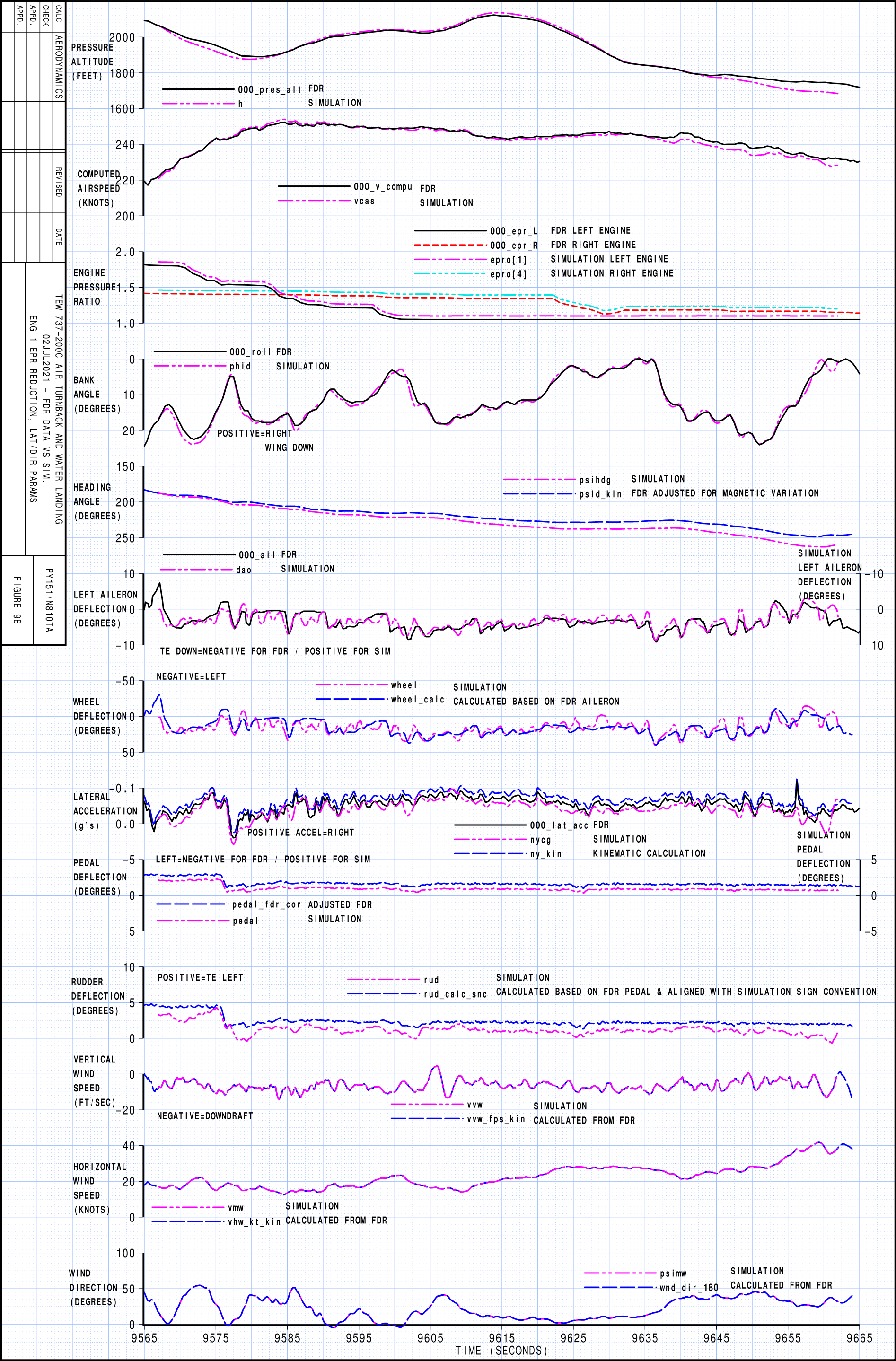


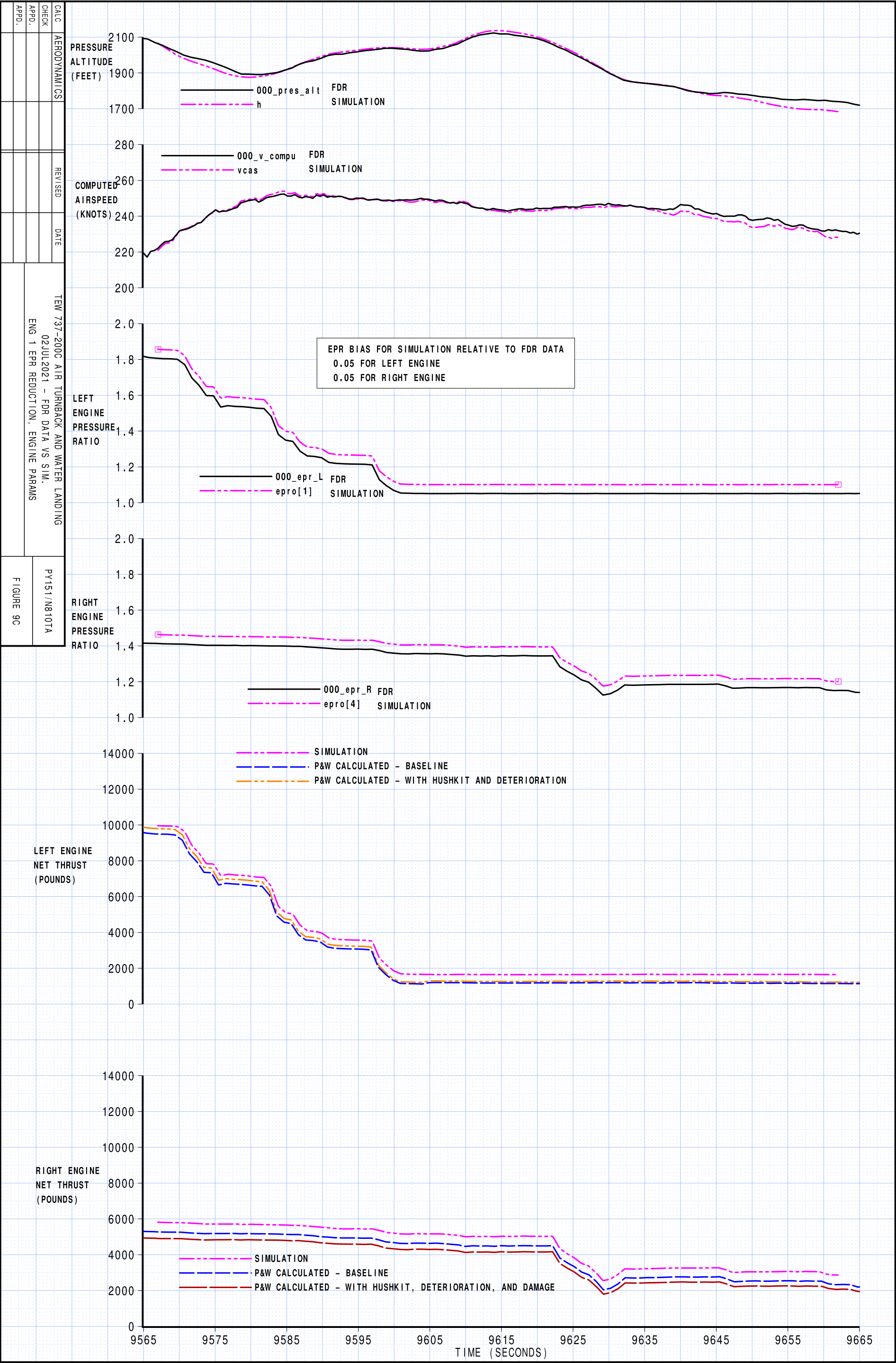


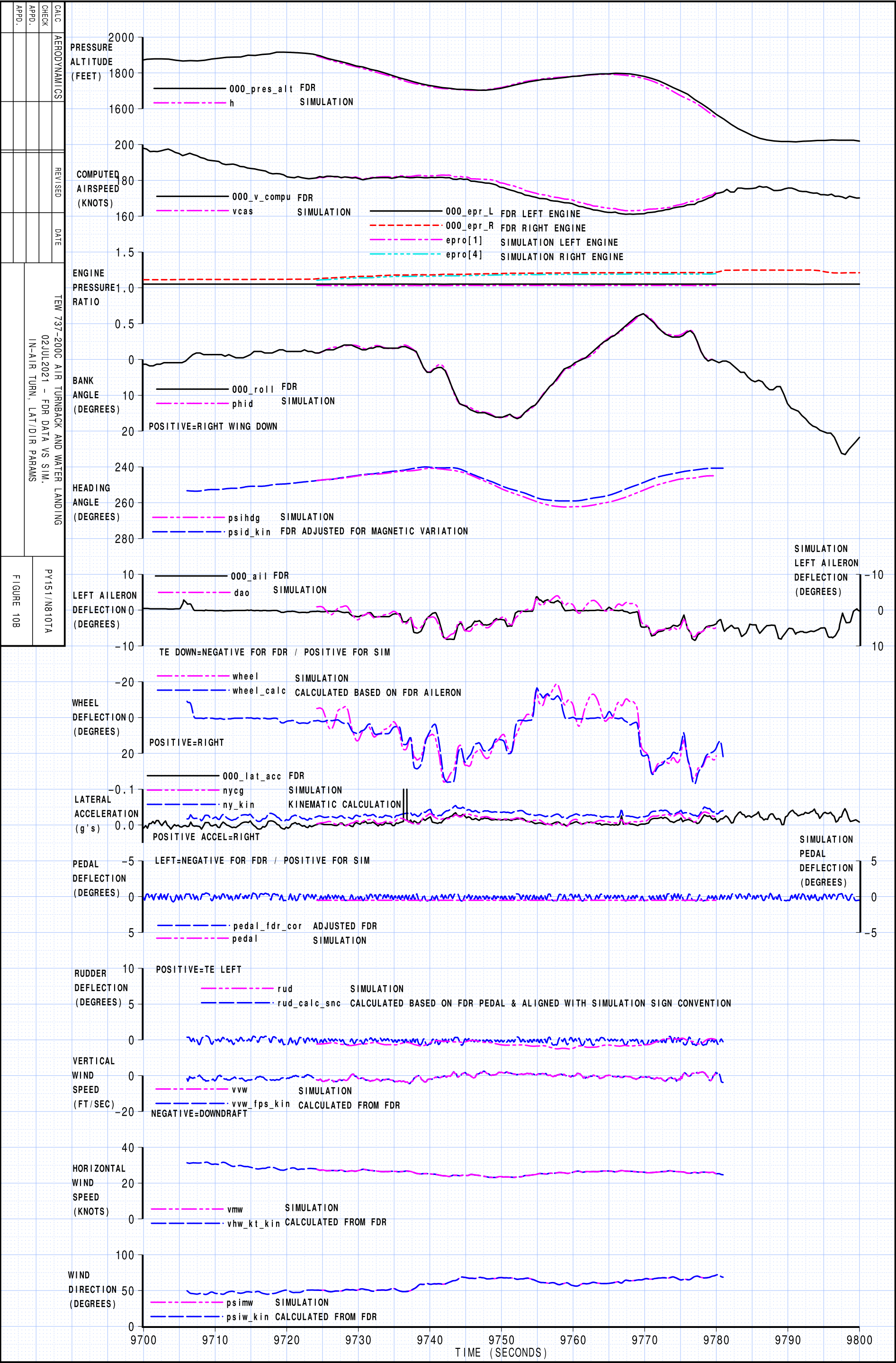


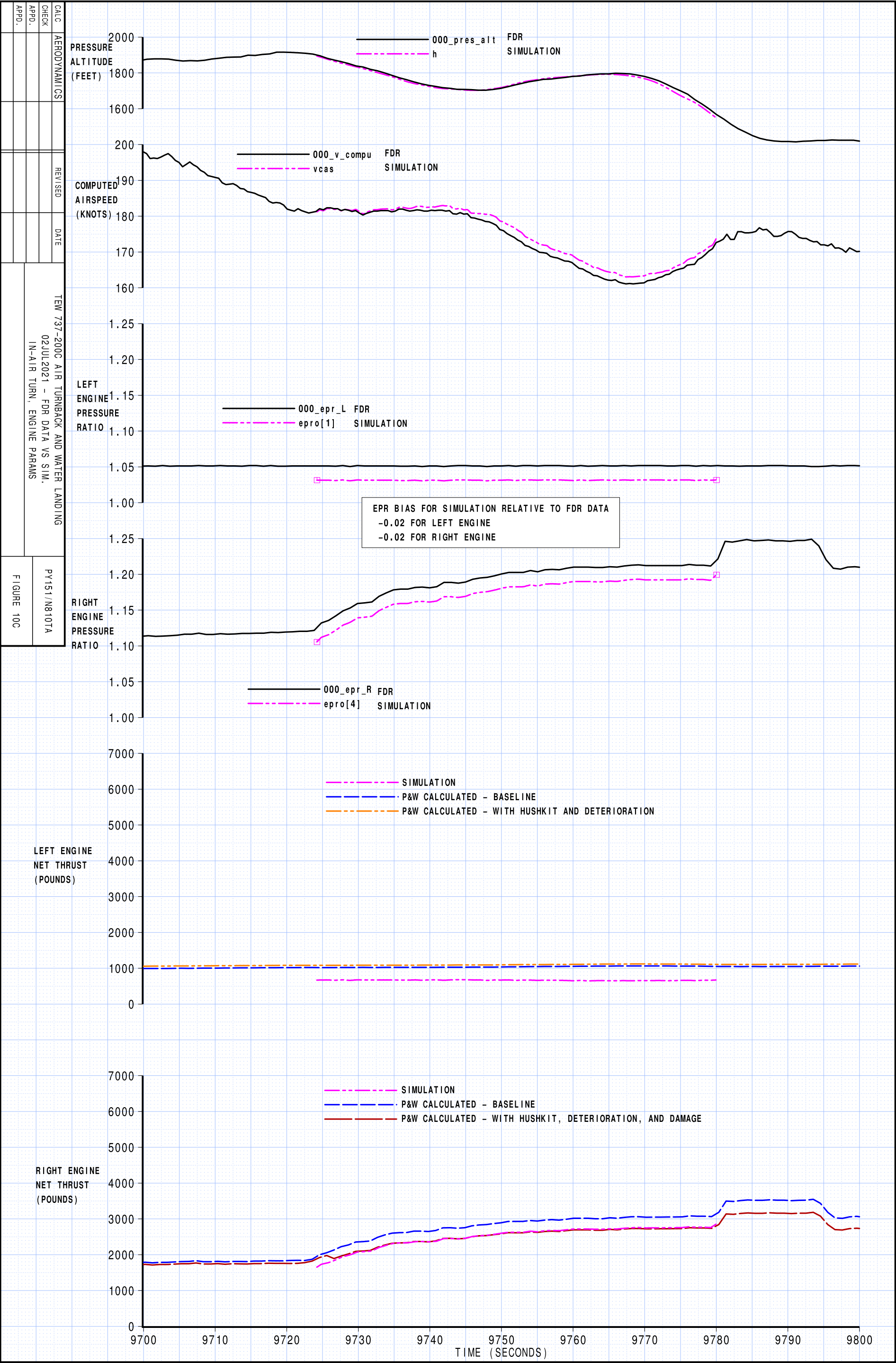
TIME (SECONDS)

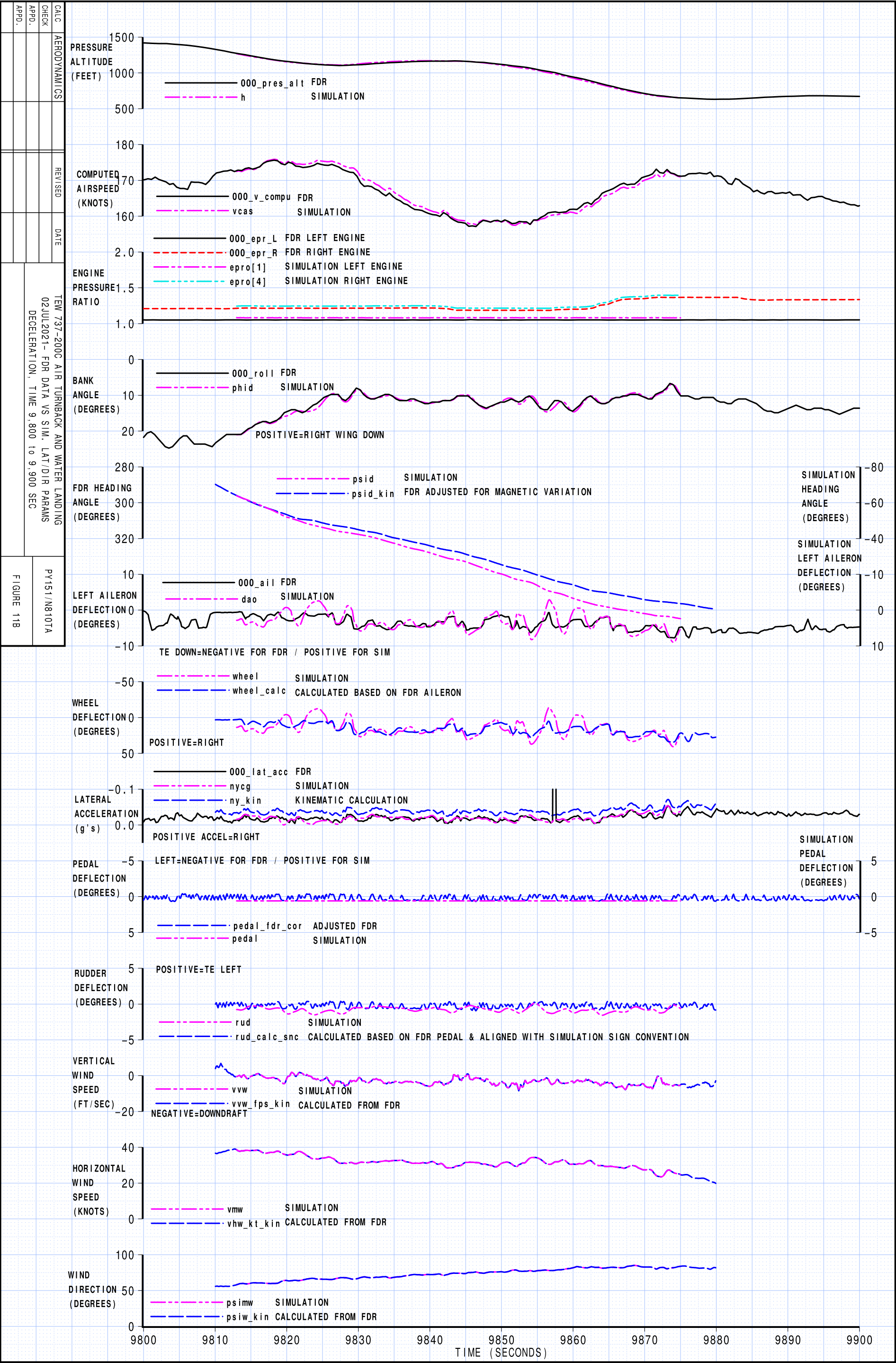


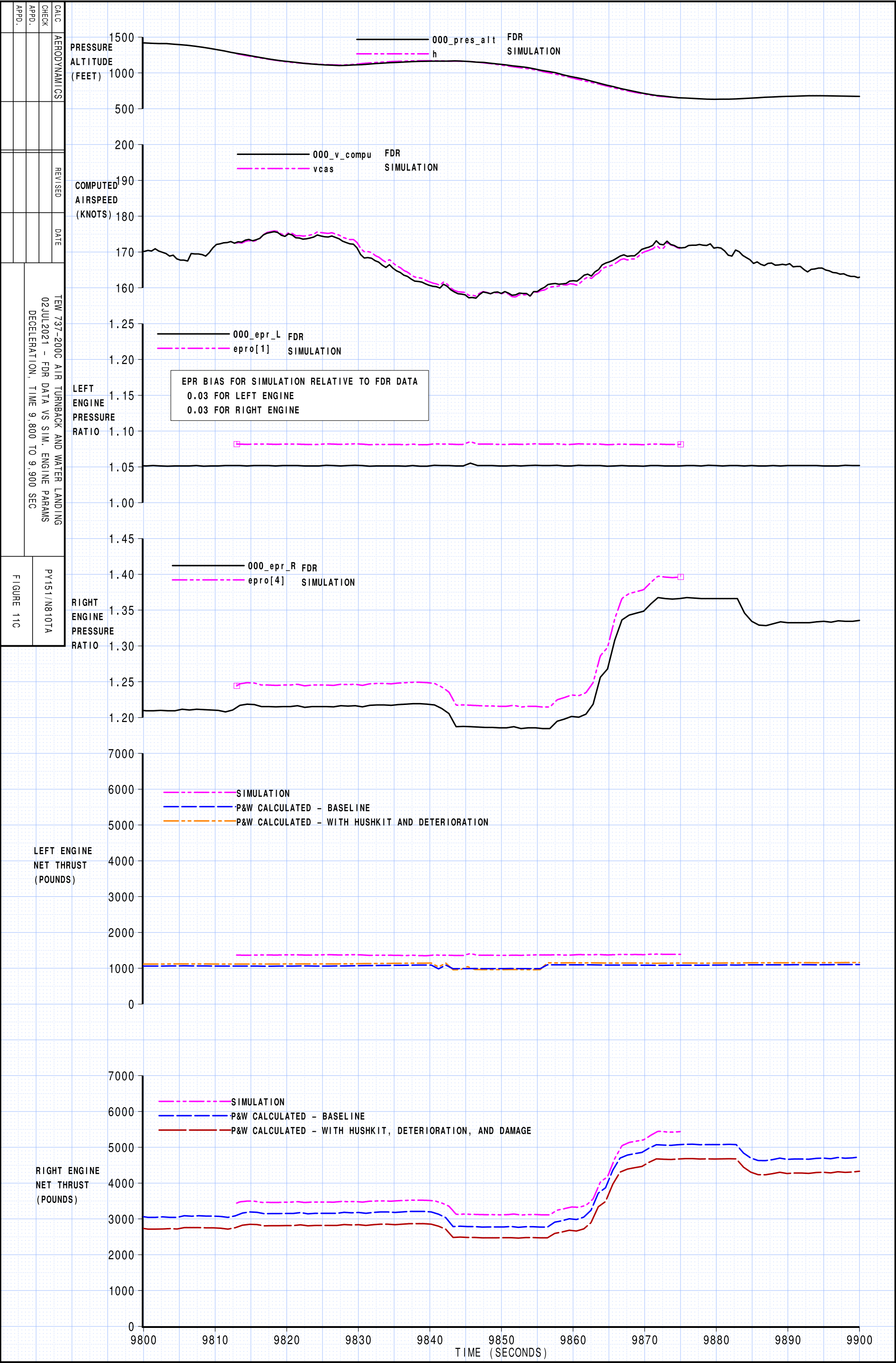












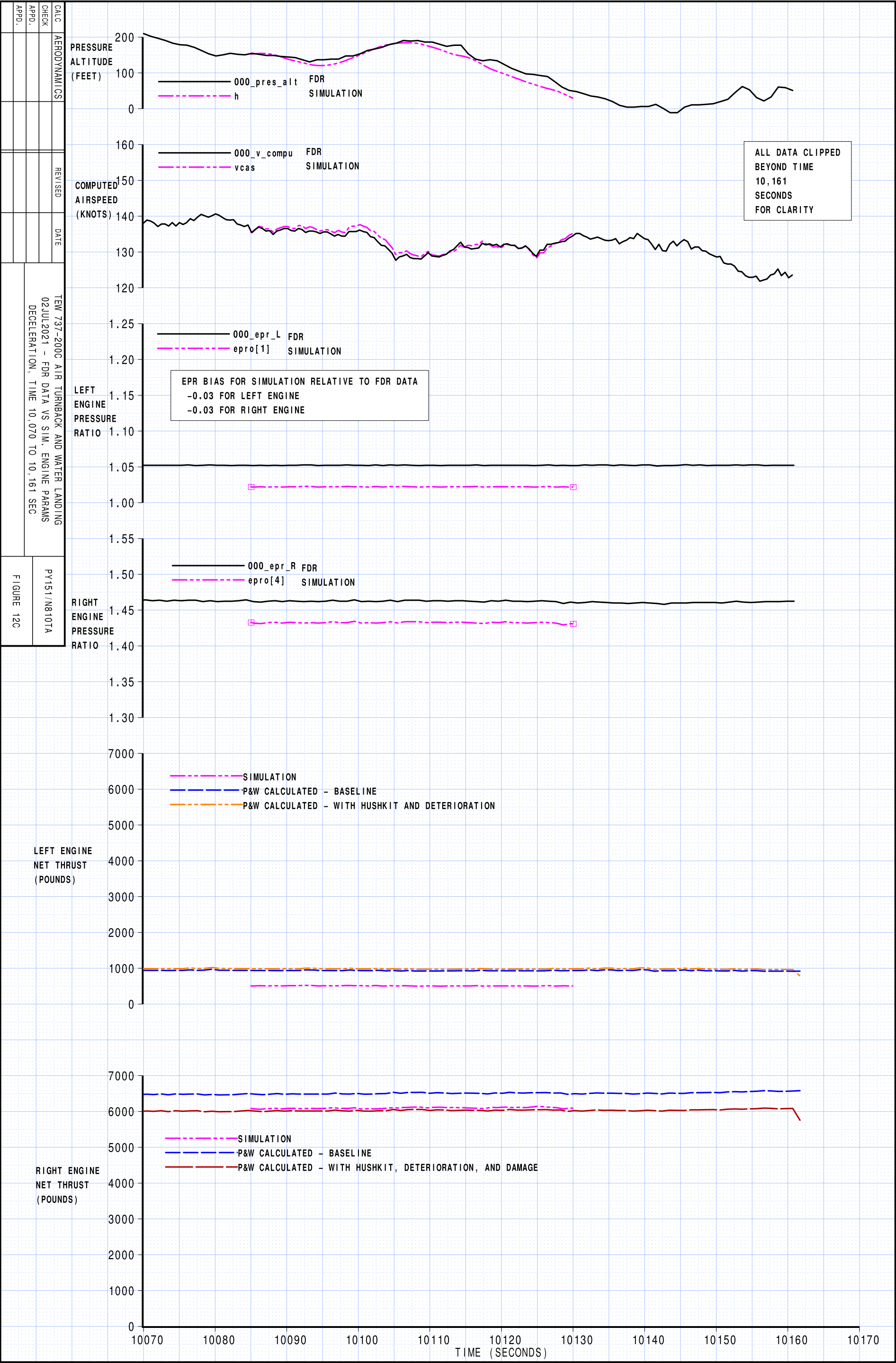


Figure 13 Performance Assessment of Event Flight Takeoff Ground Roll Acceleration

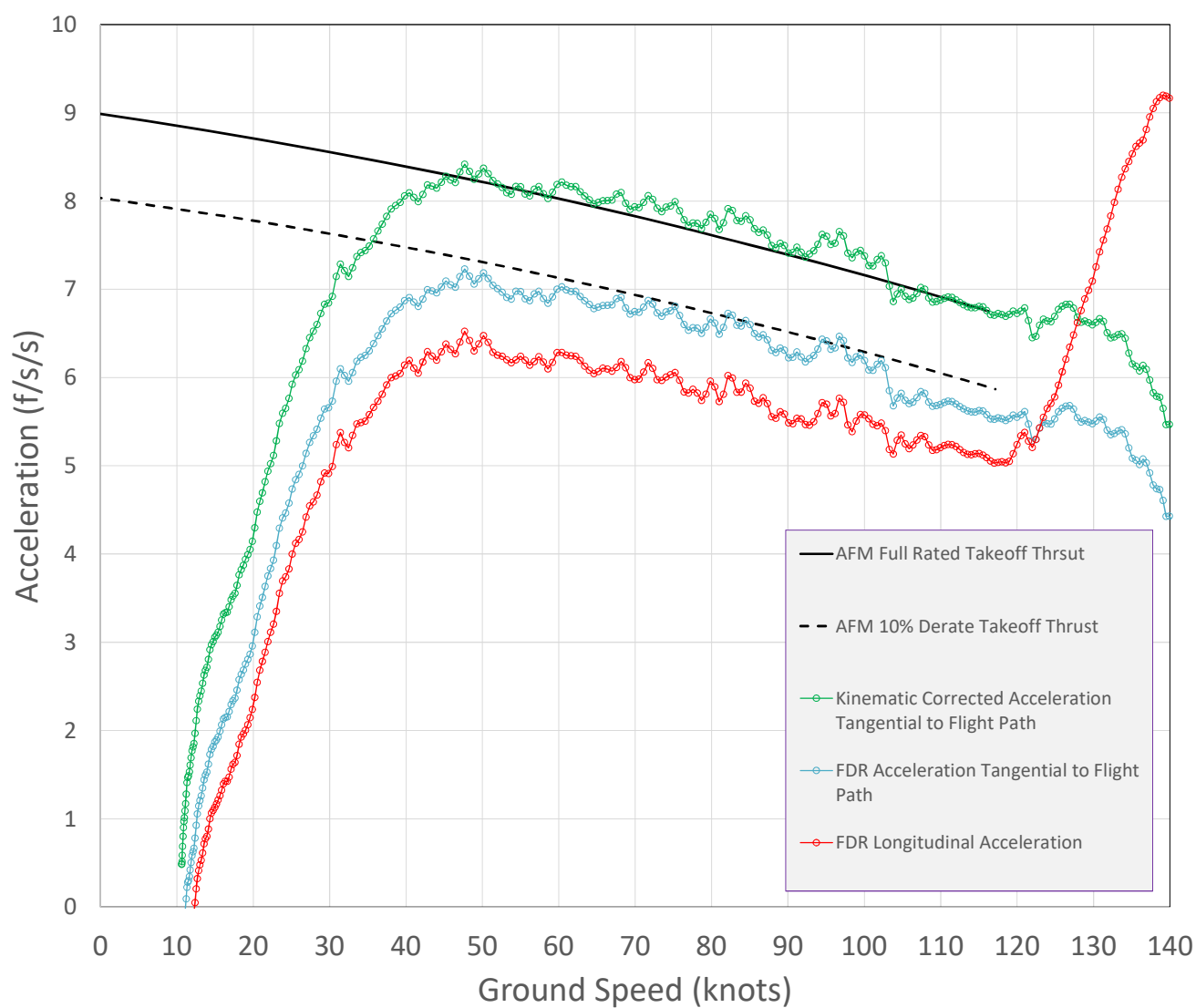


Figure 14. Performance Assessment of Climb Capability During Event Flight

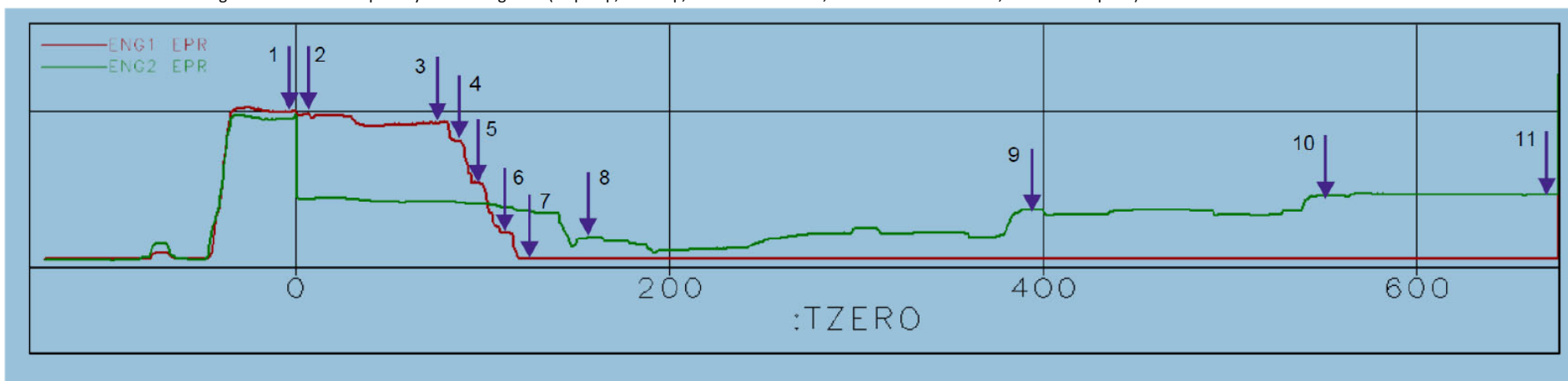
Point	TZERO (s)	Air Speed (kts)	Altitude (ft)	EPR #1	*Actual Engine #1 Thrust (lbs)	**AFM Assumed Max Takeoff Thrust (lbs)	EPR #2	*Actual Engine #2 Thrust (lbs)	**AFM Assumed Max Takeoff Thrust (lbs)	Actual Airplane-Level Thrust (lbs)	All-Engine AFM Thrust (lbs)	Engine Out AFM Thrust (lbs)
1	-1	158	298	1.994	12682	12375	1.947	12163	12375	24845	24750	12375
2	3	150	524	1.970	12349	12295	1.429	5480	12295	17829	24590	12295
3	80.5	208	2094	1.928	11036	11001	1.417	4956	11001	15992	22002	11001
4	85.6	218	2082	1.811	9831	10955	1.415	4930	10955	14761	21910	10955
5	96.7	242	1921	1.542	6993	10916	1.403	4838	10916	11831	21832	10916
6	115.8	249	2025	1.214	3211	10828	1.381	4580	10828	7791	21655	10828
7	125.9	248	2034	1.051	1291	10829	1.357	4299	10829	5590	21657	10829
8	161.1	246	1797	1.051	1285	10971	1.185	2468	10971	3753	21942	10971
9	397.8	170	634	1.051	1143	12084	1.366	4674	12084	5817	24168	12084
10	553.9	142	261	1.052	996	12525	1.452	5844	12525	6840	25050	12525
11	676.7	122	27	1.052	962	12375	1.462	6093	12375	7055	24750	12375

Assumed Flap	Event Climb Capability at Event Speed and Altitude with Actual Thrust		AFM EO Climb Capability at Event Speed and Altitude	
	Gradient (%)	Rate of Climb (feet per minute)	Gradient (%)	Rate of Climb (feet per minute)
5	19.2	3550	5.4	1000
5	11.4	2010	5.1	900
0	11.2	2770	5.4	1350
0	9.8	2550	5.3	1380
0	6.4	1830	4.9	1410
0	1.9	570	4.6	1380
0	-0.9	-270	4.7	1380
0	-2.9	-830	4.9	1420
0	-0.8	-150	5.8	1160
1	-0.4	-70	5.4	890
1	-2.5	-360	3.1	440

Relevant AFM Dispatch Requirements:

2.4% Minimum Engine Out Gradient Capability in Second Segment (Takeoff Flap, Gear Up Point, Takeoff Thrust, V2 Speed)

1.2% Minimum Engine Out Gradient Capability in Final Segment (Flaps Up, Gear Up, 1500 Feet Altitude, Max Continuous Thrust, Final Climb Speed)



* Pratt and Whitney Thrust Simulation considering hushkit, deterioration, and LPT damage on Engine #2

** Maximum Takeoff Thrust used to develop Airplane Flight Manual