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Office of Research and Engineering

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ANC25MA018

AIRPLANE PERFORMANCE STUDY

September 24, 2025
Timothy Burtch

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A. ACCIDENT

Location: Nome, Alaska
Date: February 6, 2025
Time: 1520 Alaska standard time (AKST)
0020 GMT February 7, 2025
Airplane: Cessna C-208B Grand Caravan EX, N321BA

B. AIRPLANE PERFORMANCE GROUP

No airplane performance group was formed.

C. SUMMARY

On February 6, 2025, about 1520 Alaska standard time (AKST), a Cessna 208B Grand Caravan EX, a single engine, turbine-powered airplane, N321BA, was destroyed when it was involved in an accident near Nome, Alaska. The pilot and nine passengers were fatally injured. The airplane was operated by Bering Air, Inc., as a Title 14 *Code of Federal Regulations* (CFR) Part 135 scheduled flight. The flight departed Unalakleet Airport (UNK), Unalakleet, Alaska, at 1437, on an instrument flight rules (IFR) flight plan. The flight was destined for Nome Airport (AOM), Nome, Alaska. The recorded ground track for the forty-three-minute flight is shown in Figure 1.

Times in the study are quoted in AKST unless otherwise noted. Greenwich Mean Time (GMT) = AKST + 9 hr.

D. THE AIRPLANE

A picture of the accident airplane, N321BA, a Textron Aviation (Cessna) C-208B Grand Caravan EX, is shown in Figure 2. The airplane was manufactured by Textron in 2020 and is registered to Bering Air, Inc. The airplane was equipped with a Pratt & Whitney PT6A-140 turbo-prop engine rated for 867 shaft horsepower (HP).

N321BA had the Tecalemit-Kilfrost-Sheepbridge Stokes or TKS ice protection system for flight into known icing conditions. The TKS system supplement limits the maximum takeoff gross weight to 8,807 lb for flight into known or forecast icing conditions. Preliminary weight calculations for the accident flight indicate that the gross takeoff weight was about 9,776 lbs or 969 lb over the maximum limit for flight into known or forecast icing conditions.

In addition to the weight limit, the minimum operating airspeed with the TKS system operating is 95 kt to insure proper coverage of the airplane's protected surfaces with TKS fluid. See Figure 3 for a picture of the TKS porous panel coverage. The

minimum operating airspeed when excessive ice accumulation is observed or suspected (or when the TKS ice protection system is inoperative) is 120 kt.

N321BA was also equipped with a Low Airspeed Awareness (LAA) system that is automatically armed whenever the pitot-static system heat is turned on. The LAA system is designed to warn the pilot when the airspeed falls below 97.5 kt $\pm$ 2.2 kt. The LAA is also designed to disconnect the autopilot (if engaged) when activated.

E. THE WEATHER

Nome Airport is equipped with an Automated Surface Observing System (ASOS). The ASOS is located approximately 32 miles west-northwest of the accident site at an elevation of 41 feet (ft) and issued the following observation approximately 15 minutes before the accident:

[1505 AKST] SPECI PAOM 070005Z 00000KT 10SM -SN BKN027 BKN035 OVC055 M10/M12 A3020 RMK AO2 SNB03 P0000 T11001122=

The automated surface weather observation at Nome Airport at 1505 AKST, wind calm, visibility 10 miles or greater, light snow; broken ceiling at 2,700 ft above ground level (agl), broken skies at 3,500 ft agl, overcast skies at 5,500 ft agl; temperature of -10°C, dew point temperature of -12°C, and an altimeter setting of 30.20 inches of mercury (inHg). Remarks: station with a precipitation discriminator, snow began at 1503 AKST, a trace of precipitation since 1453 AKST, temperature -10.0°C, dew point temperature -12.2°C.

The 1500 AKST sounding at AOM indicated a stable atmosphere from near the surface to 6,000 ft with a conditionally unstable atmosphere from 6,000 ft through 7,500 ft. The complete Rawinsonde Observation program (RAOB) indicated cloud cover between 400 ft agl through 8,250 ft and moderate or greater rime and mixed icing conditions between the surface and 8,250 ft.

A detailed review of icing data performed by the National Center for Atmospheric Research (NCAR) after the accident indicated that there was a 55-60% chance of freezing drizzle above the accident site at altitudes between 2,000 and 6,000 ft.

See the NTSB Meteorology Specialist's Factual Report for more weather details.

F. AIRPLANE PERFORMANCE STUDY

1.0 Garmin G1000 Data

The data used in the airplane performance study were recovered from the airplane's Garmin G1000 integrated flight instrument system. The G1000 recorded time, position, altitude, attitude, airspeed, and acceleration, as well as engine parameters.

Figure 5 contains the G1000 altitude above mean sea level (msl), rate of climb (ROC) and indicated airspeed (IAS) for the accident flight. The airplane lifted off at about 14:38:00 and reached a cruise altitude of approximately 8,000 ft at 14:48:53. The airplane remained in level flight at 8,000 ft for about 22.5 minutes.

Airspeeds recorded on the G1000 are consistent with climb and cruise for the C-208B. G1000 data show that the airplane climbed at approximately 120 kt and cruised at approximately 150 kt. The recorded engine torque and propeller revolutions per minute (RPM) as well as the calculated horsepower¹ associated with these airspeeds are shown in Figure 8.

The airspeeds during the descent to 6,000 ft and then to 4,000 were less predictable. Figure 6 highlights the last ten minutes of the flight and the descent into Nome. During the initial descent starting at 15:11:23, N321BA accelerated from about 145 kt to 160 kt as altitude was traded for airspeed with no change in power². The recorded engine torque and propeller revolutions per minute (RPM) as well as the calculated horsepower for the last ten minutes are shown in Figure 9.

At 15:13:59, the power was reduced from 2,060 ft-lb of torque (approximately 688 HP) to 873 ft-lb of torque (approximately 290 HP), and the airplane slowed from 160 kt to about 114 kt at 15:15:50. At that time, the power increased slightly, and the airplane accelerated to 126 kt at 15:18:16.

A final power reduction of about 75 HP at 15:18:16 caused the airspeed to slow from 126 kt for the remainder of the flight. (The slowest recorded airspeed was 65 kt at 15:19:52.) An increase in power about a minute later at 15:19:24 was not enough to arrest the airplane's deceleration³. The indicated airspeed was approximately 100

¹ The C-208B Pilot's Operating Handbook defines shaft horsepower (SHP) as the power delivered to the propeller shaft: $SHP = [(Propeller\ RPM) \times (Torque\ (ft-lb))] / 5252$. A propeller efficiency of 100% was assumed for the G1000 calculated horsepower unless otherwise noted.

² The Cessna C-208B Grand Caravan EX has a maximum operating speed or VMO of 175 kt indicated airspeed.

³ A simulation match of the G1000 data using flight-test-validated C-208B models indicate that the airplane's angle-of-attack was also rapidly increasing as the airspeed decayed beyond 15:19:24. See Figure 16 in the "C-208B Simulation Match with G1000 Data" section for the angle-of-attack time history. The C-208B models also indicate that 352 HP would be required to maintain straight and level

kt at 15:19:35 when the recorded Automatic Flight Control System (AFCS) status changed from 1 to 0, indicating that N321BA's autopilot was no longer engaged. Figures 7 and 10 show the airspeed and engine parameters for the final minute, respectively. At 15:19:46, the airplane was descending at 2,000 fpm when the descent rate quickly reduced to 1,400 fpm over three seconds, likely due to airplane-nose-up elevator input by the pilot.

See Figure 11 for a summary of the power changes made during the flight.

Figure 12 includes recorded pitch, roll, and heading for the final minute. The airplane remained on a westerly heading except during take-off and again near the end of the flight when the autopilot disconnected at 15:19:35; the airplane turned towards the south when the autopilot disconnected. The G1000 data recording for most parameters ended at 15:20:03, about thirty seconds after the autopilot disconnected.

Finally, Figure 13 shows the airplane lateral and vertical accelerations for the final minute of recorded G1000 data. The largest lateral and vertical accelerations were -0.77g and 2.2g, respectively, and both occurred about three seconds before the data recording ended.

2.0 C-208B Simulation Match with Garmin G1000 Data

Flight-test-validated C-208B simulation models developed by Kohlman Systems Research (KSR) for pilot training were used in the airplane performance study to supplement data recorded on the G1000. The C-208B aerodynamic, engine, and flight control models provided insight into parameters that would otherwise be unavailable.

The KSR C-208B aerodynamics model did not include a cargo pod like the one installed on N321BA. To account for the additional drag due to the pod, Textron provided a pod drag increment of 43 drag counts or $\Delta C_D = 0.0043$, and this was added to the C-208B aerodynamic model.

In addition, the KSR C-208B simulation models do not account for ice on either the protected or unprotected surfaces of the airplane. Consequently, the build-up of any significant ice during N321BA's flight to Nome would result in increasing differences between the KSR-208B simulation and the recovered G1000 data.

The airplane configuration, flight conditions, and airplane dynamics recorded on the G1000 were matched in the KSR C-208B simulation for 41 minutes, from 14:38:10 or an altitude of 173 ft to 15:19:33 or about two seconds before the autopilot

flight at 4,000 ft at the maximum gross weight of 8,809 lb. It takes 378 HP at a gross weight that is 1,000 lb over the maximum gross weight. Both the 352 HP and 378 HP power requirements are more than the approximately 300 HP that the pilot used during the descent.

disconnected⁴. Figures 14 and 15 show a good comparison between the recorded G1000 data and the simulation for altitude and calibrated airspeed (Vc), respectively, with the same airplane configuration and flight condition.

Figure 16 is a comparison of the airplane pitch attitude from the G1000 and the simulation for the same 41 minutes. Except for the first few seconds where the accident pilot used take-off flaps and the simulation used retracted flaps, the pitch attitudes match closely⁵.

The ability of a wing to generate lift is sensitive to any ice accretion on the wing surface. The wing generates most of the lift on an airplane, and lift is characterized by the angle-of-attack vs. lift coefficient relationship. For example, Figure 17 shows a lift curve for a typical wing with various forms of ice. While the effects of ice vary with ice type, all forms of ice reduce the lift-curve slope, the maximum lift coefficient, C_{Lmax} , and the stall angle-of-attack, α_{STALL} . For that wing, thin rough ice was calculated to reduce the maximum lift coefficient by about 30% and reduce the stall angle-of-attack by 8° or about 40%.

Figure 18 includes a time history estimate of the of the lift coefficient required to match the G1000 data. The data show that N321BA reached C_{Lmax} for a C-208B without ice at 15:19:46, eleven seconds after the autopilot disconnected and about the same time that the lateral/directional oscillations started to grow significantly.

A comparison between the calculated G1000 AOA⁶ and the simulation AOA is shown in Figure 19. Like pitch attitude, there is a bias between the G1000 data and the simulation for the first few seconds due to the difference in flaps. However, after the pilot retracted the take-off flaps, the G1000 and the simulation AOA's match well⁷ until about 15:15. At 15:15, the calculated G1000 AOA is approximately 0.5° greater than the simulation AOA at the same dynamic pressure. The difference is highlighted in Figure 20.

While ice affects the wing's ability to generate lift, ice also increases airplane drag. The additional drag necessitates more power to achieve the same speed. Figure

⁴ The angle-of-attack (AOA) was 11° and increasing rapidly when the simulation was stopped at 15:19:33. The KSR C-208B simulation has not been validated with flight data at AOA's beyond stall or about 15°. In addition, the recorded lateral load factor, which is an indication of sideslip, began to oscillate when the autopilot disconnected at 15:19:35 and grew to 0.4g starting at 15:19:46. The lateral load factor reached a maximum of -0.77g at 15:20:00. The simulation has not been validated at the extreme sideslip angles associated with this lateral acceleration.

⁵ A constant pitch bias of 0.8° was added to the G1000 pitch. It is believed that the bias is the result of a calibration effect in the airplane's attitude and heading reference system or AHRS.

⁶ $\alpha \cong \theta - \gamma$ where pitch attitude, θ , is recorded on the G1000 and the flight path angle, γ , can be computed from the recorded ROC and airspeed: $ROC = V_T \sin(\gamma)$.

⁷ The simulation initially required approximately 5° more AOA without the benefit of take-off flaps.

21 is a comparison of the horsepower computed from the recorded G1000 propeller rpm and engine torque (see footnote 1) as well as an assumed propeller efficiency of 90% and the simulation horsepower. The simulation horsepower was calculated directly from thrust delivered to the airframe, i.e., It does not require a propeller efficiency: $HP = [Total\ Thrust\ (lb)] \times [True\ Airspeed\ (kt)] / 325$. It should be noted that the simulation horsepower was smoothed because it was derived from thrust which was varied in the simulation in order to match the G1000 airspeed. The thrust magnitudes are what is significant.

G. SUMMARY AND CONCLUSIONS

A comparison between recorded G1000 data recovered from N321BA and flight-test-validated C-208B model data without any adjustments for ice show a good match for the 43-minute accident flight from Unalakleet to Nome. Lift and drag, which are both sensitive to the presence of ice, were comparable to values from the C-208B aerodynamic model without ice until about 15:15 when N321BA was descending through 6,250 ft. From 15:15 until the end of the data, the calculated G1000 AOA was about a 0.5° greater than the simulation AOA.

The NTSB Meteorology Specialist determined that N321BA entered moderate or greater icing with super-cooled large droplets likely at 15:14:55. While the TKS system should have kept ice from accreting on the protected surfaces, the small difference between the G1000 AOA and simulation AOA could be the result of ice accreting on N321BA's unprotected surfaces⁸.

While some ice was present on the airplane, the accident flight was uneventful until the final 30 seconds. At 15:19:35, about 30 seconds before the G1000 data ended⁹, the autopilot, which had been on since the airplane climbed through 600 ft on take-off, was disconnected through the LAA system (vs. the pilot). The airplane had just leveled off at 4,000 ft 15 seconds earlier at 15:19:20.

N321BA appears to have stalled at approximately 15:19:46 when the pilot apparently pulled back on the yoke to arrest a 2,000 fpm descent while at an airspeed of about 89 KCAS. This led to airplane loss of control. The power had reached 560 HP and was increasing from a low of 260 HP twenty seconds earlier. Bank angle was about 30° left-wing-down, and Δn_z , Δn_y both were about 0.1g at the time of stall. Wind gusts do not appear to have been a factor.

⁸ Based on airplane performance and autopilot data recorded on the G1000 and weather information for around the time of the accident, it is believed that the TKS system on N321BA was turned on and operating properly. However, ice was found attached to unprotected portions of the wreckage. See Figure 4. Note: the ice/snow on and behind the TKS panel likely resulted after impact.

⁹ The G1000 recording for all parameters except airspeed ended at 15:20:03. The airspeed recording ended at 15:19:54.

The G1000 data and simulation models indicate that N321BA had an angle-of-attack stall margin¹⁰ between 10°-13° for most of the flight. However, the AOA began to increase as the airplane leveled off at 4,000 ft at 15:19:20. The wing exceeded α_{STALL} shortly after the pilot pulled the elevator column back at 15:19:46 which resulted in an aerodynamic stall and airplane loss of control.

The C-208B Pilot's Operating Handbook (POH) lists the maximum gross weight, 1g, stall speed as 78 KCAS. The POH stall speed increases to 84 KCAS in a level, 30° banked turn due to load factor (above 1g). However, N321BA was almost 1,000 lb over the 8,807 lb maximum gross weight. The extra weight increases the stall speed by about 6 kt. The additional load factor plus the additional weight put N321BA's 89 kt airspeed (when the pilot pulled back on the yoke) close to the POH stall speed without ice. This also indicates that ice had little effect on airplane stall speed.

However, the overall airplane handling qualities at the excessive gross weight and with ice on the unprotected surfaces could not be determined.

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National Transportation Safety Board

¹⁰ Stall margin in the context of the airplane performance study is defined as the difference between the critical angle-of-attack, or about 15° for the C-208B, and the calculated G1000 angle-of-attack.

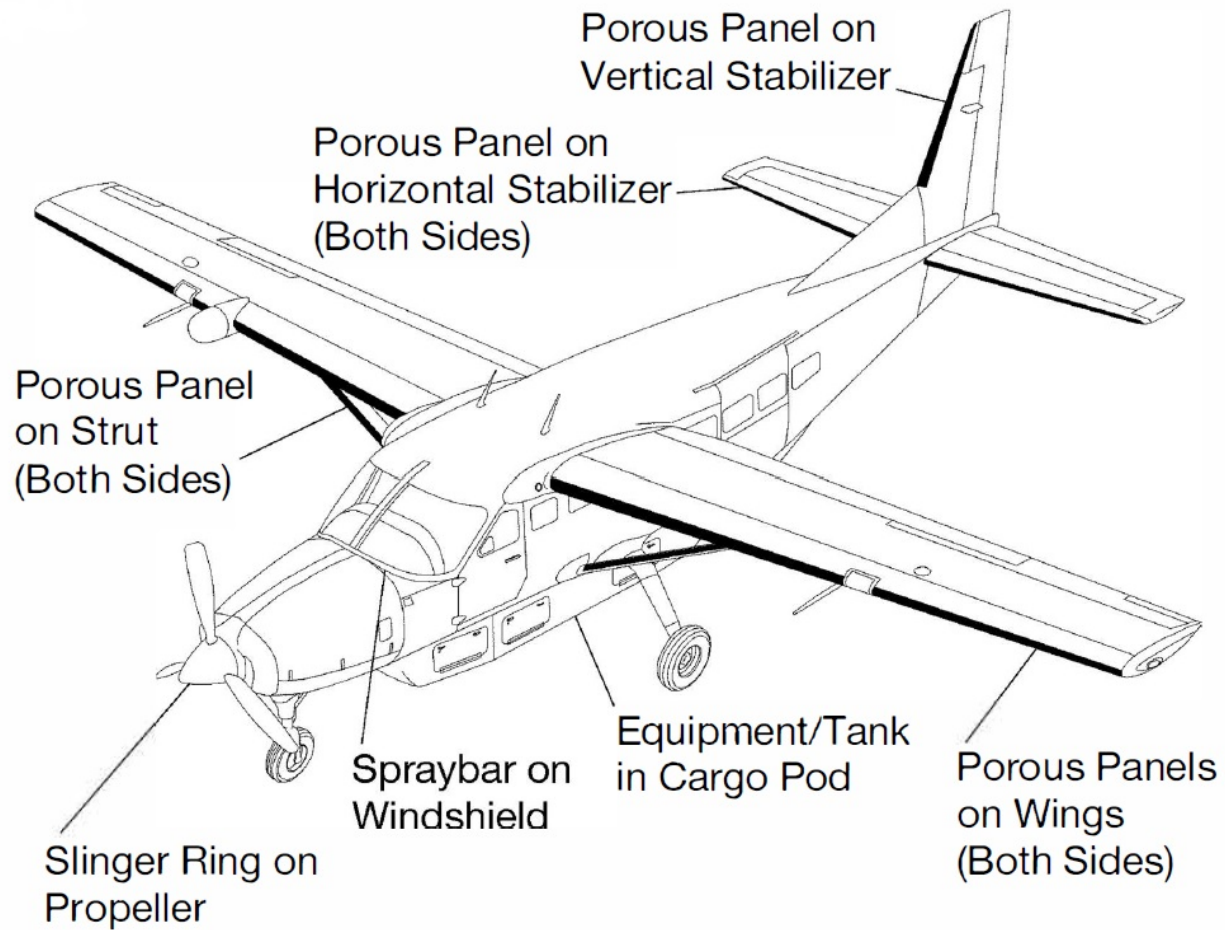
H. FIGURES



1.0 G1000 Ground Track for the 43 Minute Flight from Unalakleet to Nome



2.0 Accident Airplane, a Cessna 208B Grand Caravan EX, N321BA

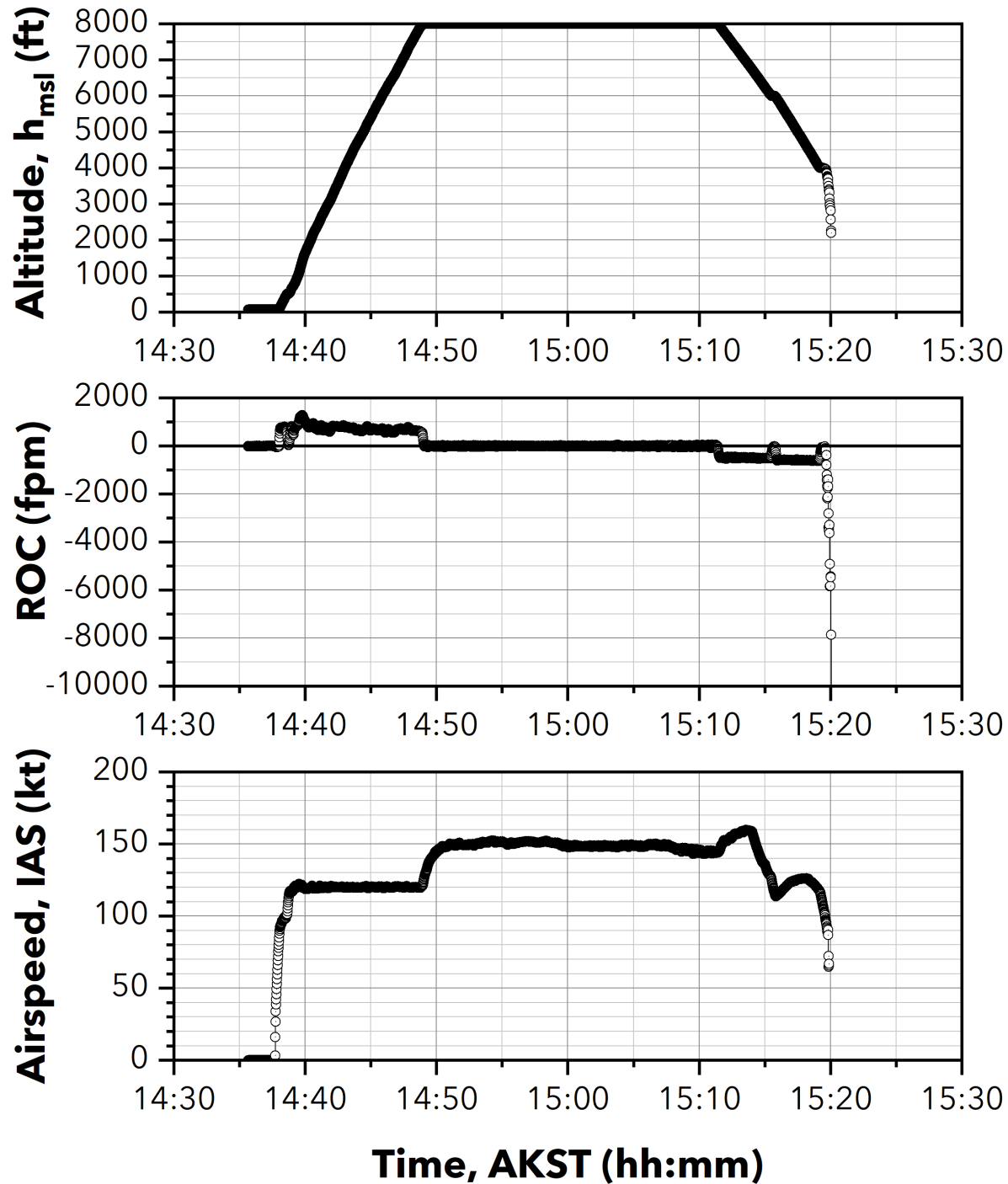


3.0 C-208B TKS Ice Protection System Installation



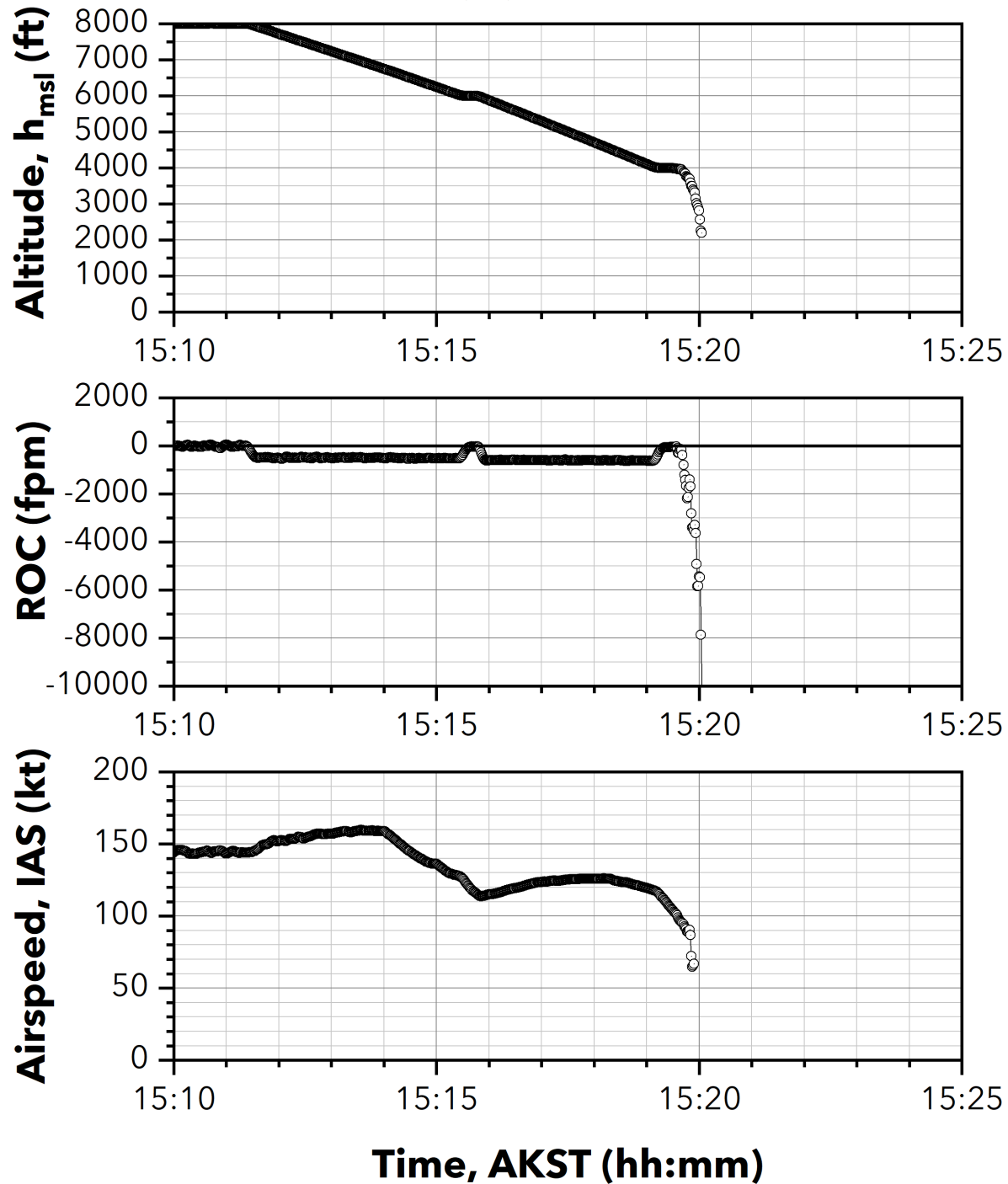
4.0 Ice Attached to Unprotected Portions of the Wreckage

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Nome, AK
2/6/2025



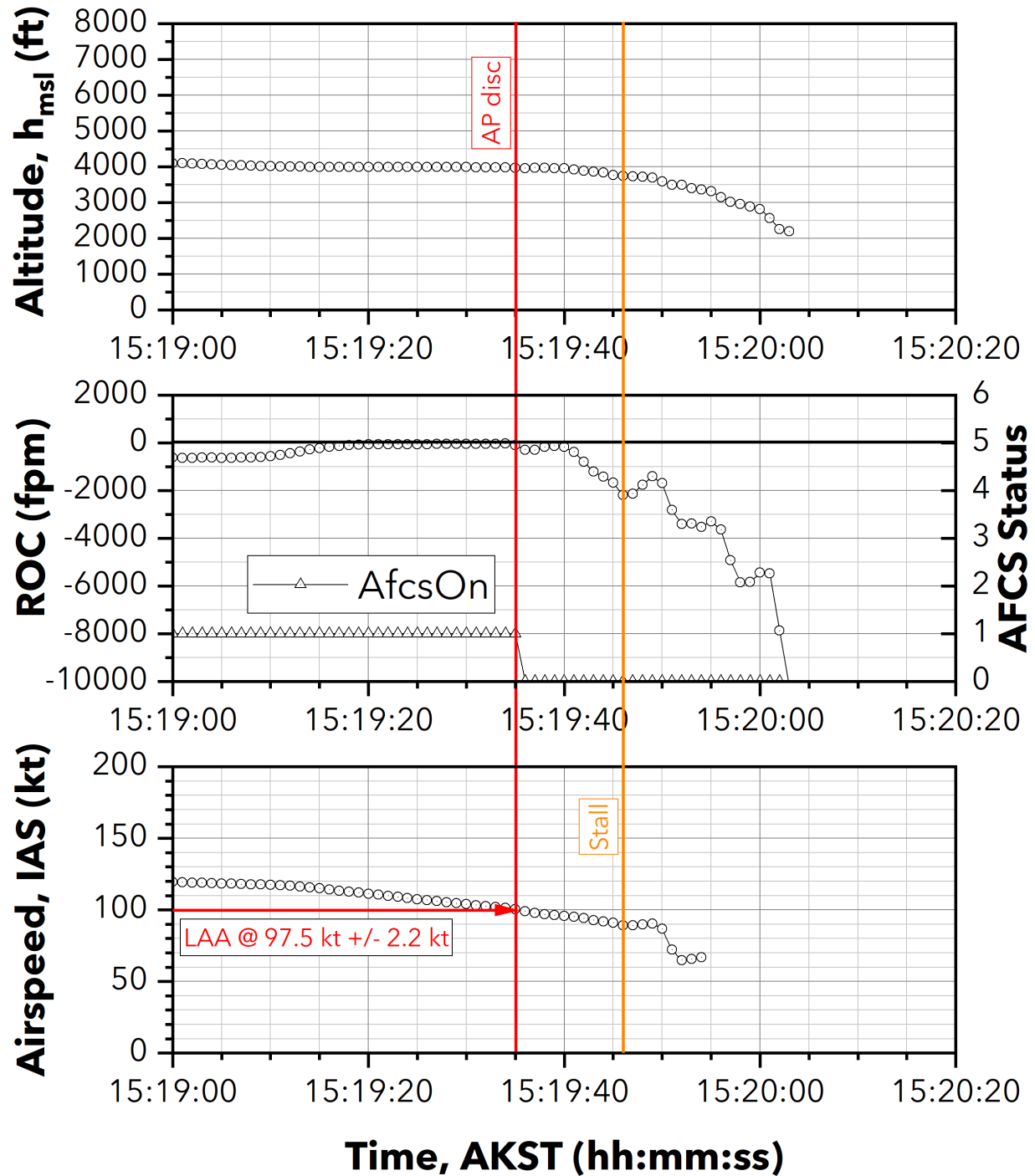
5.0 G1000 Altitude, ROC, and Airspeed for Accident

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2/6/2025



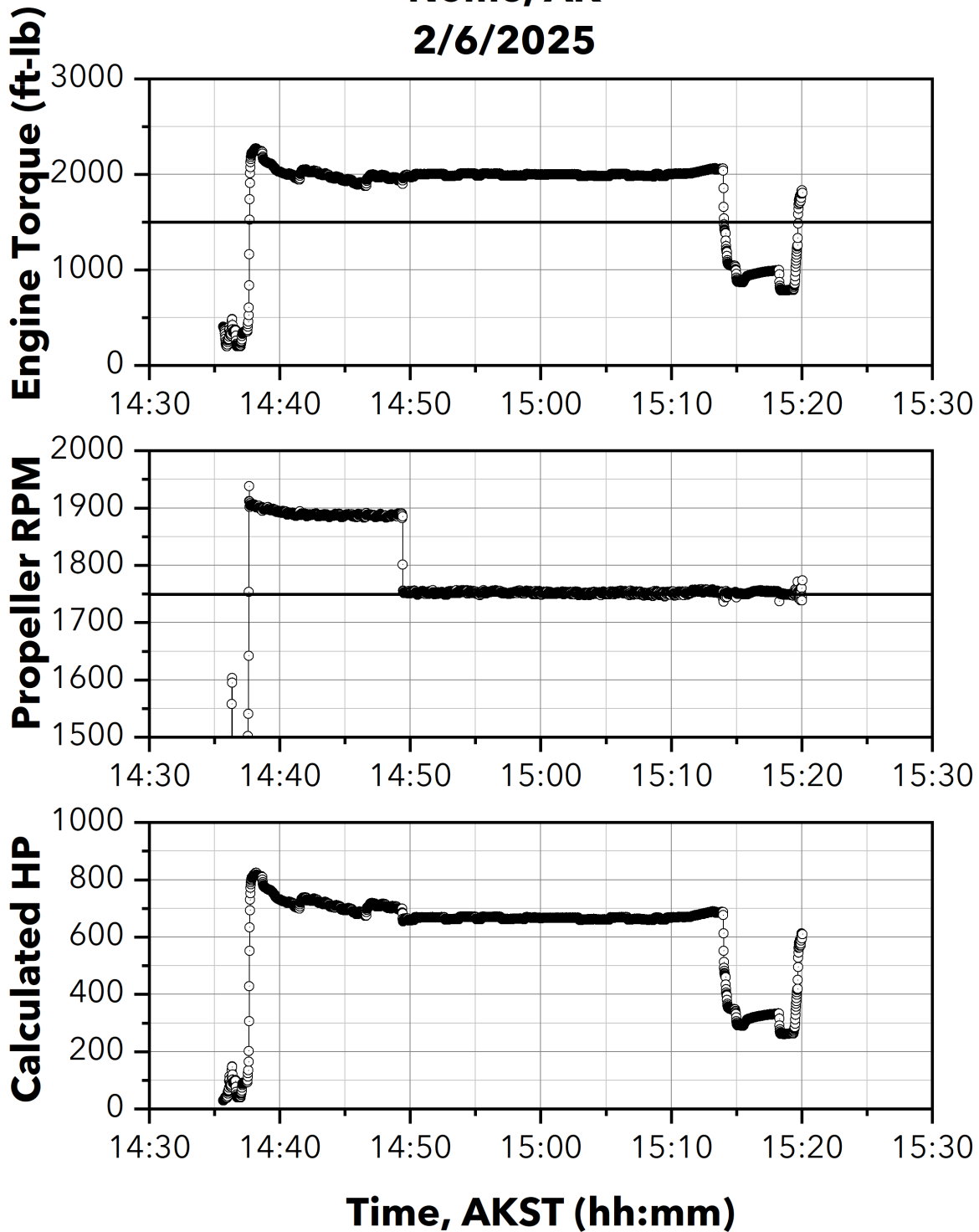
6.0 G1000 Altitude, ROC, and Airspeed for Final Ten Min.

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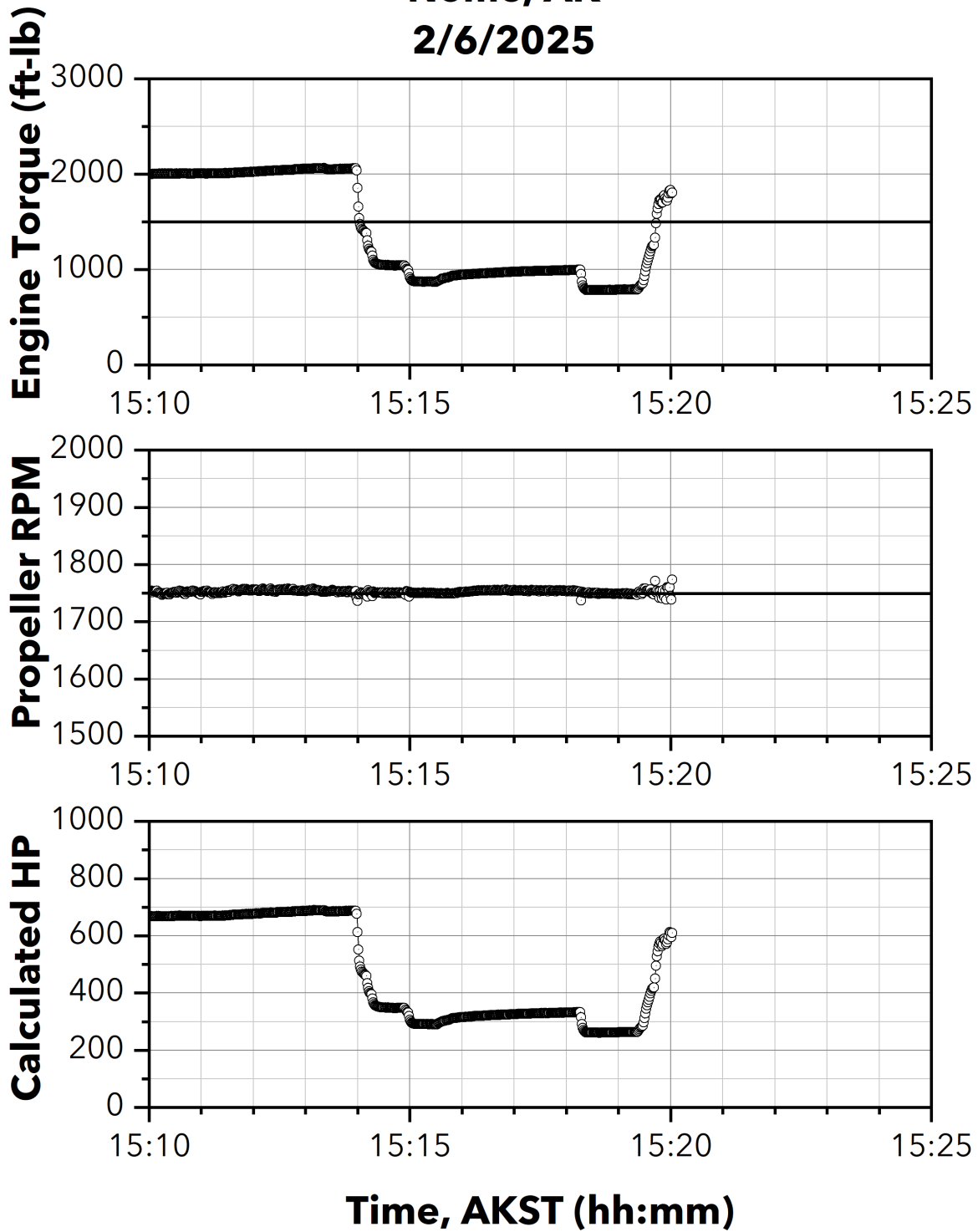
7.0 G1000 Altitude, ROC, and Airspeed for Final Minute

ANC25MA018: Cessna C-208B, N321BA
Nome, AK
2/6/2025



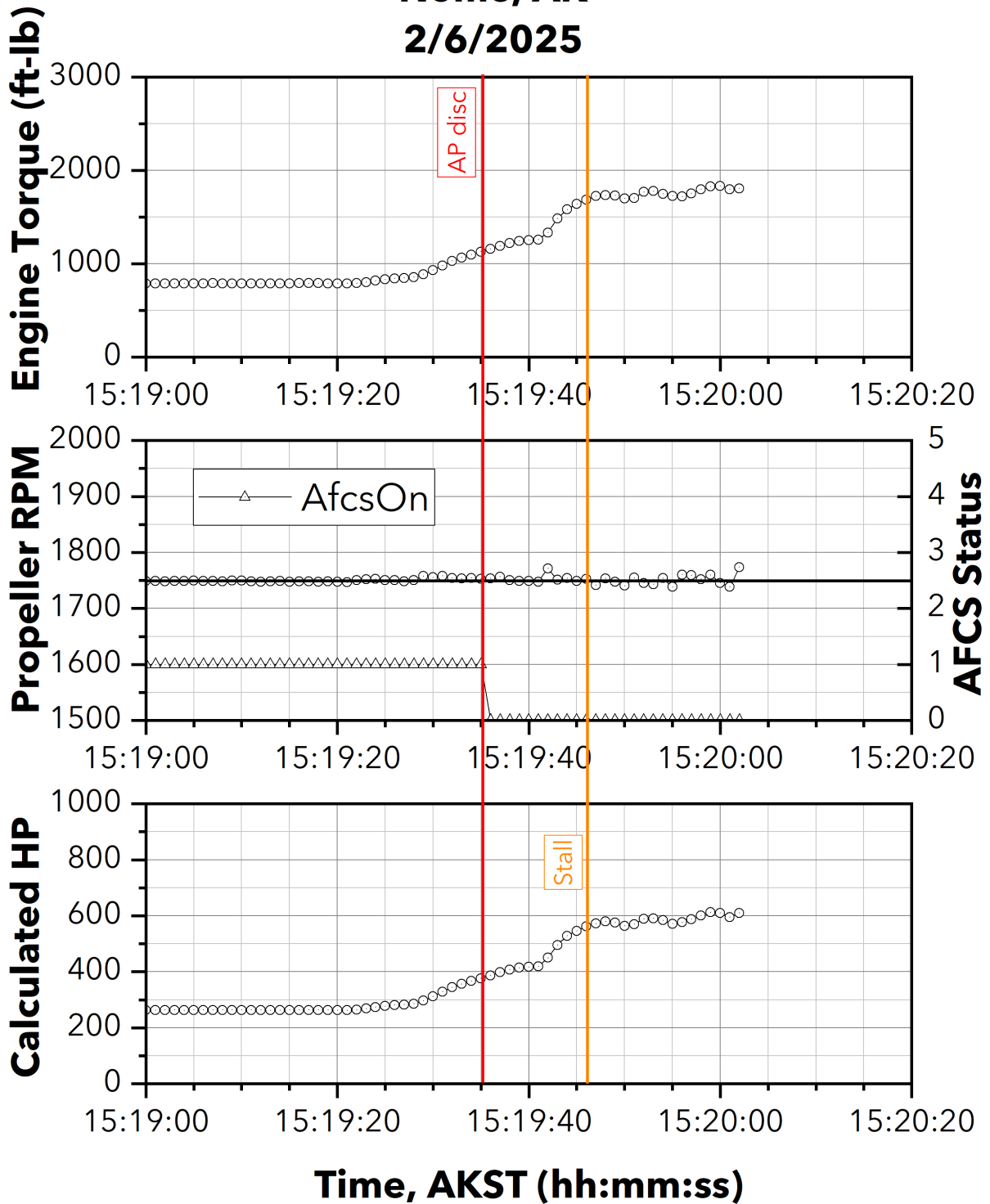
8.0 G1000 Engine Torque, Prop RPM, and Calculated HP for Accident

ANC25MA018: Cessna C-208B, N321BA
Nome, AK
2/6/2025



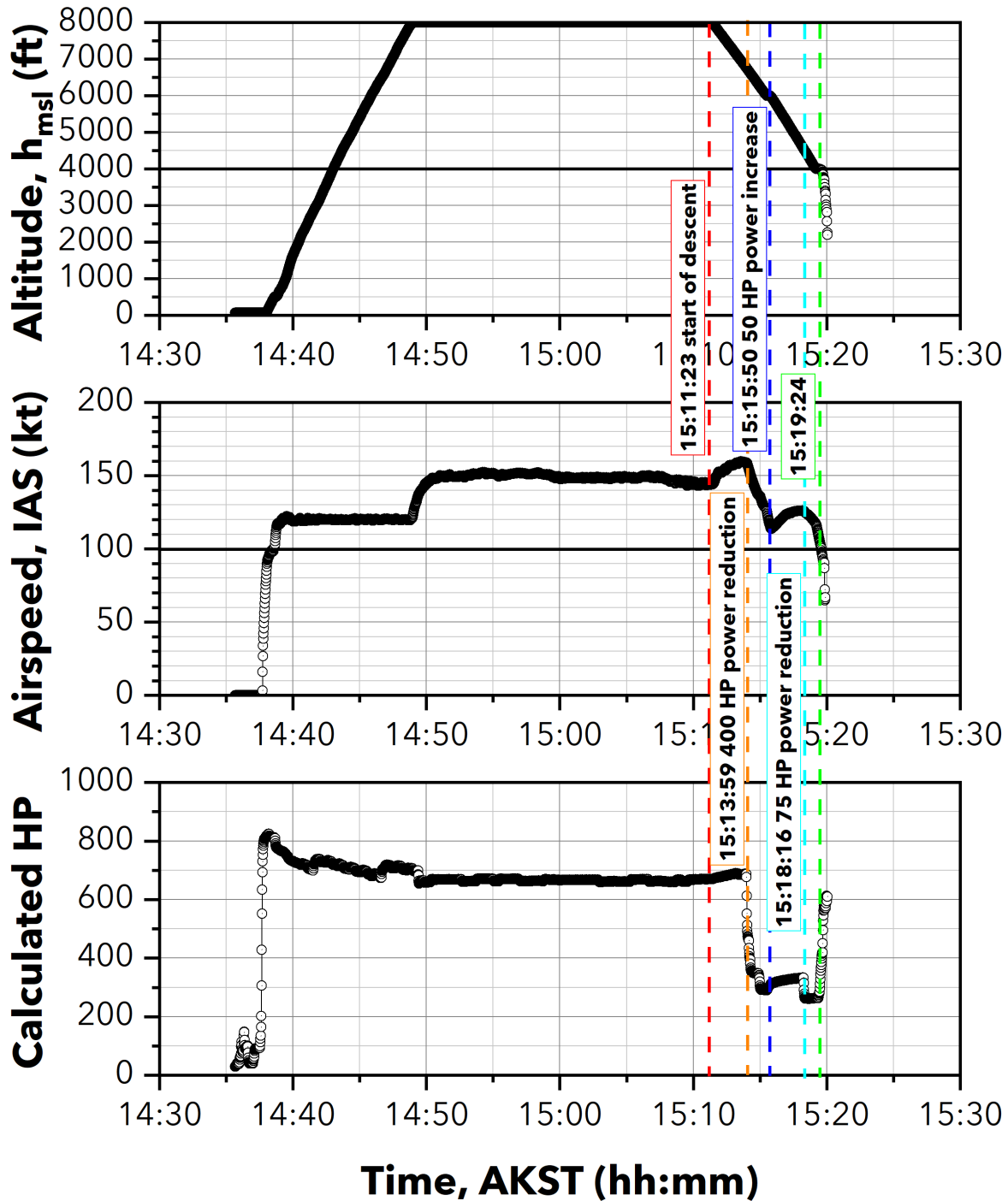
9.0 G1000 Engine Torque, Prop RPM, and Calculated HP for Final Ten Min.

ANC25MA018: Cessna C-208B, N321BA
Nome, AK
2/6/2025



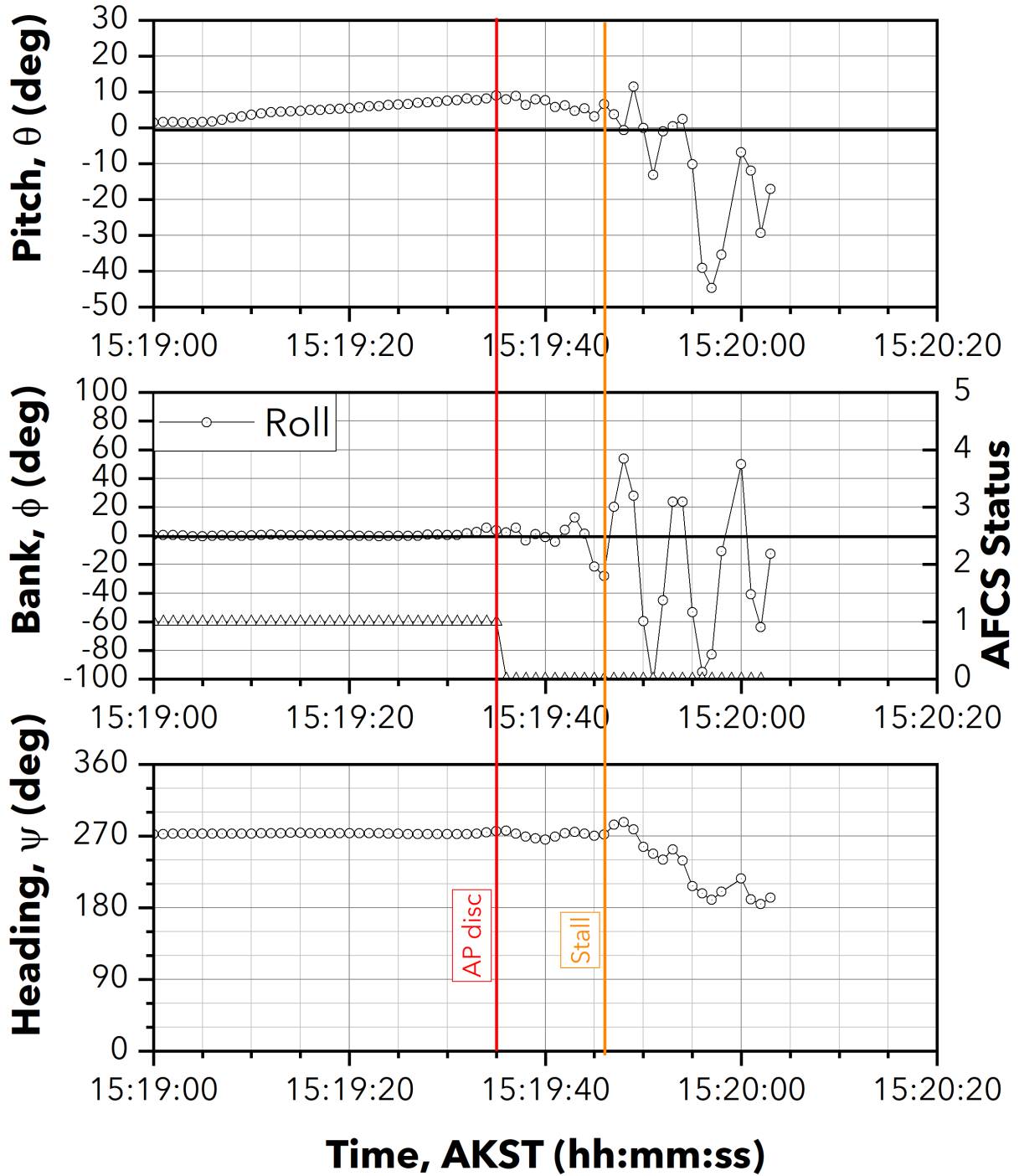
10.0 G1000 Engine Torque, Prop RPM, and Calculated HP for Final Minute

ANC25MA018: Cessna C-208B, N321BA **Nome, AK** **2/6/2025**



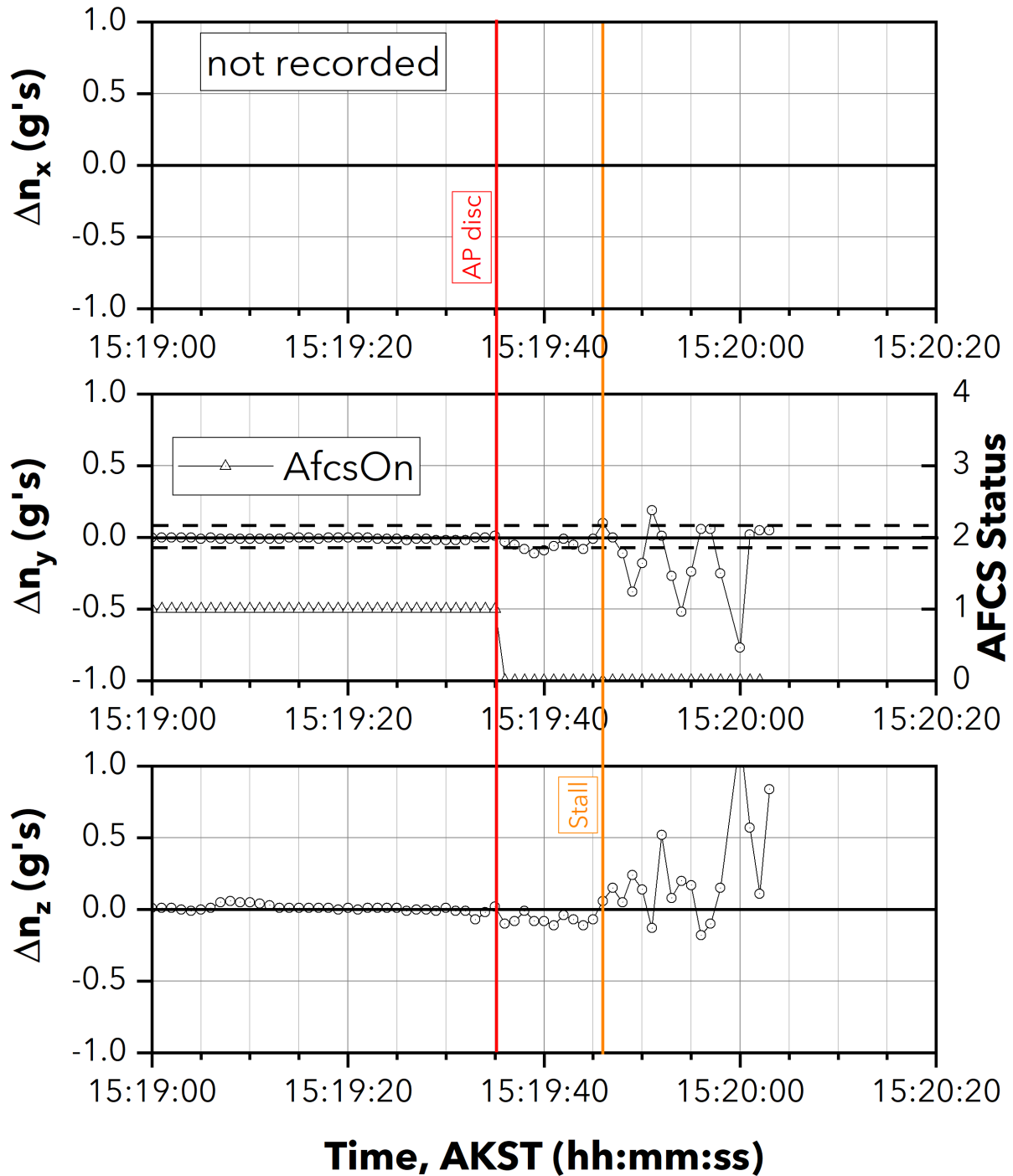
11.0 Summary of Power Changes Made During the Flight

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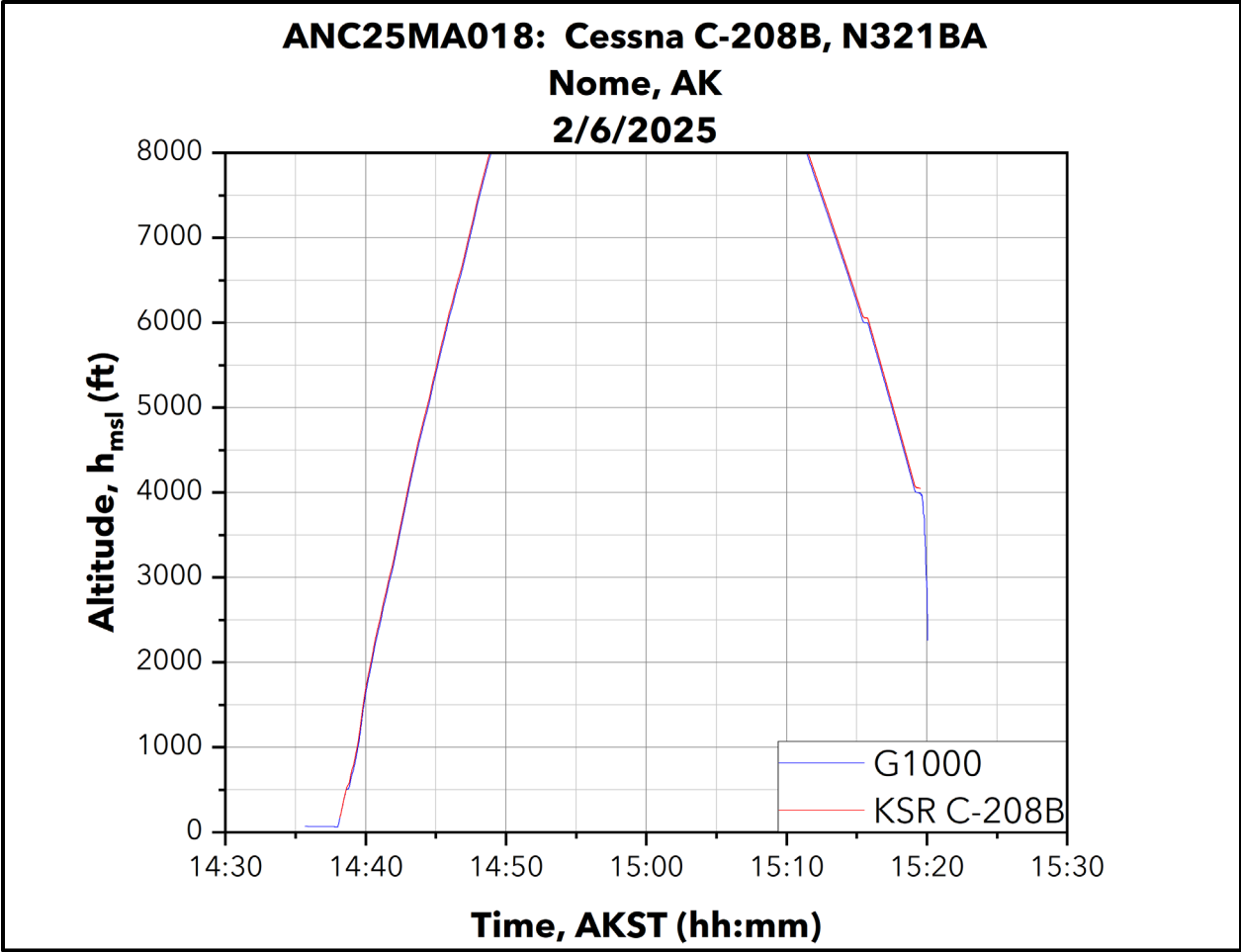


12.0 G1000 Euler Angles Final Minute

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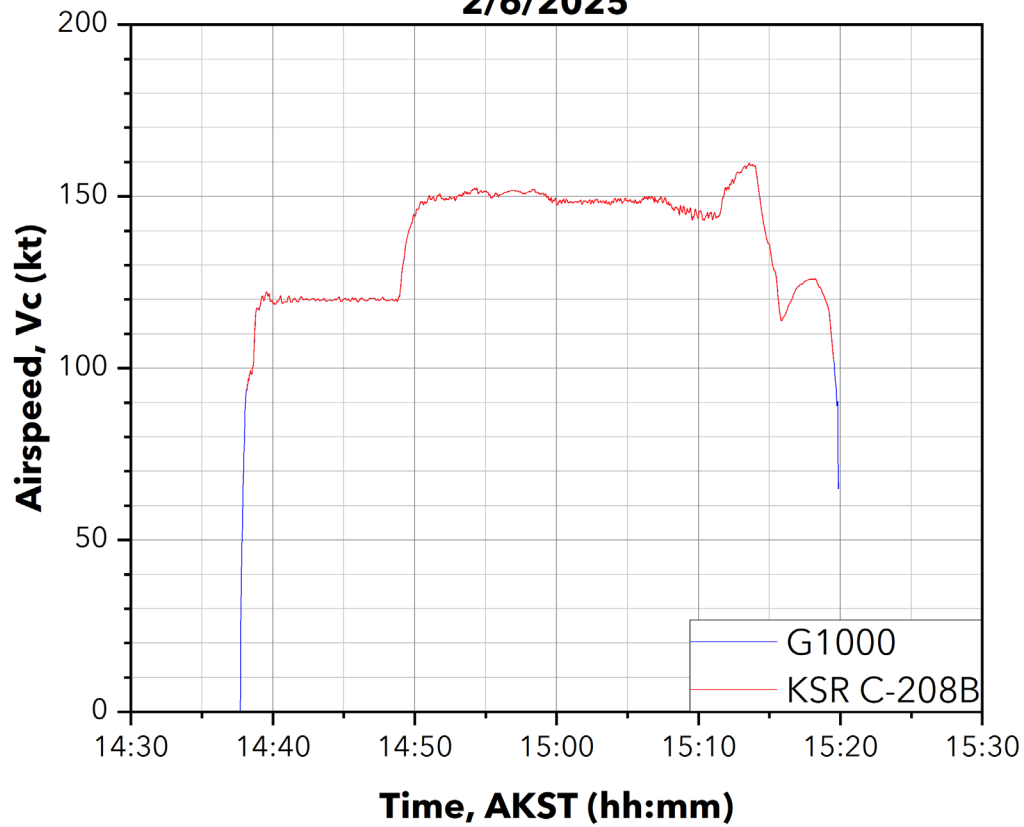


13.0 G1000 Airplane Accelerations for Final Minute



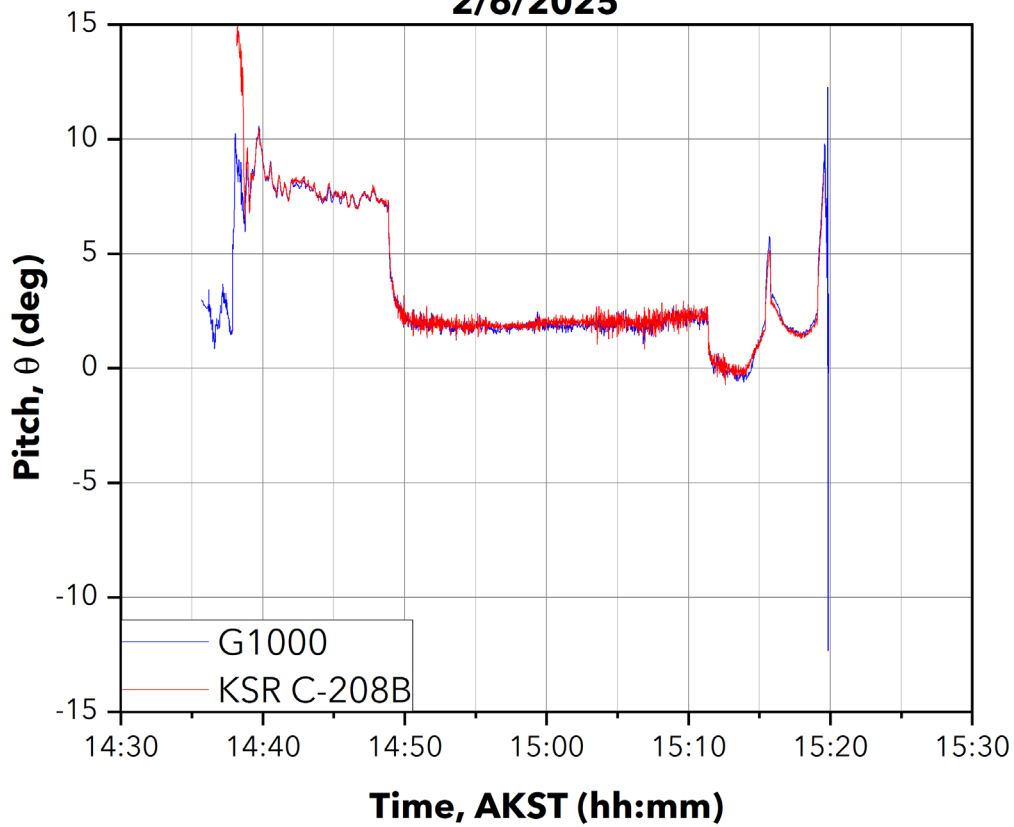
14.0 Comparison of Recorded G1000 and C-208B Simulation Altitude

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2/6/2025

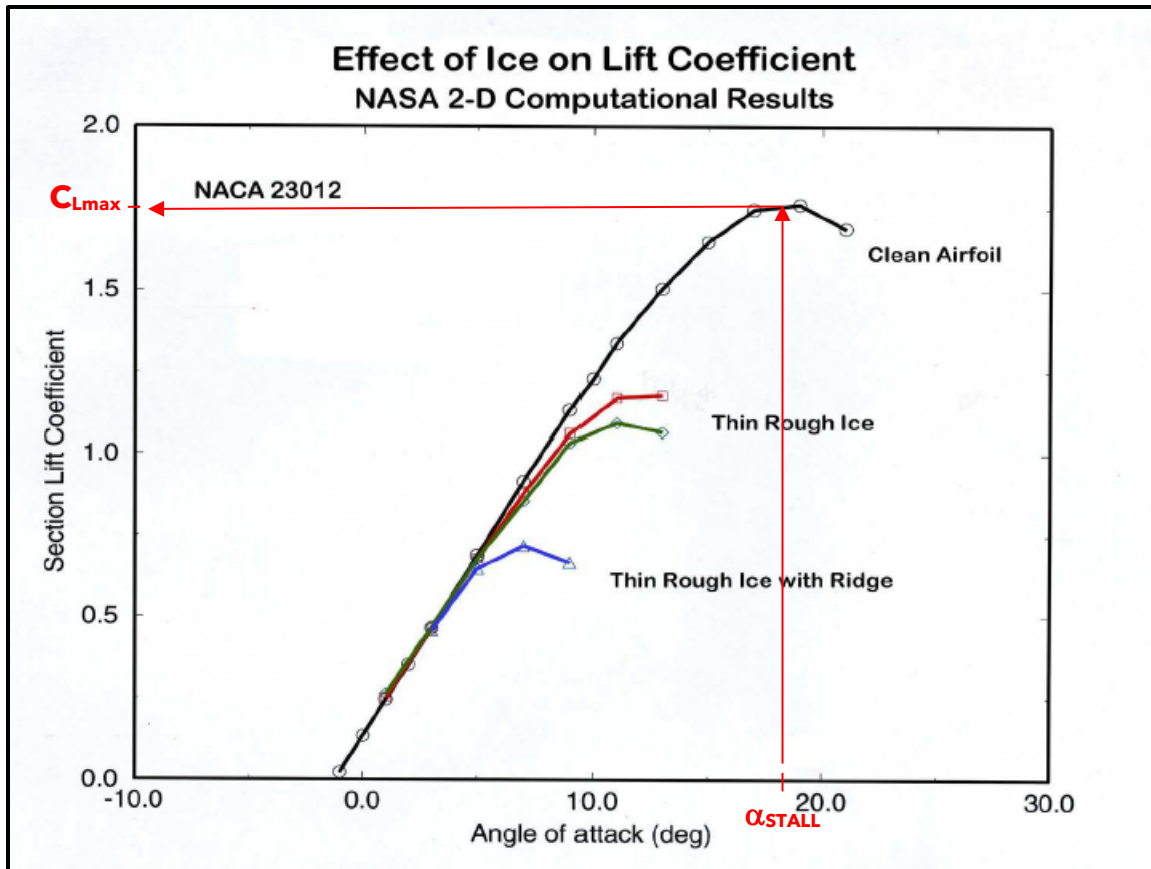


15.0 Comparison of Recorded G1000 and C-208B Simulation Airspeed

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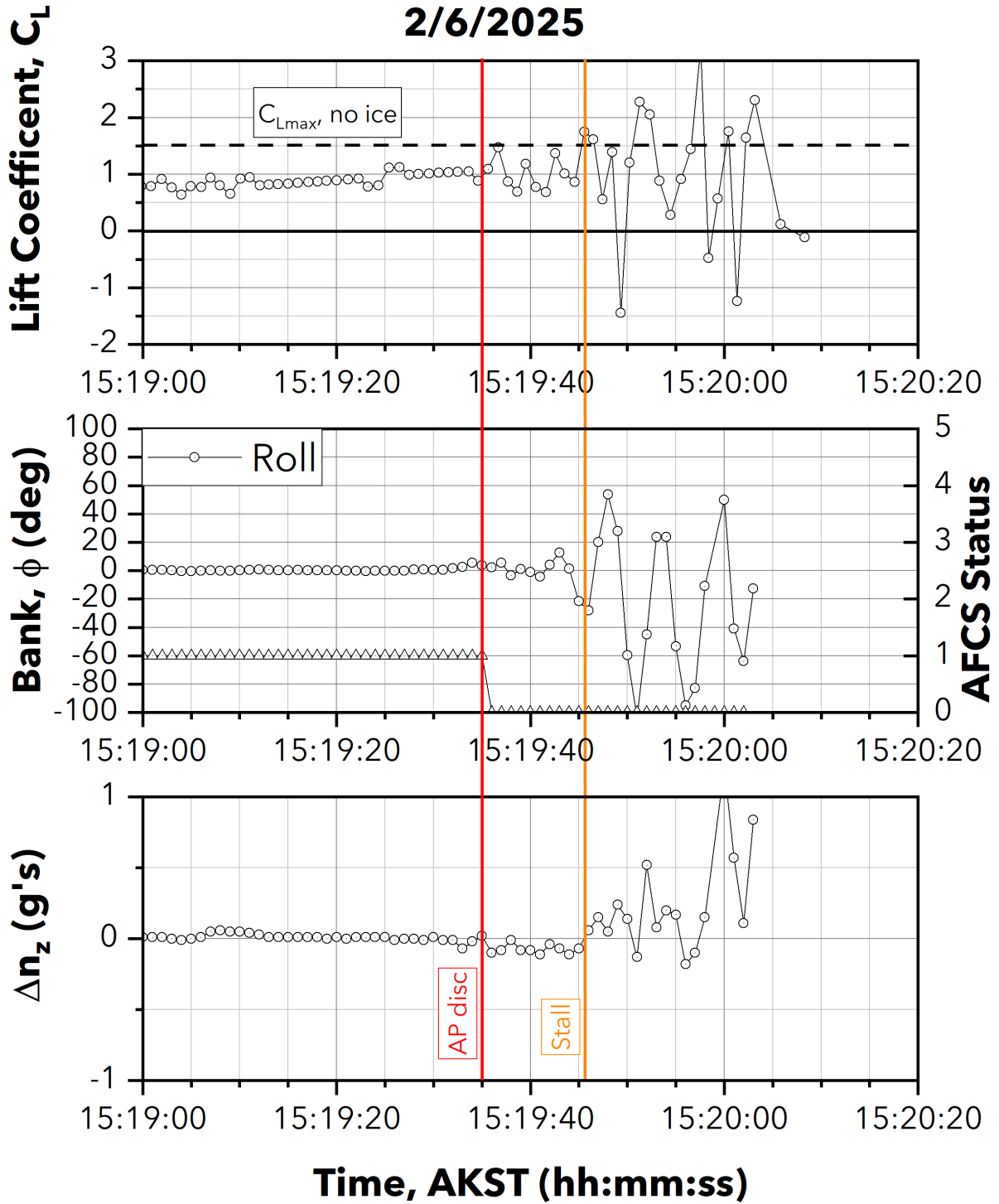


16.0 Comparison of Calculated G1000 and C-208B Simulation Pitch Attitude



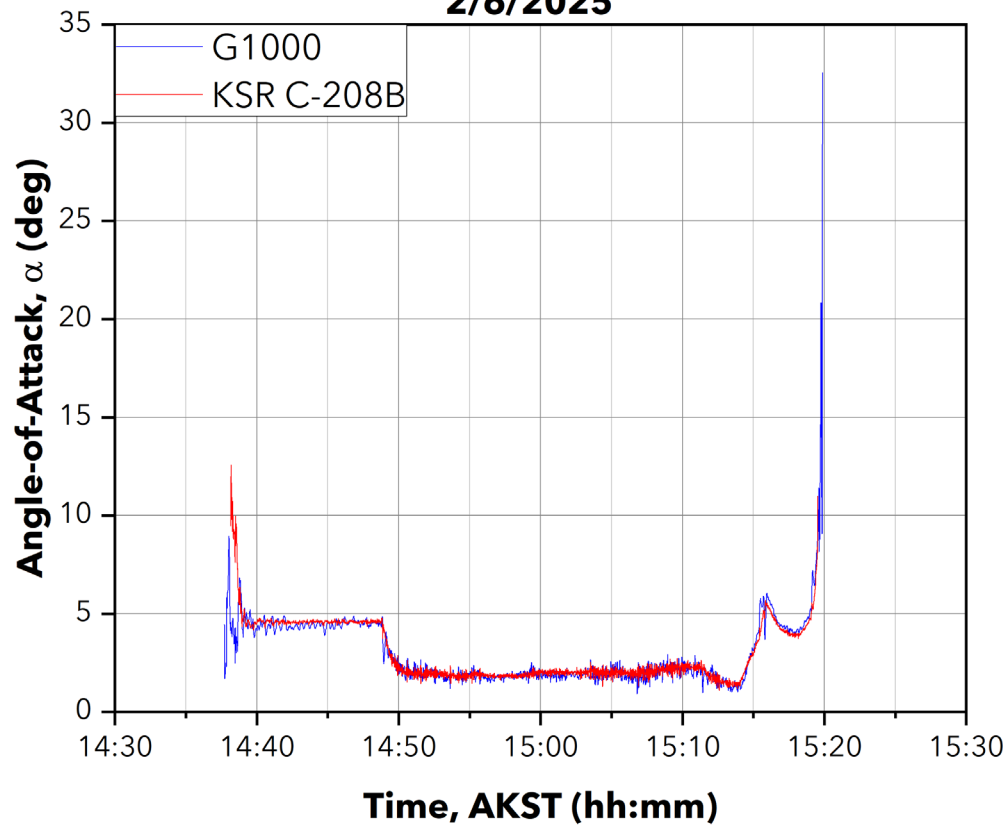
17.0 Effects of Ice on Lift Coefficient

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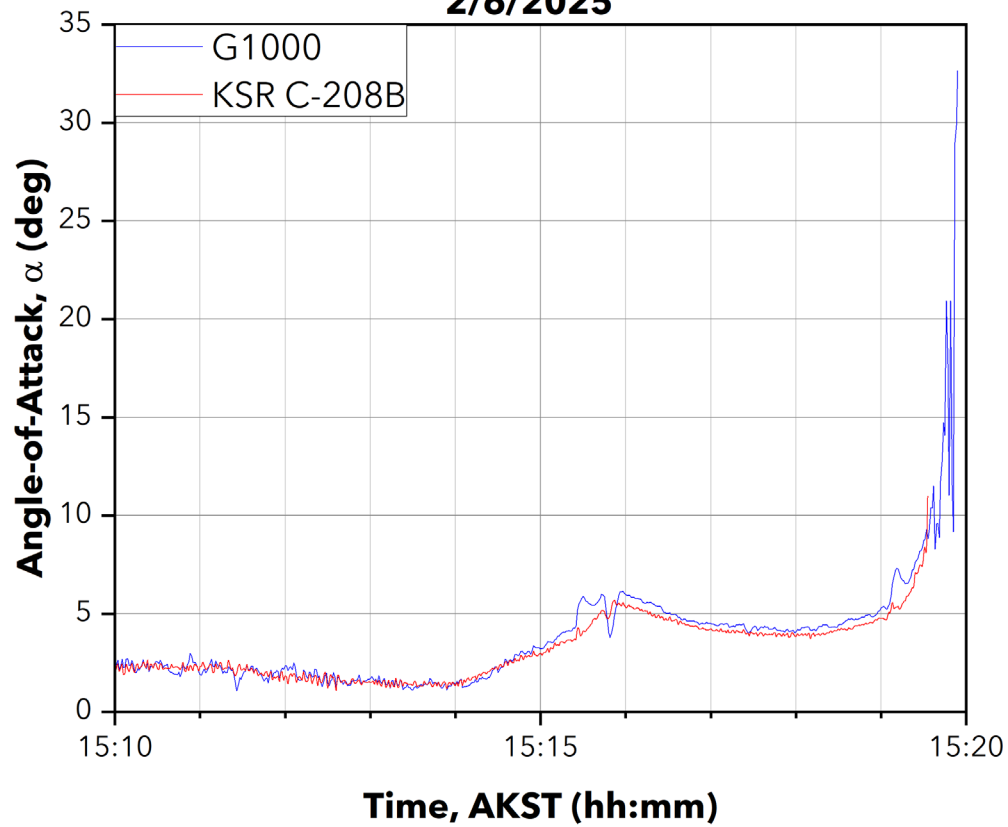
18.0 Estimated Lift Coefficient for Final Minute

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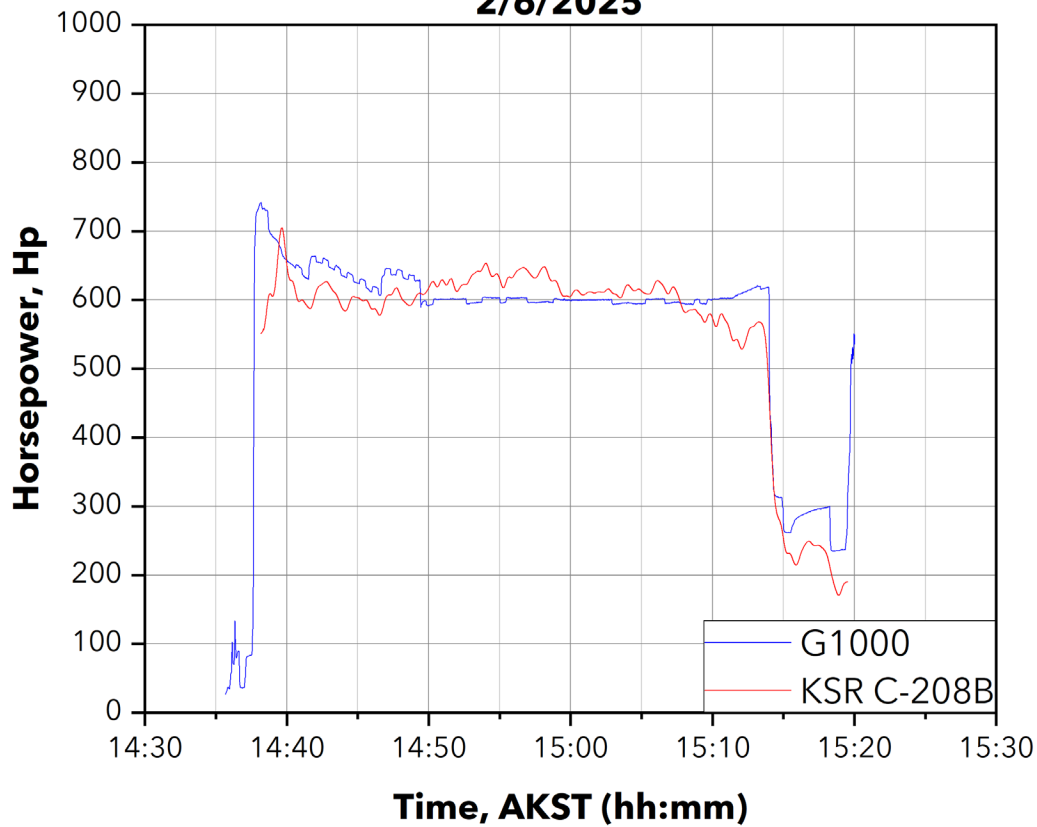
19.0 Comparison of Calculated G1000 and C-208B Simulation AOA

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2/6/2025



20.0 Comparison of Calculated G1000 and C-208B Simulation AOA for Final Ten Minutes

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21.0 Comparison of Calculated G1000 with 90% Propeller Efficiency and C-208B Simulation Horsepower