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AIRCRAFT PERFORMANCE STUDY

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A. ACCIDENT

Location: Leyden, Massachusetts
Date: January 14, 2024
Time: 11:25 Eastern Standard Time (EST)
16:25 Coordinated Universal Time (UTC)
Airplane: Beechcraft Baron 95-B55, registration N7345R

B. AIRCRAFT PERFORMANCE GROUP

Chairman: John O'Callaghan
National Transportation Safety Board (NTSB), RE-60
Washington, D.C.

Members: N/A

C. SUMMARY

C.1. Introduction

On January 14, 2024, at 11:25 EST, a Beechcraft 95-B55 (Baron) airplane, N7345R, was substantially damaged when it impacted terrain near Leyden, Massachusetts. The flight instructor, commercial pilot, and the passenger were fatally injured. The airplane was operated as a Title 14 *Code of Federal Regulations* Part 91 instructional flight.

Automatic Dependent Surveillance-Broadcast (ADS-B) surveillance data for the flight revealed that the airplane departed runway 20 at Westfield-Barnes Regional Airport, Westfield/Springfield, Massachusetts (KBAF), at about 11:06. After departure, the airplane made a 180° left turn toward the north-northeast. The airplane then climbed to between 3,000 to 3,300 ft. mean sea level (MSL) and made four alternating 360° turns while continuing to fly northbound. After the fourth 360° turn, the airplane began to climb, reaching an altitude of about 4,000 ft. MSL. The airplane then entered a rapid descent until data ended at 11:25:35.

The airplane was not receiving any air traffic control services during the flight and there were no recorded radio communications to or from the airplane.

Several witnesses heard and/or observed the airplane before the accident. One eyewitness was walking his dog when he first heard the airplane's engines and looked up. He said the airplane was "trying to gain altitude," "then stopped" before the nose of the airplane dropped and "made a straight line" toward the ground. The airplane "corkscrewed" straight down and went out of view. The witness described that the airplane did not appear to make any movements that would indicate it was going to

exit the spinning descent. The witness said the airplane, which he estimated was about $\frac{3}{4}$ -mile away from him, descended "fast." From the time he first observed the airplane until it went out of sight was about 8 seconds. The witness described the weather conditions as very windy and cold, but it was not snowing, and the visibility was good.

Another eyewitness said she heard and saw the airplane flying overhead. The airplane was flying "somewhat erratically." It eventually flew east over a wooded area, then "turned nose down and spiraled out of sight."

Two witnesses were hiking with their dog in the woods when the sound of the airplane's "engine" caught their attention. They did not see the airplane. The witnesses both stated that the "airplane's engine" was really loud and "clunky." It then shut off, before it re-started. When it re-started, it was much quieter. Another witness reported hearing the airplane's engine RPMs "fluctuate drastically."

The airplane impacted terrain located in the Leyden Wildlife Management Area. The wreckage came to rest in a clearing on a hill facing a magnetic heading of about 260°. All major components of the airplane were located at the accident site and there was no postimpact fire. The disposition of the wreckage was consistent with the airplane landing in a relatively flat position with little forward movement. Both wings, along with their respective engines and propeller systems, remained attached to the fuselage. The right wing impacted a tree about mid-span. The tail section was partially separated from the empennage but remained attached via control cables. The fuselage was compressed and crushed downward. Airframe icing was observed on the leading edge of both wings and horizontal stabilizers, both engine nacelles, and the leading edge of the rudder. Ice was also observed on the front face of one of the left engine's propeller blades, and on the navigation antenna located on the vertical stabilizer.

Weather reported at 11:52 from Orange Municipal Airport, Orange, Massachusetts (KORE), about 12 miles east of the accident site, indicated wind from 220° at 11 knots gusting to 23 knots, visibility 10 miles, broken clouds at 4,600 ft., temperature 2° C, dewpoint -7° C, and altimeter setting 29.68 inches of mercury ("Hg).

At the time of the accident, two AIRMETs (Airman Meteorological Information bulletins) were issued and active, including AIRMET Zulu for moderate icing conditions.

There was also a SIGMET (Significant Meteorological Information bulletin) for occasional severe turbulence between 3,000 and 16,000 ft. MSL due to strong low-level winds.

The wreckage was recovered to a secure facility for further examination.

C.2. Objective and scope of the *Aircraft Performance Study*

The objective of this *Aircraft Performance Study* is to determine and analyze the motion of the airplane and the physical forces that produce that motion. In particular, the *Study* attempts to define the airplane's position and orientation during the relevant portion of the flight, and determine the airplane's response to control inputs, external disturbances, ground forces, and other factors that could affect its trajectory.

The data used to determine and analyze the airplane motion includes the following:

- Automatic Dependent Surveillance – Broadcast (ADS-B) data.
- Wreckage location and condition.
- Weather information.
- Airplane performance information in the Airplane Flight Manual (AFM).

The airplane was not equipped (and was not required to be equipped) with a Flight Data Recorder (FDR) or Cockpit Voice Recorder (CVR). Consequently, the Euler angles (pitch, roll, and heading), engine power, airspeed, and acceleration of the airplane could not be determined with precision. In addition, the airplane's weight at the time of the accident is an estimate, because the exact fuel loading is unknown. In this *Study*, a weight of 4,569 lb. is assumed based on the airplane's known empty weight, known weights of the occupants, and estimated weights of fuel and miscellaneous items.

The airplane's altitude, position, ground speed, and rate of climb during the flight were obtained from ADS-B data. These data, together with winds aloft from a High Resolution Rapid Refresh (HRRR) sounding model, airplane performance data published in the Beechcraft Baron AFM (Reference 1), and additional performance information derived from data in the AFM are used in this *Study* to compare the airplane's computed performance during the accident flight with its nominal performance.

C.3. Summary of results

The witness statements and condition of the wreckage indicate that N7345R entered a spin from which it did not recover. Since an airplane must first stall before it can spin, either an inadvertent or deliberate stall must have immediately preceded the spin. The observation of ice on the airplane's wings and tail in the wreckage raises the possibility that the airplane's aerodynamic characteristics (such as its maximum lift coefficient, C_{Lmax}) were adversely affected by ice contamination, which could have led to an inadvertent and premature stall. Furthermore, a yawing moment coincident with the stall is required to start the airplane spinning. Such a yawing moment could arise from a rudder input, from an asymmetric stall (perhaps due to ice), or from asymmetric thrust resulting from operation of the engines at different thrust levels (for example, during a

demonstration of the airborne minimum control airspeed (V_{MCA}),¹ one engine is deliberately shut down or set to minimum thrust, and the other is set to maximum thrust). Consequently, two items of interest addressed by this *Study* are:

1. Comparing the lift coefficient (C_L) at which the final stall occurred to the nominal C_{Lmax} implied by the stall speeds published in the AFM.
2. Determining whether the airplane was operating with one engine inoperative (OEI) during the final stall, as would be the case for a V_{MCA} demonstration.

The results of the *Study* indicate that N7345R performed two stalls in the minute preceding its final spin to the ground, and that in both cases the airplane achieved the nominal flaps-up C_{Lmax} implicit in the AFM stall speeds. Consequently, there is no evidence that the ice observed in the wreckage adversely affected the airplane's C_{Lmax} . Furthermore, the first of the two stalls indicates that, within a minute of the final stall and spin, the airplane could in fact be stalled and recovered successfully.

In addition, the computed engine power required during the time surrounding the first stall exceeds the power available from one engine, indicating that both engines must have been operating at the time (which would have been inconsistent with a V_{MCA} demonstration).

The sections that follow present the data used in this *Study* (as listed above), and describe the methods used to calculate additional performance information from this data. The results of these calculations are presented in the Figures and Tables described throughout the *Study*.

D. DETAILS OF THE INVESTIGATION

D.1. The Beechcraft Baron 95-B55 airplane

The Beechcraft Baron is a 4 to 6 seat, unpressurized light twin airplane, powered by two Continental IO-470-L reciprocating engines producing 260 brake horsepower (BHP) each, with a maximum takeoff weight of 5,100 pounds.

Figure 1 shows a 3-view schematic of the airplane, taken from Reference 1. Figure 2 is a pre-accident photograph of N7345R.

¹ In Title 14 Code of Federal Regulations (CFR) §25.149(b), V_{MCA} is called V_{MC} . In this *Study*, V_{MCA} is used instead of V_{MC} for consistency with the AFM. The minimum control speed on the ground, V_{MCG} , is different from V_{MCA} ; see 14 CFR §25.149(e).

The weight and center of gravity (CG) location of the airplane at the time of the accident were estimated based on the airplane's weight and balance records, known weights of the occupants, an estimated baggage weight of 100 lb., and an estimated fuel weight. According to the operator, N7345R was fueled to 136 gal. of useable fuel on January 12, and then flew for 1.5 hours on January 13 before the 19-minute accident flight on January 14. The resulting weight and CG position for the accident flight are shown in Table 1, and are within the weight and balance limits published in the AFM.

Item	Weight, lb.	Arm, in.	Moment, in-lb
Empty weight	3,477.85	79.86	277,739.93
Front left seat (#1)	165	87	14,355
Front right seat (#2)	190	87	16,530
Seat #4	140	129	18,060
Rear bags	100	150	15,000
Fuel	496.6		40,011
Total	4,569	83.53	381,695.93

Table 1. Estimated accident weight and CG position of N7345R.

D.2. Wreckage location and condition

The airplane crashed in the Leyden Wildlife Management Area in a clearing on a hill. The Global Navigation Satellite System (GNSS) coordinates of the crash site are:

Latitude: 42° 39' 26.5" North

Longitude: 72° 36' 01.2" West

Elevation (per *Google Earth*): 595 ft. above Mean Sea Level (MSL)

The general condition of the wreckage is described above in section C.1.

D.3. ADS-B data

D.3.1. Overview

Automatic Dependent Surveillance – Broadcast (ADS-B) capability enables aircraft to broadcast their three-dimensional position (latitude, longitude, and altitude) to other ADS-B equipped aircraft and to ADS-B ground stations.² ADS-B data broadcast from N7345R during the accident flight was received and recorded by Federal Aviation Administration (FAA) and provided to the NTSB.

² For more information about ADS-B, see https://www.faa.gov/air_traffic/technology/adsb.

ADS-B latitude and longitude are determined using GNSS signals, including those from Global Positioning System (GPS) satellites, and altitudes determined both barometrically and by GNSS are included in ADS-B messages. The GNSS positions are very accurate compared to radar data; radar range uncertainty alone (without even considering azimuth uncertainty) is about $\pm 1/16$ nm, or ± 380 ft., and GNSS positions are generally accurate to within 60 ft. (see Reference 2). Furthermore, ADS-B data are available at a higher frequency than radar data: typically at 1 sample/second for ADS-B, and at best, 1 sample every 4.5 seconds for radar.

The recorded ADS-B data includes the following parameters:

- UTC time of the ADS-B report, in hours, minutes, and seconds. EST = UTC - 5 hours.
- Aircraft identifying information.
- Latitude and longitude, to a resolution of 0.01 arc-seconds (≈ 1 ft.)
- Pressure altitude in feet, to the nearest 25 ft. (an uncertainty band of ± 12.5 ft.)
- Geometric (GNSS) altitude in feet, to the nearest 25 ft. The GNSS altitude is the height above the WGS84 ellipsoid, which differs from MSL altitude by the height of the geoid.³ In this *Study*, GNSS altitudes are corrected to MSL altitude by adding 95 ft.⁴
- North-south and east-west components of ground speed, to a resolution of 1 kt.
- Rate of climb, to a resolution of 1 ft./min.
- Numerous parameters documenting the quality and accuracy of each reported GNSS position.

The time interval between ADS-B data points for N7345R is about 1 second. The last ADS-B data point from N7345R was received at 11:25:34.9, at a GNSS altitude of 870 ft. MSL, about 275 ft. above and 22 ft. northeast of the crash site.

The ADS-B data are presented in Figures 3-5 and discussed throughout the *Study*. In this *Study*, the position of the airplane is described by its north and east coordinates relative to the crash site. The airplane's ADS-B latitude and longitude coordinates are transformed into east and north coordinates from the crash site using the WGS84 ellipsoid model of the earth, and the latitude and longitude coordinates of the crash site presented in Section D.2.

³ "The geoid ... is the shape that the ocean surface would take under the influence of the gravity of Earth, including gravitational attraction and Earth's rotation, if other influences such as winds and tides were absent." (Wikipedia.org, accessed 10/10/2022.)

⁴ Per <https://geographiclib.sourceforge.io/cgi-bin/GeoidEval>, the geoid at the accident site is 28.98 m (95 ft.) below the surface of the WGS84 ellipsoid.

D.3.2. Calculation of additional performance parameters from ADS-B data

To calculate performance parameters (such as ground speed, track angle, pitch and roll angles, etc.) from surveillance data, it is convenient to express the position of the airplane in rectangular Cartesian coordinates. The Cartesian coordinate system used in this *Study* is centered on the crash site, and its axes extend east, north, and up from the center of the Earth. Figure 3 presents a plan view of N7345R's flight track during the accident flight. Figure 4 plots the airplane's north and east coordinates vs. time, and Figure 5 plots the airplane's altitude vs. time.⁵

If the position (latitude, longitude, and altitude) of an airplane is known as a function of time, then its orientation (that is, its Euler angles – pitch (θ), roll (ϕ), and heading (ψ)) can also be estimated as long as the following are true:

- The motion of the air mass relative to the Earth, i.e., the wind, is known;
- The lift coefficient (C_L) of the airplane as a function of angle of attack (α) is known;
- The gross weight of the airplane is known;
- The sideslip angle and lateral acceleration are negligible (corresponding to coordinated flight).

The position coordinates of an airplane as a function of time define its velocity and acceleration components. In coordinated flight, these components lie almost entirely in the plane defined by the airplane's longitudinal and vertical axes. Furthermore, any change in the *direction* of the velocity vector is produced by a change in the lift vector, either by increasing the magnitude of the lift (as in a pull-up), or by changing the direction of the lift (as in a banked turn). The lift vector also acts entirely in the aircraft's longitudinal-vertical plane, and is a function of the angle between the aircraft longitudinal axis and the velocity vector (the angle of attack, α). These facts allow the equations of motion to be simplified to the point that a solution for the airplane orientation can be found given the additional information about wind and the airplane lift curve (C_L vs. α).

In this *Study*, the winds aloft are based on a HRRR sounding model for the location of the accident at 11:00, as described in the *Meteorology Specialist's Factual Report* for this accident (Reference 3). An altimeter setting of 29.68" Hg is assumed based on the 11:52 EST Aviation Routine Weather Report (METAR) from KORE. The HRRR winds were validated by an analysis of the ADS-B recorded ground speed of the airplane during the four 360° turns performed during the flight, as described in Section D.4.

⁵ Several Figures in this *Study* have an "a" and a "b" version, which present the same information but at different scales, or with different background images. When the *Study* refers to a Figure with two or more versions without specifying the version, all versions are meant to be included in the reference.

The Baron B55 flaps-up lift curve is estimated using textbook methods based on the wing planform geometry to compute the lift curve slope ($\partial C_L / \partial \alpha$), and an assumption that the fuselage α is designed to be 0° at cruise speed, which sets C_L at $\alpha = 0^\circ$. The airplane's flaps-up C_{Lmax} is computed based on the stall speed information published in the AFM.

The thrust delivered by the engines during the flight, and the associated *BHP* required, can be computed knowing the aerodynamic drag and propeller efficiency characteristics of the airplane. These quantities can be estimated using classical models of airplane drag and propeller momentum theory, informed by sea-level engine power and climb performance data published in the AFM.

Comparing the maximum power each engine can produce (at altitude) with the power required to match the airplane trajectory described by the ADS-B data can help to determine whether portions of the flight could have been flown with only one engine producing thrust, or whether the thrust demands were high enough that thrust from both engines was required. The Baron's engines are not turbocharged, and so the power they produce will decrease with altitude. The maximum power the engines can produce at a given altitude can be estimated from the rate of climb data at altitude published in the AFM, and from aerodynamic drag and propeller efficiency characteristics estimated from the sea-level rate of climb data (at which the full-rated power of the engines is produced).

The rate of climb at a constant airspeed is approximately

$$\dot{h} = V_T \sin \gamma = V_T \left(\frac{T-D}{W} \right) \quad [1]$$

Where V_T is the true airspeed, γ is the flight path angle, T is thrust, D is drag, and W is weight. Consequently,

$$DV_T = TV_T - W\dot{h} \quad [2]$$

The two-engine rate of climb data presented in the AFM corresponds to a single climb speed (107 knots indicated airspeed (KIAS)) at all weights and altitudes. The drag at a constant *indicated* airspeed is approximately constant, so

$$\frac{T_{sl}V_{Tsl} - W\dot{h}_{sl}}{V_{Tsl}} = \frac{T_aV_{Ta} - W\dot{h}_a}{V_{Ta}} \quad [3]$$

Where the subscript *sl* denotes conditions at sea-level, and the subscript *a* denotes conditions at altitude. (Note that the true airspeed at altitude, V_{Ta} , differs from the true airspeed at sea level, V_{Tsl} , even though the indicated airspeed in the climb is the same at altitude and at sea level).

TV_T is the power delivered by the engines to the airframe, which is equal to the brake horsepower of the engines multiplied by the propeller efficiency:

$$TV_T = (BHP)\eta \quad [4]$$

Where BHP is the total brake horsepower of both engines, and η is the propeller efficiency. Combining Equations [3] and [4] gives

$$(BHP_a) = (BHP_{sl}) \left(\frac{V_{Ta}}{V_{Tsl}} \right) - \frac{W}{\eta} \left[\dot{h}_{sl} \left(\frac{V_{Ta}}{V_{Tsl}} \right) - \dot{h}_a \right] \quad [5]$$

The BHP of the engines at altitude can be computed using Equation [5], where $\dot{h}_{sl}$ and $\dot{h}_a$ are given in the AFM at the indicated climb speed (107 KIAS) as a function of W . As mentioned previously, η is estimated from the AFM sea-level climb performance data and propeller momentum theory (at the time of the accident stall, the resulting η is about 0.85). For the accident conditions, at an altitude of 4,000 ft., temperature of 17°F, and altimeter setting of 29.68 "Hg, the total available BHP from the engines would have been about 478 HP, or 239 HP per engine, compared to a total of 520 HP or 260 HP per engine at sea level.

For all the performance calculations presented in this *Study*, a gross weight of 4,569 lb. is assumed, corresponding to the weight estimate shown in Table 1.

The results of the performance calculations based on the ADS-B data for the accident flight are presented in Figures 8-12 and discussed in subsequent sections.

D.4. Winds aloft

The wind speed and direction and air temperature as a function of altitude from the HRRR model are plotted in Figure 6. Note that the wind speed at the altitudes of interest (where the airplane was operating, between about 3,200 and 4,100 ft.) are 26 to 28 knots. Winds of these magnitudes will have a significant effect on the airspeed computed from the ADS-B ground speed, since

$$\vec{V}_A = \vec{V}_G - \vec{V}_W \quad [6]$$

Where $\vec{V}_A$ is the true airspeed vector, $\vec{V}_G$ is the ground speed vector, and $\vec{V}_W$ is the wind vector. The computed airspeed, in turn, will affect the computed C_L , which is the best measure of the airplane's proximity to an aerodynamic stall. Consequently, if the winds are incorrect, the computed C_L will also be incorrect and a misleading indicator of proximity to stall.

As noted in section C.1, N7345R made four alternating 360° turns (“circles”) at approximately level altitude during the accident flight (see Figures 3 and 5). The ADS-B recorded ground speed during these circles fluctuated by about ± 25 knots (see Figure 8), as would be expected if the circles were flown at a constant airspeed, but in a strong wind. Assuming that the airspeed during the circles is approximately constant, the fluctuations in the north and east components of ground speed can be used to compute the average north and east components of wind, and hence the average wind speed and direction, during the circles.

From Equation [6], the maximum north component of ground speed occurs when the airplane is flying north, and is given by

$$V_{G,N,max} = V_A + V_{W,N} \quad [7a]$$

Where V_A is the airspeed and $V_{W,N}$ is the north component of the wind (positive blowing *towards* the north). Similarly, the minimum north component of ground speed occurs when the airplane is flying south, and is given by

$$V_{G,N,min} = -V_A + V_{W,N} \quad [7b]$$

Adding Equations [7a] and [7b] and solving for $V_{W,N}$ gives

$$V_{W,N} = \frac{V_{G,N,max} + V_{G,N,min}}{2} \quad [7c]$$

The east component of wind ($V_{W,E}$) can be computed similarly:

$$V_{W,E} = \frac{V_{G,E,max} + V_{G,E,min}}{2} \quad [7d]$$

The wind speed and direction can be computed once $V_{W,N}$ and $V_{W,E}$ are known. Note that the wind direction is given as the compass heading that the wind is blowing *from* (whereas $V_{W,N}$ and $V_{W,E}$ are positive blowing *towards* the north and east, respectively – so a positive $V_{W,N}$ would be south wind, and a negative $V_{W,E}$ would be an east wind).

The top two plots in Figure 7 show the wind speed and direction encountered by N7345R as a function of time based on the HRRR model (black lines), and based on the average winds computed from the maximum and minimum ground speed components during the four circles (dashed blue lines). The bottom plot of Figure 7 shows a matrix of wind speeds vs. wind directions corresponding to speed and direction increments added to the HRRR model. The speed increments considered are $\Delta V = \pm 10$ knots and the direction increments considered are $\Delta \psi = -20^\circ$ and $\Delta \psi = +30^\circ$. The colored lines correspond to the combinations of wind speed and direction from the HRRR model, with these increments added, over the time span of the data

presented in the top two plots of the Figure. The wind speed and direction computed during each of the circles using Equations [7c] and [7d] are shown by the yellow diamonds. The combination of wind speed and direction averaged over all the circles is shown by the red square.

The wind calculations shown in Figure 7 indicate that the baseline HRRR wind speed and direction (without any increments added) match the average wind speed and direction during the circles very well. The speeds match almost exactly for much of the flight, and the wind directions only differ by about 5° . Consequently, it is reasonable to use the HRRR winds to compute N7345R's airspeed, and to use the corresponding C_L to ascertain whether the airplane achieved the C_{Lmax} associated with the stall speeds in the AFM.

D.5. Yaw control with one engine inoperative

To start an airplane spinning, a yawing moment must be present as the airplane stalls. In a deliberate spin, the yawing moment is usually provided by a rudder input. In inadvertent spins, the yawing moment might result from an asymmetry: either an asymmetric stall (one wing stalling before the other due to ice contamination or other cause), or from asymmetric thrust resulting from operation of the engines at different thrust levels (as during a V_{MCA} demonstration). An improper or inadvertent rudder input at the moment of stall can also provide the yawing moment necessary for an unintended spin.

To determine whether N7345R might have been operating with one engine inoperative (OEI) during the final stall, the yawing moment on the airplane resulting from all of the thrust being provided by one engine can be compared with the yawing moment that can be balanced with the rudder. If the required thrust on the airplane is more than what can be provided by one engine, then both engines must have been operating. If the required thrust can be provided by a single engine, but the resulting yawing moment is more than can be balanced by the rudder, then it is more likely that both engines contributed to the total thrust.

The V_{MCA} published in the "Limitations" section of the AFM is 80 knots calibrated airspeed (KCAS) and 78 knots indicated airspeed (KIAS).⁶ The AFM defines this speed as the "minimum speed for directional controllability after sudden loss of engine." To have sufficient rudder authority to maintain directional control after an engine failure, the airplane must be operating at or above V_{MCA} . Implicit in the definition of V_{MCA} is that it is a higher speed than the stall speed, since the airplane can't operate below the stall speed. However, at higher altitudes, the available engine power decreases, and hence

⁶ KCAS is KIAS corrected for the instrument error resulting from differences between the sensed and true static pressure in the freestream air at a distance from the airplane.

the yawing moment resulting from an OEI condition also decreases. This lower yawing moment can be balanced with full rudder at an airspeed lower than the published V_{MCA} . Above a certain altitude, the maximum available engine thrust is low enough that the airplane will stall before running out of rudder authority available to balance an OEI condition. Because of the yawing moment resulting from asymmetric thrust, a stall in an OEI condition will likely result in a spin.

Section X of the AFM, titled "Safety Information," describes this situation in a subsection titled "Stalls, Slow Flight and Training:"

The single-engine stall speed of a twin-engine airplane is generally slightly below the power off (engines idle) stall speed, for a given weight condition. Single-engine stalls should not be conducted in multi-engine airplanes by other than qualified engineering test pilots.

Engine-out minimum control speed generally decreases with altitude, while the single engine stall speed remains approximately constant for normally aspirated engines. No such demonstration [of V_{MCA}] should be attempted when the altitude and temperature are such that the engine-out minimum control speed is known, or discovered to be, close to the stalling speed. Loss of directional or lateral control, just as a stall occurs, is potentially hazardous.

V_{SSE} , the airspeed below which an engine should not be intentionally rendered inoperative for practice purposes, was established because of the apparent practice of some pilots, instructors, and examiners, of intentionally rendering an engine inoperative at a time when the airplane is being operated at a speed close to, or below the power-idle stall speed. Unless the pilot takes immediate and proper corrective action under such circumstances, it is possible to enter an inadvertent spin.

It is recognized that flight below V_{SSE} with one engine inoperative, or simulated inoperative, may be required for conditions such as practice demonstration of V_{MCA} for multiengine pilot certification. Refer to the procedure set forth in the Pilot's Operating Handbook and FAA Approved Airplane Flight Manual for your airplane. This procedure calls for simulating one engine inoperative by reducing the power level (throttle) on one engine to idle while operating at an airspeed above V_{SSE} . Power on the other engine is set at maximum, then airspeed is reduced at approximately one knot per second until either V_{MCA} or stall warning is obtained. During this transition, rudder should be used to maintain directional control, and ailerons should be used to maintain a 5° bank toward the operative engine. At the first sign of either V_{MCA} or stall warning (which may be evidenced by inability to maintain longitudinal, lateral or directional control, aerodynamic stall buffet, or stall warning horn sound), recovery must be initiated immediately by reducing power to idle on operative engine and lowering the nose to regain V_{SSE} . Resume normal flight. This entire procedure should be used at a safe altitude of at least 5,000 feet above the ground in clear air only.

If stall warning is detected prior to the first sign of V_{MCA} , an engine-out minimum control speed demonstration cannot be accomplished under the existing gross weight conditions and should not be attempted.

The V_{SSE} published in the "Emergency Procedures" section of the AFM is 84 KIAS (86 KCAS) at a weight of 5,100 lb. The AFM does not specify the altitude or other conditions at which the effective V_{MCA} decreases below the single-engine stall speed. However,

the effective V_{MCA} at 4,000 ft. MSL, and the magnitude of the OEI thrust that could be balanced by the airplane's available rudder authority, can be estimated knowing the sea-level power and V_{MCA} published in the AFM.

The yawing moment produced by the operating engine in an OEI situation is

$$N_e = Ty_e \quad [8]$$

Where T is the thrust of the engine and y_e is the distance from the airplane's centerline to the thrust line of the engine. The yawing moment available from the rudder at its maximum deflection is given by

$$N_{rmax} = C_{N,rmax} \left(\frac{1}{2} \rho V^2 \right) S b \quad [9]$$

Where $C_{N,rmax}$ is the yawing moment coefficient of the rudder at its maximum deflection, ρ is the air density, V is the true airspeed, S is the wing area, and b is the wing span. At V_{MCA} , $N_e = N_{rmax}$, and we can compute $C_{N,rmax}$:

$$C_{N,rmax} = \frac{T_{MCA} y_e}{\left(\frac{1}{2} \rho [V_{MCA}]^2 \right) S b} = C_{T,MCA} \left(\frac{y_e}{b} \right) \quad [10]$$

Where $C_{T,MCA}$ is the thrust coefficient at V_{MCA} (see Equation [12]). The engine power, propeller efficiency, and V_{MCA} at sea level can be used to compute T_{MCA} , $C_{T,MCA}$, and $C_{N,rmax}$. The yawing moment coefficient produced throughout the flight, assuming all the required thrust comes from one engine, can be computed as

$$C_{N,OEI} = C_T \left(\frac{y_e}{b} \right) \quad [11]$$

Where C_T is the thrust coefficient corresponding to the total thrust required at each point in the flight:

$$C_T = \frac{T}{\left(\frac{1}{2} \rho V^2 \right) S} = \frac{T}{\bar{q} S} \quad [12]$$

Where V is the true airspeed, and $\bar{q}$ is the dynamic pressure. If at any point in the flight $C_T > C_{N,rmax}$, then at that point the airplane cannot be in an OEI condition because there would not be sufficient rudder authority to offset the asymmetric thrust. In addition, knowing the available power at 4,000 ft. (see section D.3) and the propeller efficiency at the sea-level V_{MCA} , the OEI thrust at 4,000 ft. can be computed. The effective V_{MCA} at 4,000 ft. then follows by solving for V_{MCA} in Equation [10]. In this case, the result is $V_{MCA}|_{4000 \text{ ft}} = 77 \text{ KCAS}$ (vs. 80 KCAS at sea level). Figure 12 compares $C_T(y_e/b)$ to $C_{N,rmax}$ throughout the accident flight, and is discussed further below.

D.6. Performance calculation results

The results of the performance calculations based on the ADS-B and winds aloft data for N4978B, and of the estimation of the nominal Barron B55 performance based on textbook methods and data presented in the AFM, are presented in Figures 8-12.

Figure 8 presents N7345R's speeds and rate of climb during the flight. The ADS-B recorded ground speed and vertical speed are shown, along with the airspeeds based on the ADS-B ground speed and the HRRR winds plotted in Figure 6. The estimated time during which the second and final stall probably occurred (immediately preceding the airplane's spin) is highlighted in yellow Figure 8b and other Figures. The left boundary of this time range (11:24:55.3) is based on the time that the computed C_L exceeds the nominal flaps-up C_{Lmax} implied by the AFM (see Figure 11 and the discussion below). The right boundary of the time range (11:25:01, the likely latest time at which the stall occurred) is defined by the sudden roll to the left computed based on the sudden change in ground track angle at this time (see Figure 9b). The AFM flaps-up and flaps-down stall speeds at a weight of 4,500 lb. are also depicted in Figure 8, along with the V_{MCA} and V_{SSE} speeds published in the AFM.

Figure 9 presents the pitch angle, flight path angle, angle of attack, roll angle, heading angle, and ground track angle computed from the ADS-B data and winds aloft during the flight. In Figure 9a, the times of the four 360° turns (circles) are highlighted in different colors in the roll and heading plots.

In Figure 9b, the change in the roll angle at 11:25:01 from about -5° left to over -50° left coincides with peaks in the airplane's rate of climb and computed flight path angle, followed by sudden decreases in these parameters. These behaviors are consistent with an aerodynamic stall.

Figures 8 and 9 provide evidence that the airplane also experienced an aerodynamic stall about 24 to 29 seconds before the final stall, at about 11:24:31, when the airspeed decreased below the flaps-up stall speed, the flight path angle and pitch angle peaked and then dropped, and the computed C_L reached the nominal flaps-up C_{Lmax} (see Figure 11). Significantly, Figures 8 and 9 indicate that the airplane *recovered* from this first stall. The roll angle only dipped to about -16° left, and the airplane did not depart from controlled flight. These facts suggest that the power on the two engines was balanced, and that any ice on the airframe at that time was not severe enough to result in an asymmetric stall and spin.

Figure 10 presents the computed longitudinal (n_x) and normal (nlf) load factors, and the rate of change of calibrated airspeed (dV_C/dt) during the accident flight. The plot of dV_C/dt indicates that prior to the first stall at about 11:24:32, the deceleration rate was about -2 knots/second, whereas prior to the final stall the deceleration rate was -2.5

to -3 knots/second, suggesting a more “aggressive” approach to the second stall. This difference is also reflected in the plot of pitch angle in Figure 8b; during the first approach to stall, the pitch rate is roughly 1°/second, whereas during the approach to the final stall the pitch rate is roughly 1.8°/second.

Figure 11 plots the ADS-B ground speed and computed calibrated airspeed (in the top plot) and the computed C_L (in the bottom plot). The C_L is computed as

$$C_L = \frac{(nlf)W}{\bar{q}s} \quad [13]$$

Where W is the airplane weight and nlf is the normal load factor. The values of C_{Lmax} implied by the idle-power flaps-up and flaps-down stall speeds published in the AFM are also shown in the top plot of Figure 11b.

The calculations of nlf and, consequently, C_L near the stall become somewhat uncertain because of uncertainties in the winds and the precise airplane motions (such as pitch rate) that affect the calculations. Because of these uncertainties, the time of the actual final stall is depicted as the range between 11:24:55.3 and 11:25:01 highlighted in yellow in Figure 11b and other Figures. The sudden roll at 11:25:01 suggests that this is the latest time at which the airplane stalled; the earliest time (11:24:55.3) corresponds to when the computed C_L exceeds the idle-power flaps-up C_{Lmax} implied by the AFM. The nlf and C_L calculations show a sudden drop in these parameters at 11:24:57, near the middle of the yellow range, though it is unlikely that the actual C_L achieved was above the flaps-down idle-power C_{Lmax} , as shown in Figure 11b. After the stall, the assumptions of non-stalled, coordinated flight that underlie the performance calculations based on the ADS-B data are no longer valid, and so the computed performance parameters are not reliable after the computed C_L exceeds the nominal C_{Lmax} at 11:24:55.3. However, the computed parameters reliably indicate an approach to stall, and behavior (a loss of altitude and a change in ground track due to a roll-off) that is consistent with post-stall dynamics.

Figure 12 plots the computed thrust coefficient (C_T) and power required during the flight in the top two plots, and the value of $C_T(y_e/b)$ (see Equation [11]) in the bottom plot. The power delivered to the airframe, TV_T (see Equation [4]), is depicted by the blue line in the middle plot of Figure 12, and the total brake horsepower developed by the engines, BHP , is depicted by the black line. Figure 12b shows that at the time of the first stall at 11:24:31.3, the total power delivered by the engines was more than the OEI power, and so both engines must have been operating at the time. In addition, even if the required power could have been delivered by one engine alone, the resulting yawing moment coefficient ($C_T(y_e/b)$) would have been greater than that which could have been balanced with the rudder, again indicating that the required power must have been shared by both engines.

At the time of the second stall, the required power is reduced compared to that required during the approach to the first stall. The oscillations in the required power calculation prior to the second stall, which result from oscillations in the computed n_x associated with the rate of change of speed, make it hard to determine the exact power level present at the stall. However, given that this second stall occurs only about half a minute after the first, it is very unlikely that the second stall is associated with an attempted V_{MCA} demonstration. It is also very unlikely that the pilots were attempting a single-engine stall, which the AFM warns should not be done "by other than qualified engineering test pilots." Given these observations, and the fact that the first stall was performed and recovered from successfully, it is not likely that the yawing moment that induced the spin following the second stall resulted from either an asymmetrical thrust condition or an asymmetrical aerodynamic condition associated with ice accumulation. Instead, the required yawing moment might have resulted from an improper stall recovery technique (perhaps involving an excessive or inadvertent rudder input).

E. CONCLUSIONS

The material in this *Study* supports several observations and conclusions regarding the performance of N7345R during its accident flight. At 11:23.00, while the airplane was flying approximately level at about 3,500 ft., total engine power was reduced from about 400 HP to about idle, and the airplane slowed from about 169 KCAS (at 11:23:00) to about 90 KCAS (at 11:24:05). Power was then slowly applied to maintain an airspeed of approximately 90 KCAS and an altitude of about 3,500 ft.

At 11:24:15, power was increased to about 300 HP, and the rate of climb started to increase. The airspeed remained at about 90 KCAS until about 11:24:25, when it started to decrease, while the pitch angle increased. With the computed power between 300 and 400 HP, the C_L reached the flaps-up C_{Lmax} at 11:24:31.3 as the airspeed decreased to 77 KCAS (1 knot above the AFM 1-G stall speed of 76 KCAS). At 11:24:32.3, the pitch angle peaked at about 25° before dropping to -2° at 11:24:38, and then increased steadily to about 21° at 11:24:52. The rate of climb peaked at about 1,800 ft./min., dropped to -1,500 ft./min. at 11:24:39, and then increased to 1,700 ft./min. at 11:24:52. The airspeed bottomed out at about 73 KCAS at 11:24:34 before increasing to 100 KCAS at 11:24:44 and then decreasing again through 84 KCAS at 11:24:52. The roll angle increased from -3° left at 11:24:31.3 to -16.5° left at 11:24:36, and then recovered to -2.5° left at 11:24:39.

At 11:24:55.3, the C_L again reached the flaps-up C_{Lmax} as the airspeed dropped to 76 KCAS (the flaps-up stall speed). The computed pitch, roll, and nlf parameters indicate that the airplane stalled a second time between 11:24:55.3 and 11:25:01. Following this stall, the airplane entered a spin from which it did not recover.

The behavior just described is consistent with two power-on stalls, with the first stall break occurring at 11:24:31.3, the airplane recovering from the stall, and then pulling up into a second stall 24 to 29 seconds after the first stall. The airplane started to spin following the second stall. To induce a spin in an airplane, a yawing moment must be present as the airplane stalls. Given N7345R's successful recovery from the first stall, it is not likely that the yawing moment that induced the spin following the second stall resulted from either an asymmetrical thrust condition or an asymmetrical aerodynamic condition associated with ice accumulation. Instead, the required yawing moment might have resulted from an improper stall recovery technique (perhaps involving an excessive or inadvertent rudder input).

Submitted by:

John O'Callaghan
National Resource Specialist – Aircraft Performance

F. REFERENCES

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2. International Civil Aviation Organization (ICAO), *The Tenth Meeting of Automatic Dependent Surveillance – Broadcast (ADS-B) Study and Implementation Task Force (ADS-B SITF/10) Agenda Item 6: Review States' activities and interregional issues on trials and implementation of ADS-B and multilateration: ADS-B / GPS Accuracy (Presented by Australia)*. Singapore, 26-29 April 2011. Document available at: https://www.icao.int/APAC/Meetings/2011_ADS_B_SITF10/IP10_AUS%20AI.%206%20-%20GPS%20Accuracy.pdf.
3. National Transportation Safety Board, Office of Aviation Safety, *Meteorology Specialist's Factual Report, Beechcraft 95-B-55, N7345R, Leyden, Massachusetts, January 14, 2024, NTSB Accident ERA24FA088*, dated April 19, 2024. (Available through the NTSB CAROL search tool at <https://data.nts.gov/carol-main-public/landing-page>).

G. GLOSSARY

Acronyms

ADS-B	Automatic Dependent Surveillance – Broadcast
AFM	Airplane Flight Manual
AGL	Above ground level
AIRMET	Airman Meteorological Information bulletin
BHP	Brake horsepower
EST	Central Daylight Time
CFR	Code of Federal Regulations
CG	Center of Gravity
CVR	Cockpit Voice Recorder
FAA	Federal Aviation Administration
FDR	Flight Data Recorder
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
"Hg	Inches of mercury
HP	Horsepower
HRRR	High Resolution Rapid Refresh atmospheric sounding model
KBAF	Westfield-Barnes Regional Airport, Westfield/Springfield, Massachusetts
KCAS	Knots calibrated airspeed
KIAS	Knots indicated airspeed
KORE	Orange Municipal Airport, Orange, Massachusetts
KTAS	Knots true airspeed
METAR	Meteorological Terminal Air Report
MSL	Mean Sea Level
NTSB	National Transportation Safety Board
OEI	One Engine Inoperative
POH	Pilot's Operating Handbook
RPM	Revolutions Per Minute
SIGMET	Significant Meteorological Information bulletin
UTC	Universal Coordinated Time

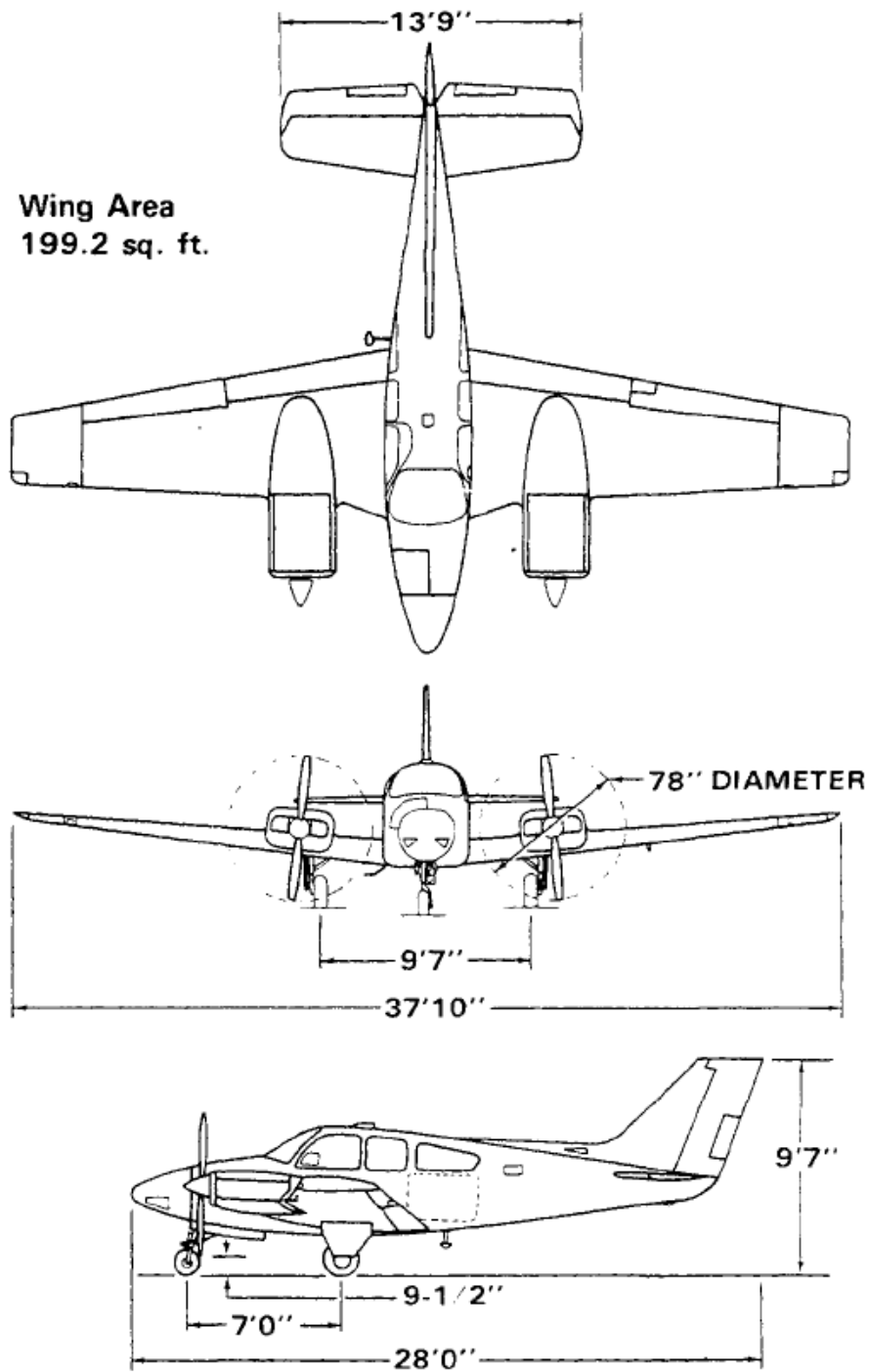
Symbols

α	Angle of attack
γ	Flight path angle
θ	Pitch angle
η	Propeller efficiency
ρ	Air density
ϕ	Roll angle
ψ	Heading angle
ψ_T	Ground track angle
b	Wing span
BHP	Brake horsepower produced by the engines
C_L	Lift coefficient
$C_{L,max}$	Maximum lift coefficient ($=C_L$ at stall)
$C_{N,OEI}$	Yawing moment coefficient produced by the engine in an OEI situation
$C_{N,rmax}$	Yawing moment coefficient of the rudder at its maximum deflection
C_T	Thrust coefficient
$C_{T,MCA}$	Thrust coefficient at V_{MCA}
D	Drag
h	Altitude
$\dot{h}$	Rate of climb (time derivative of $h = dh/dt$)
$\dot{h}_a$	Rate of climb at altitude
$\dot{h}_{sl}$	Rate of climb at sea level
nlf	Normal load factor
n_x	Longitudinal load factor
N_e	Yawing moment produced by the operating engine in an OEI situation
N_{rmax}	Yawing moment available from the rudder at its maximum deflection
$\bar{q}$	Dynamic pressure
S	Wing area
t	Time
T	Thrust
T_a	Thrust at altitude
T_{sl}	Thrust at sea level
$\vec{V}_A$	True airspeed vector
V_C	Calibrated airspeed
$\vec{V}_G$	Ground speed vector
$V_{G,i}$	Ground speed component in i direction, where i = north (N) or east (E)
$V_{G,i,max}$	Maximum ground speed component in i direction, where i = north (N) or east (E)
$V_{G,i,min}$	Minimum ground speed component in i direction, where i = north (N) or east (E)
V_{MCA}	Airborne minimum control airspeed
V_T	True airspeed
V_{Ta}	True airspeed at altitude
V_{Tsl}	True airspeed at sea level
$\vec{V}_W$	Wind vector
$V_{W,i}$	Wind speed component in i direction, where i = north (N) or east (E)
W	Weight
y_e	Distance from the airplane's centerline to the thrust line of the engine

FIGURES

BEECHCRAFT Baron B55
Serial TC-1608 thru TC-2002

Section I
General



AIRPLANE THREE-VIEW

May 1978

1-7

Figure 1. 3-view of the Beechcraft Baron 95-B55 airplane (from Reference 1).



Figure 2. Pre-accident photograph of N7345R (photo credit: Paul Chandler via Jetphotos.net).

ERA24FA088: Beech 95-B55, N7345R, Leyden, MA 01/14/2024

Plan view of flight path

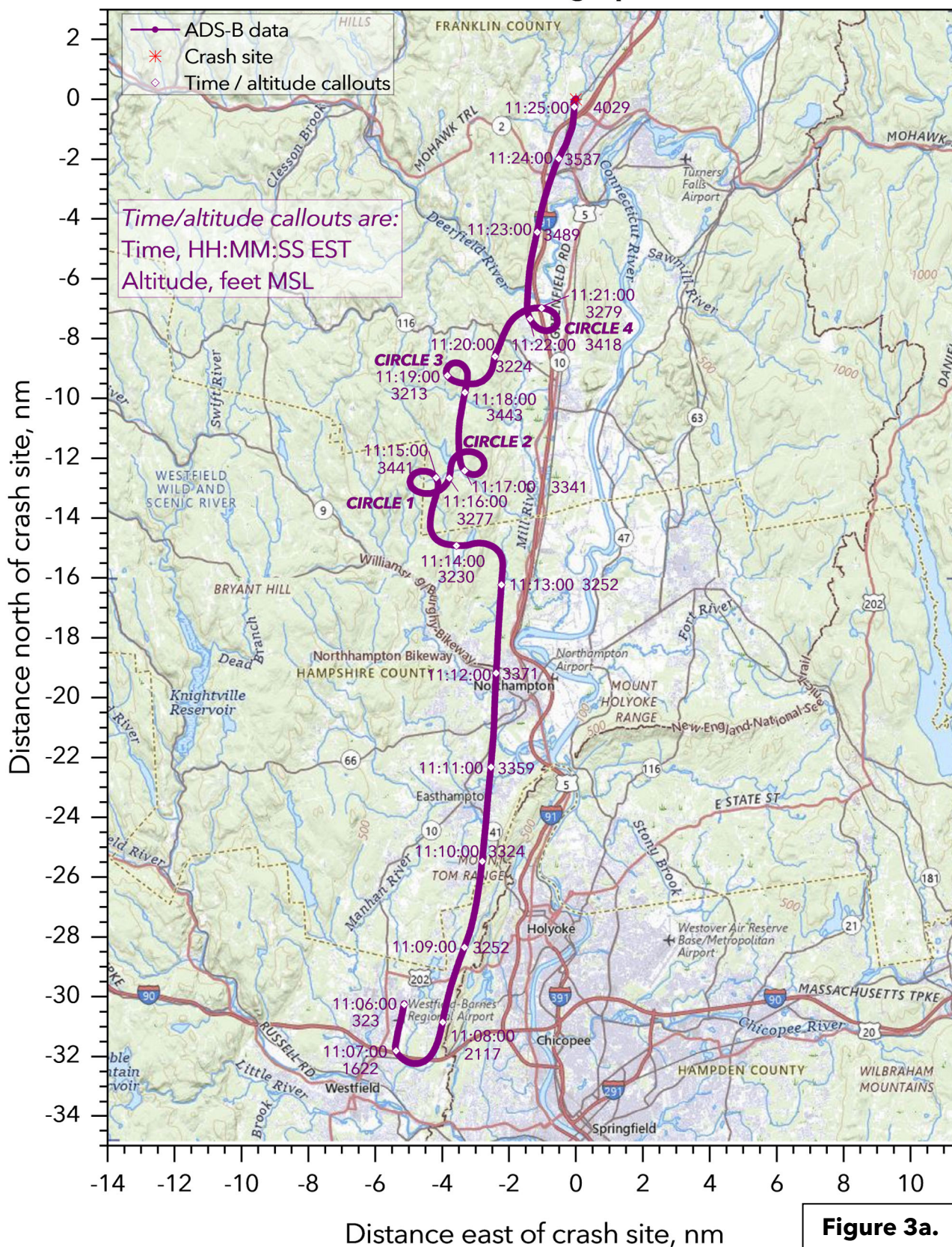


Figure 3a.

ERA24FA088: Beech 95-B55, N7345R, Leyden, MA 01/14/2024

Plan view of flight path (detail)

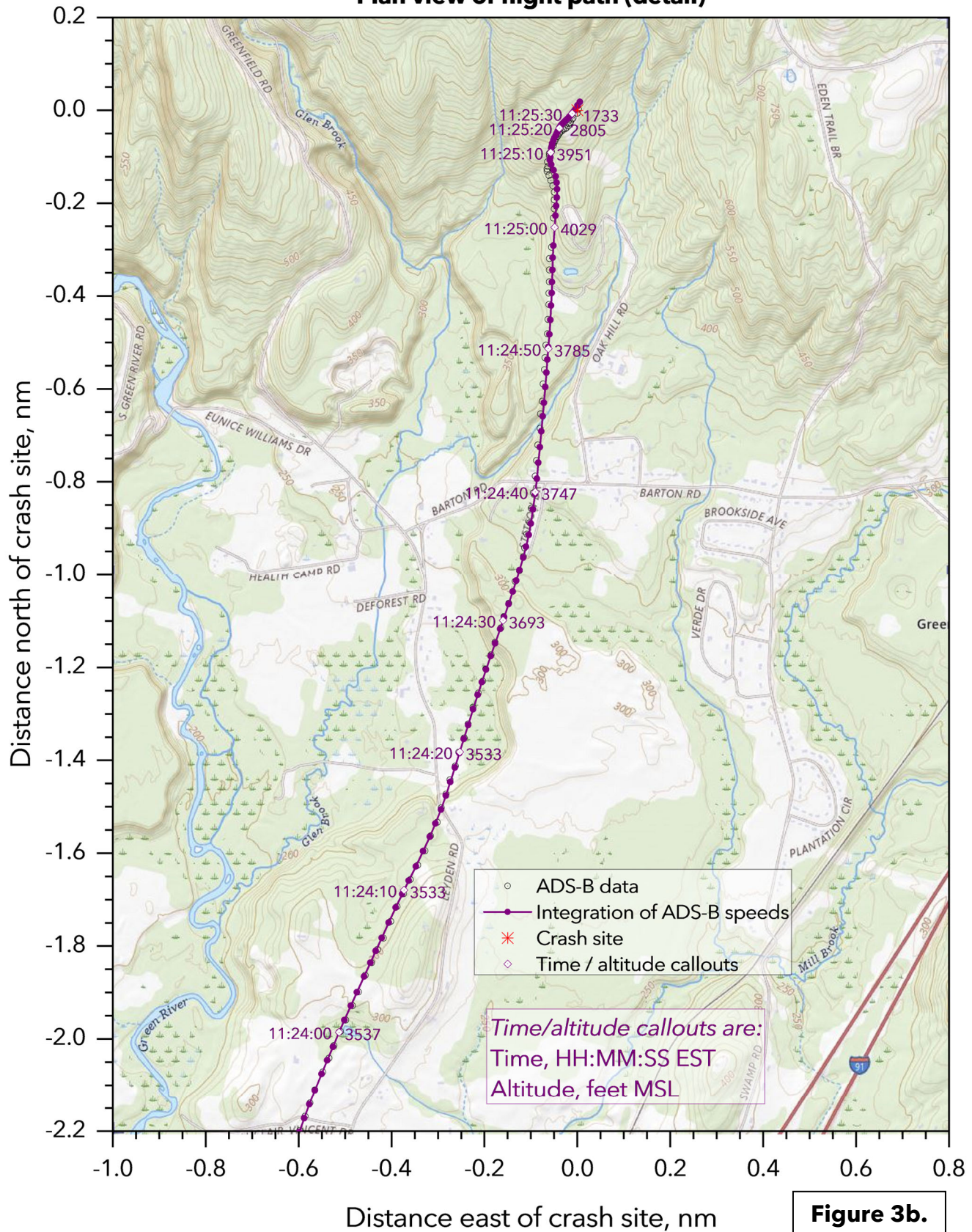


Figure 3b.

ERA24FA088: Beech 95-B55, N7345R, Leyden, MA 01/14/2024

North & east coordinates from crash site

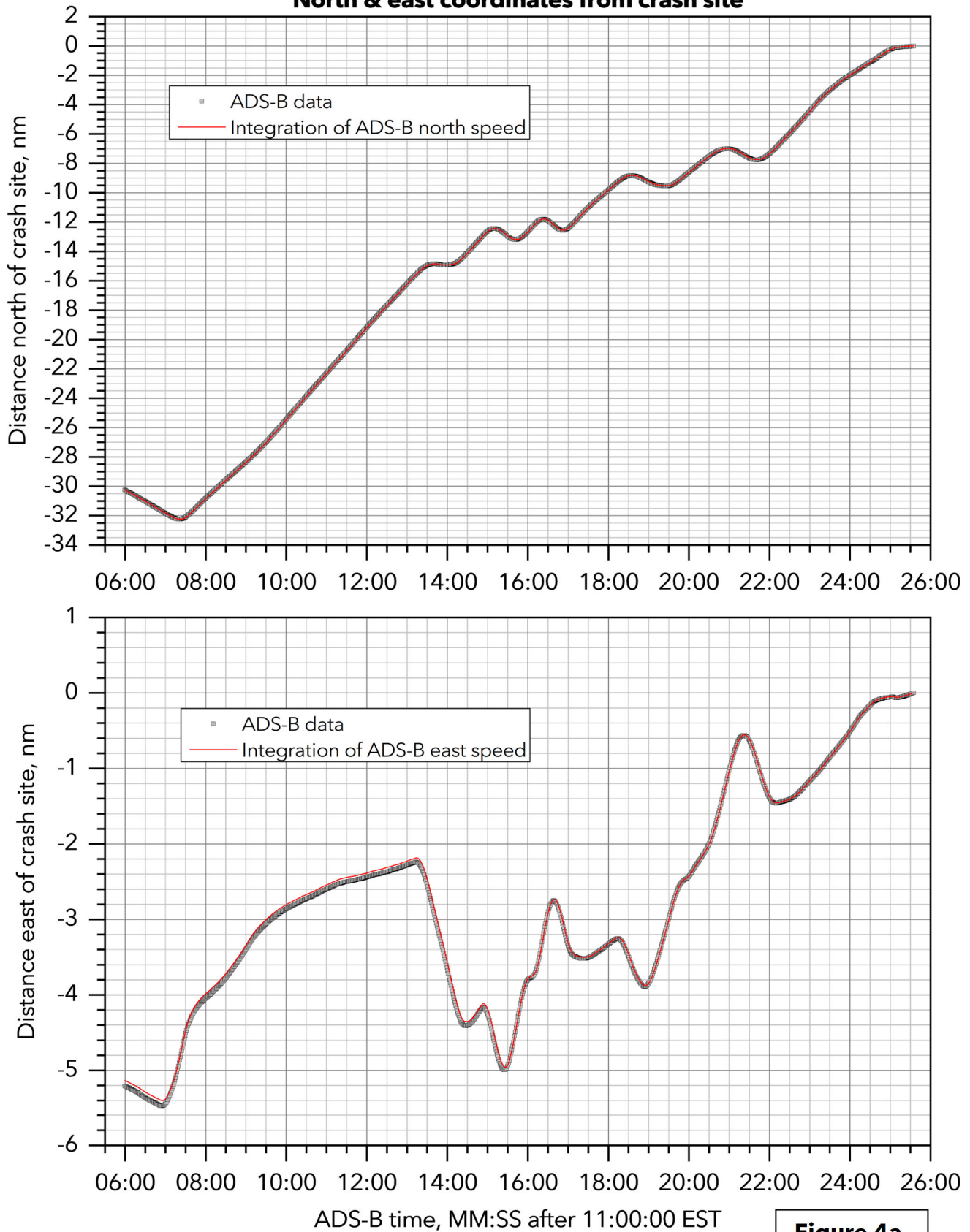


Figure 4a.

ERA24FA088: Beech 95-B55, N7345R, Leyden, MA 01/14/2024

North & east coordinates from crash site (detail)

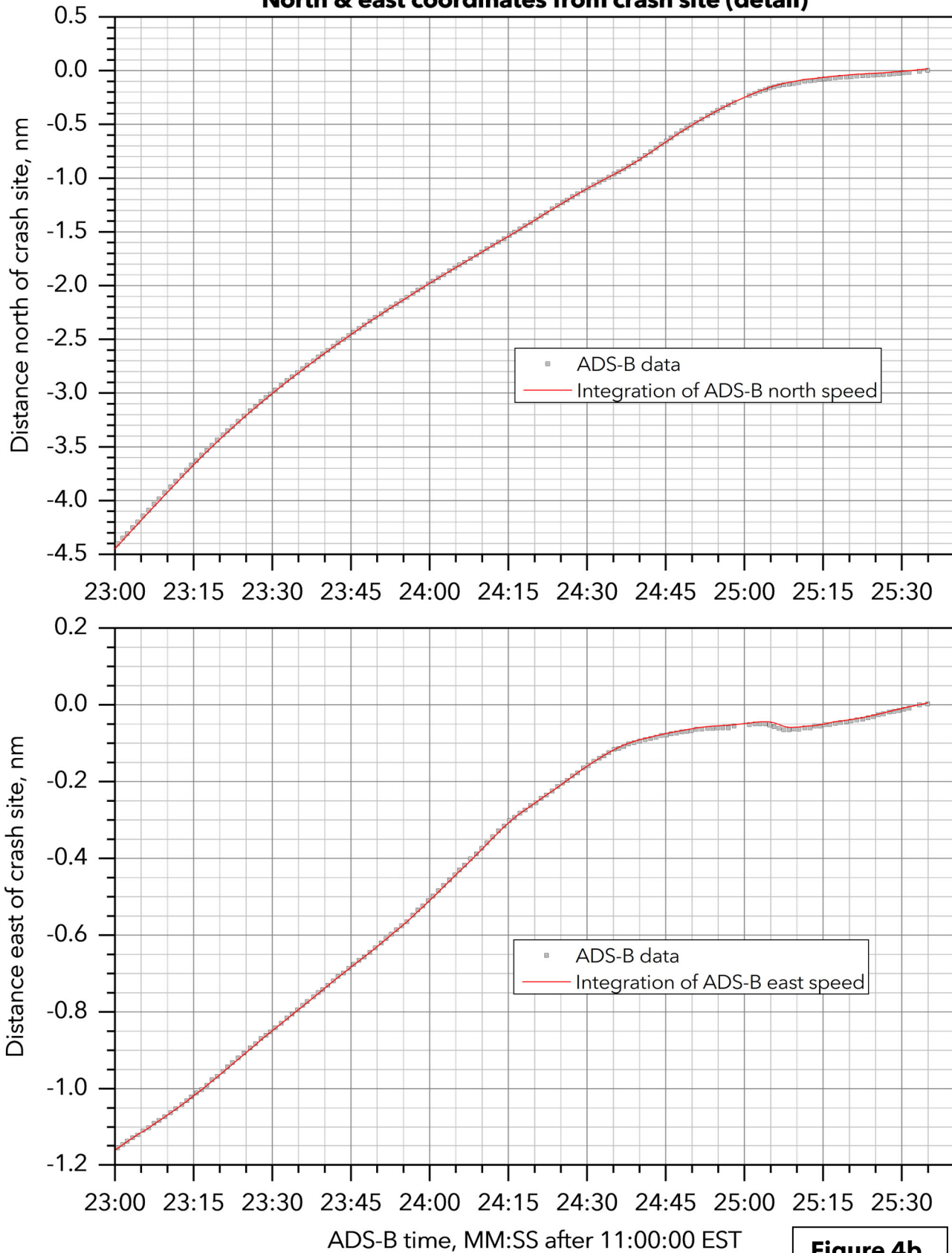
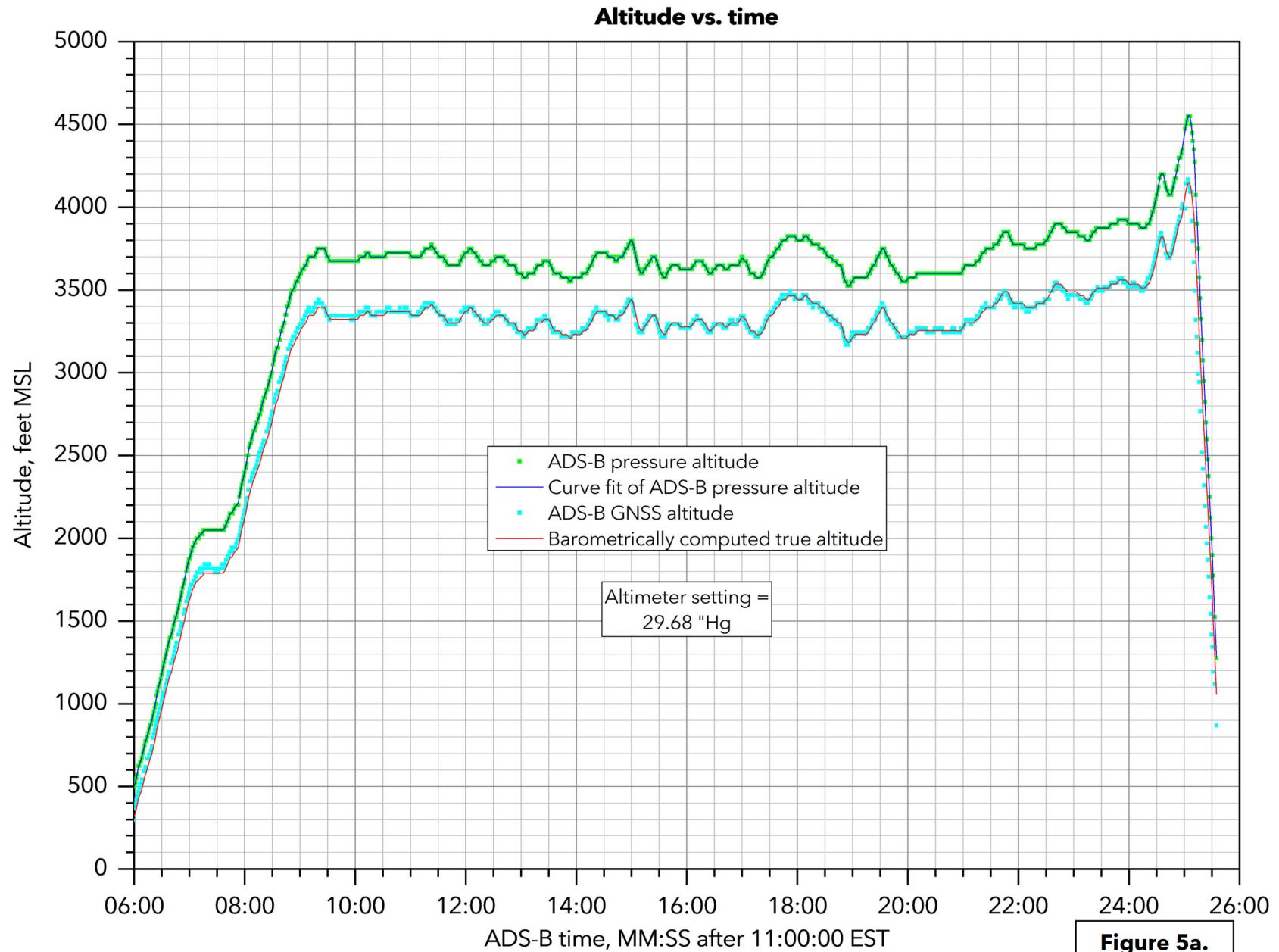


Figure 4b.

ERA24FA088: Beech 95-B55, N7345R, Leyden, MA 01/14/2024



ERA24FA088: Beech 95-B55, N7345R, Leyden, MA 01/14/2024

Altitude vs. time (detail)

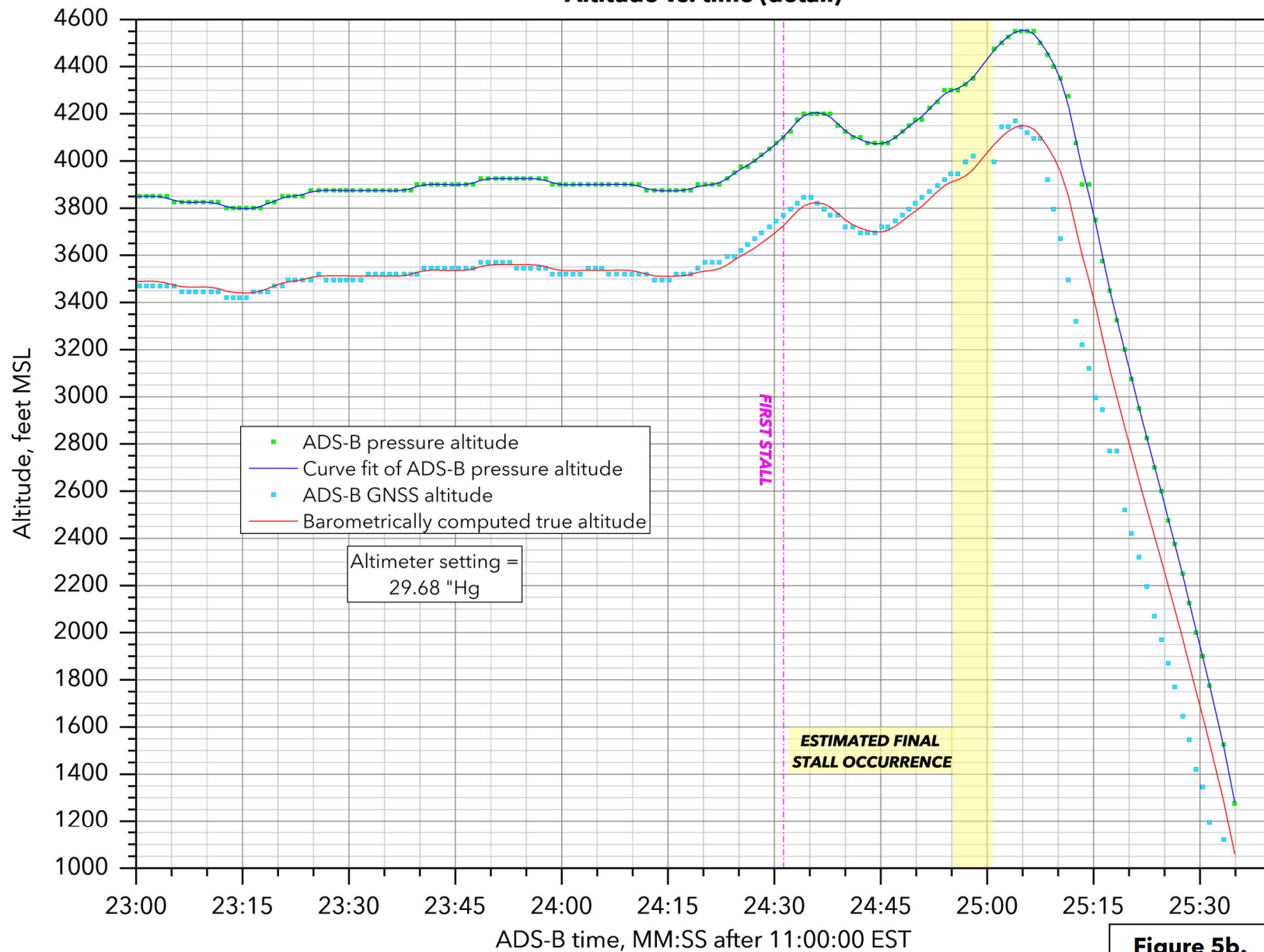


Figure 5b.

ERA24FA088: Beech 95-B55, N7345R, Leyden, MA 01/14/2024

Winds aloft from 11:00 EST HRRR model

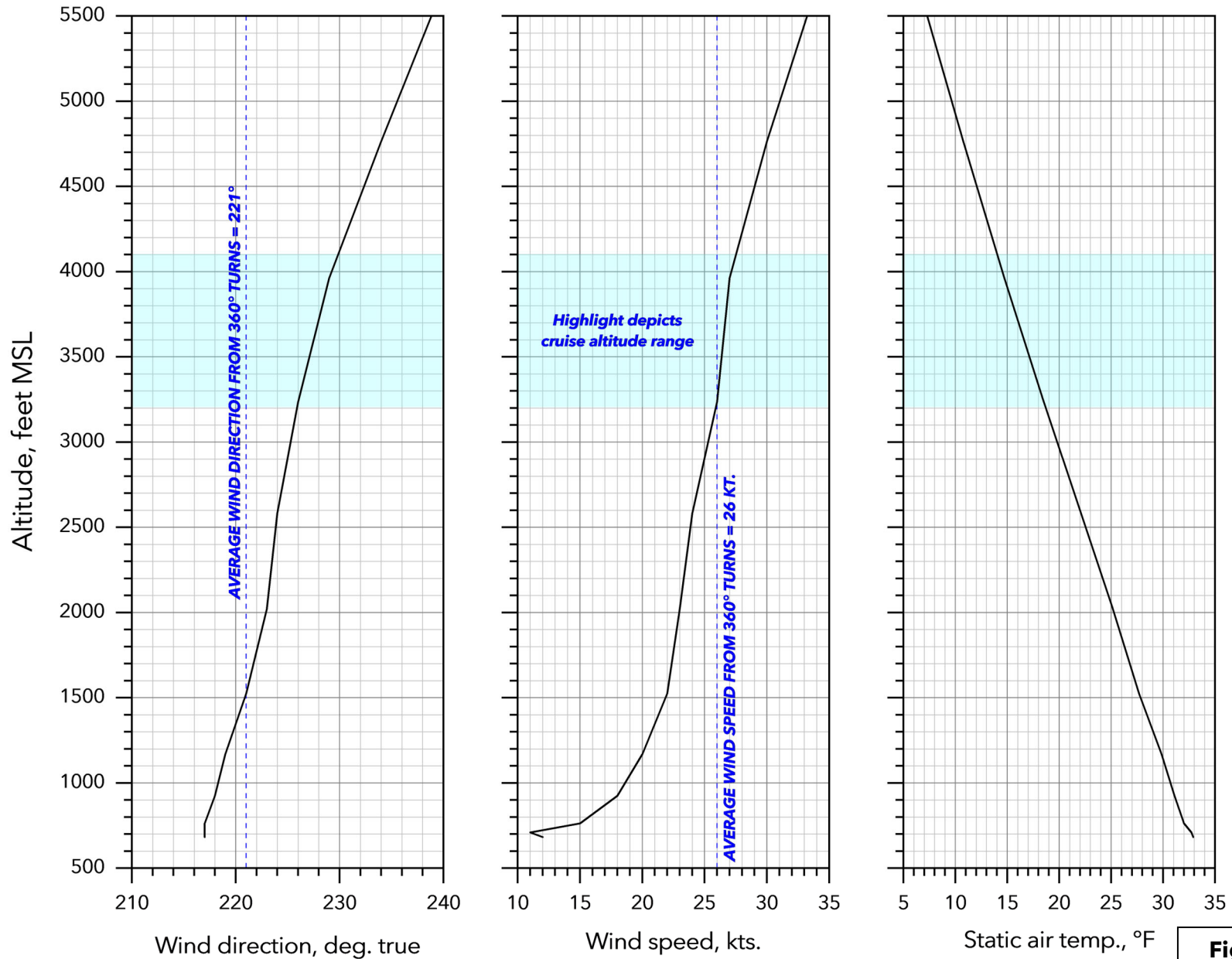


Figure 6.

ERA24FA088: Beech 95-B55, N7345R, Leyden, MA 01/14/2024

Matrix of wind conditions evaluated in performance calculations

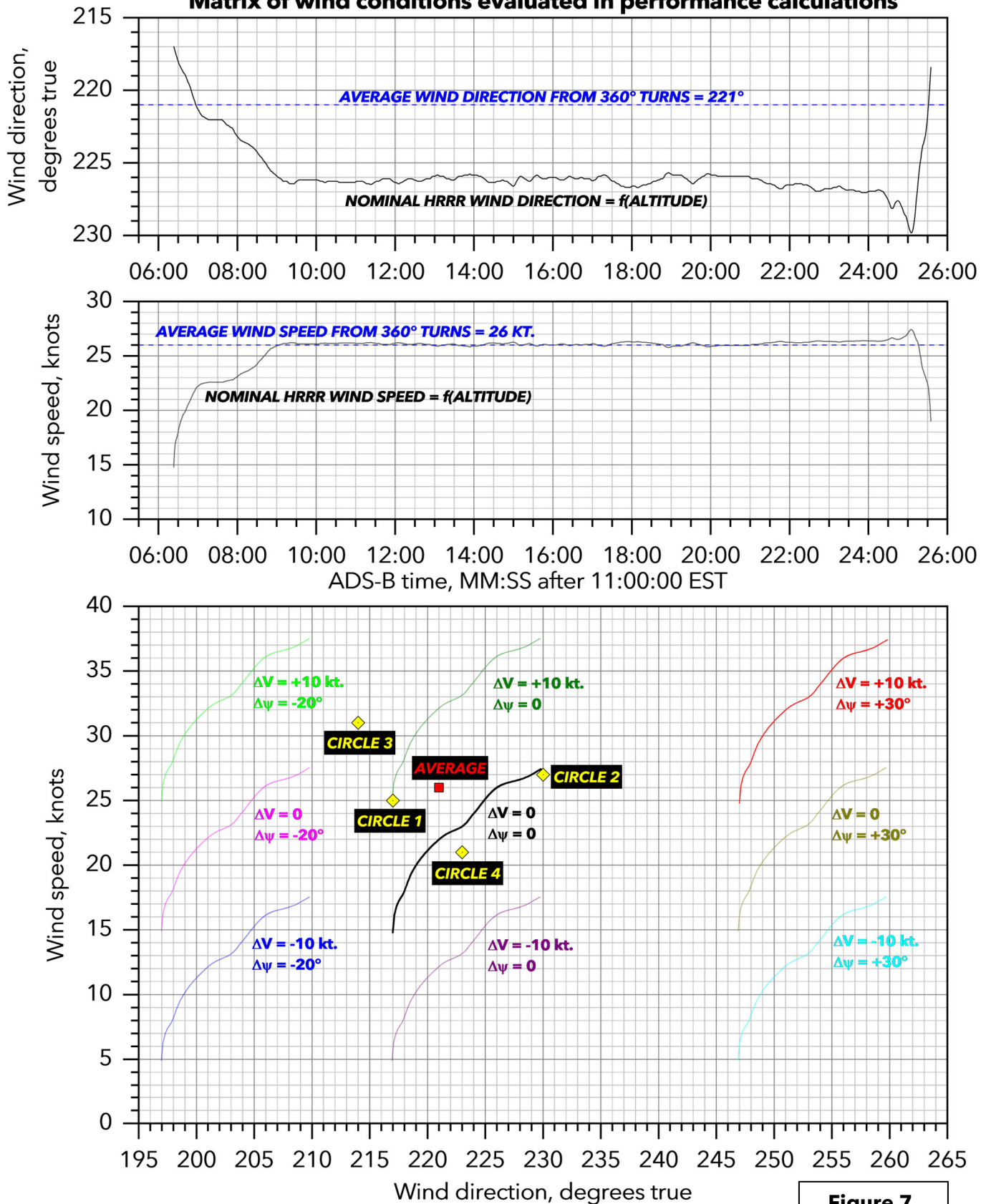


Figure 7.

ERA24FA088: Beech 95-B55, N7345R, Leyden, MA 01/14/2024

Speeds and rate of climb

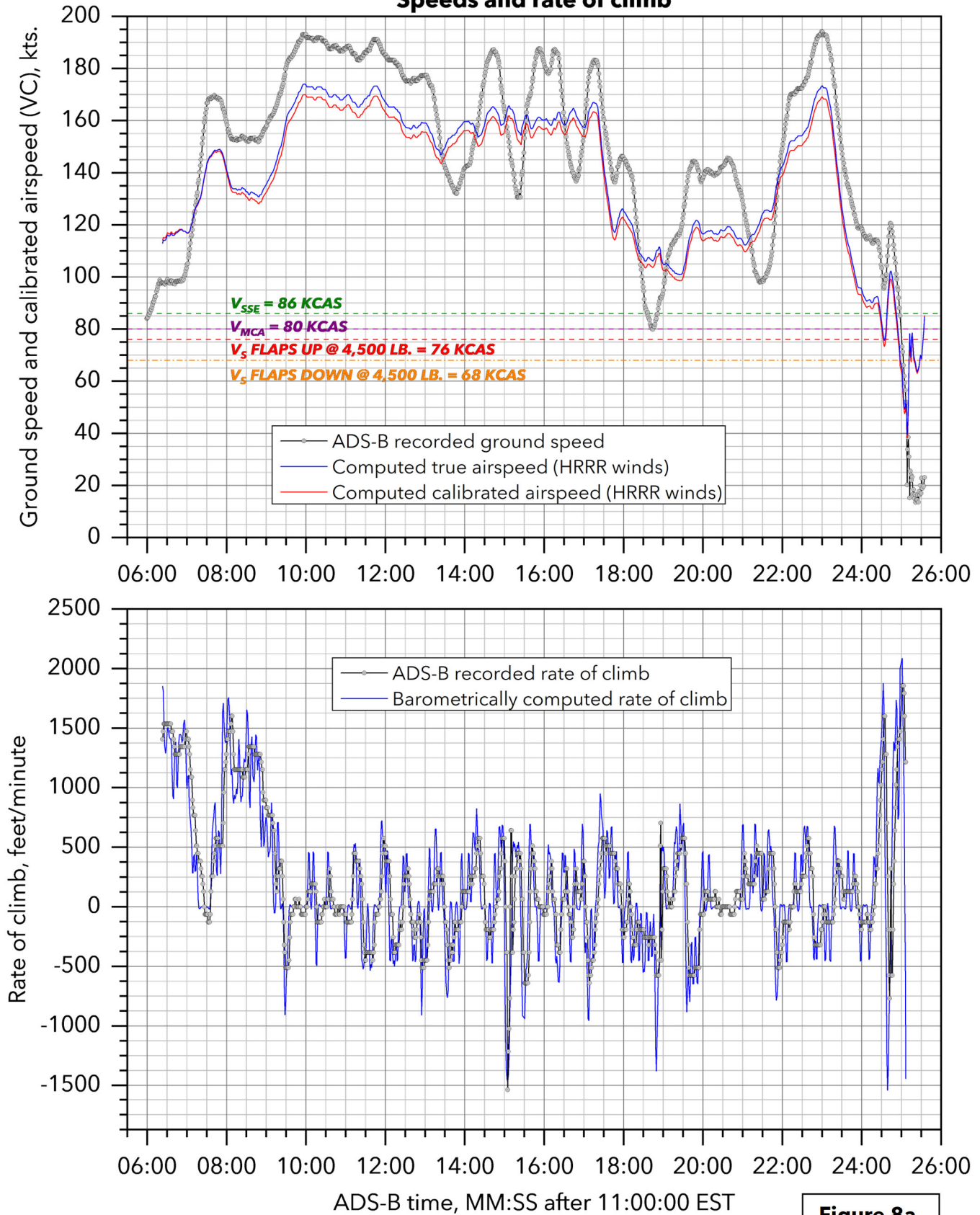


Figure 8a.

ERA24FA088: Beech 95-B55, N7345R, Leyden, MA 01/14/2024

Speeds and rate of climb (detail)

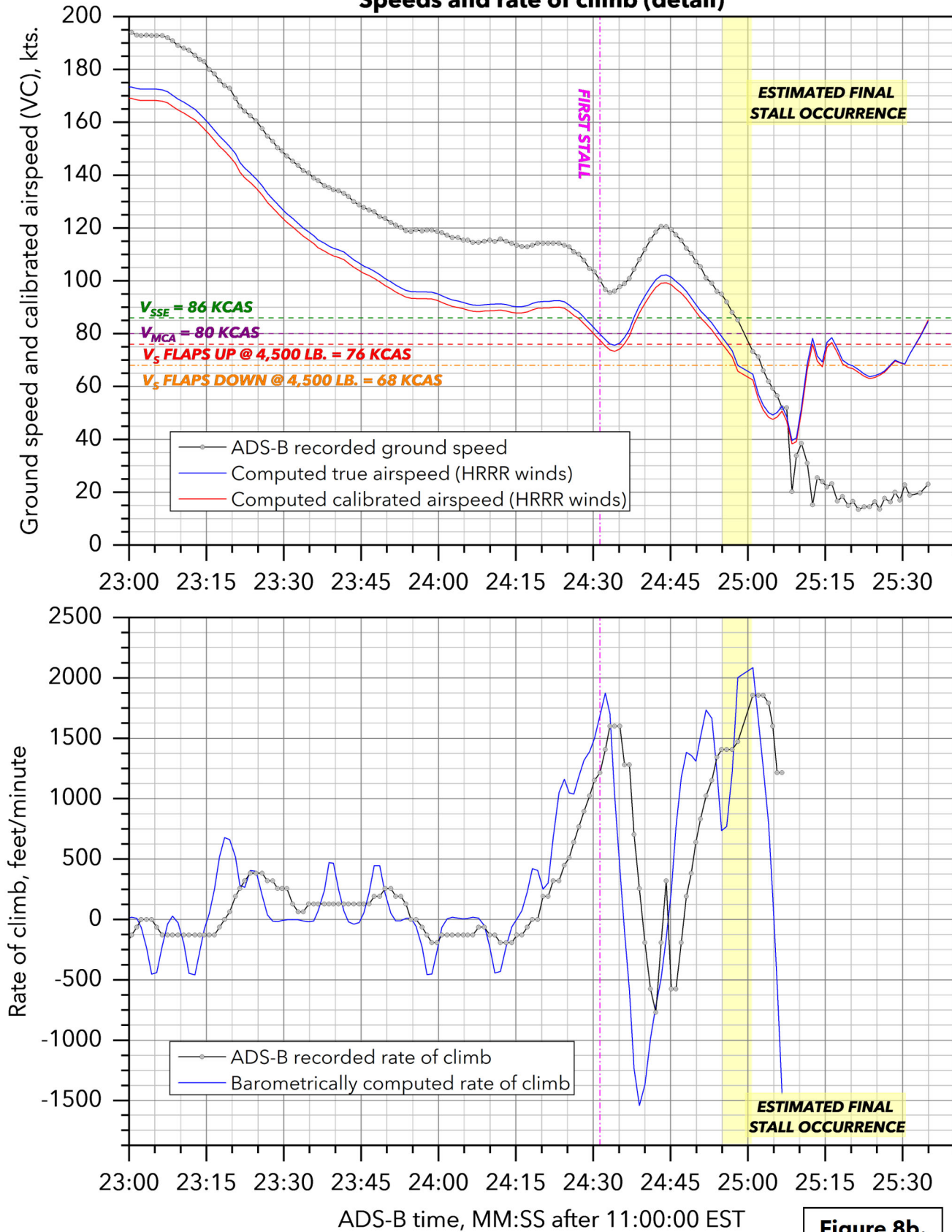
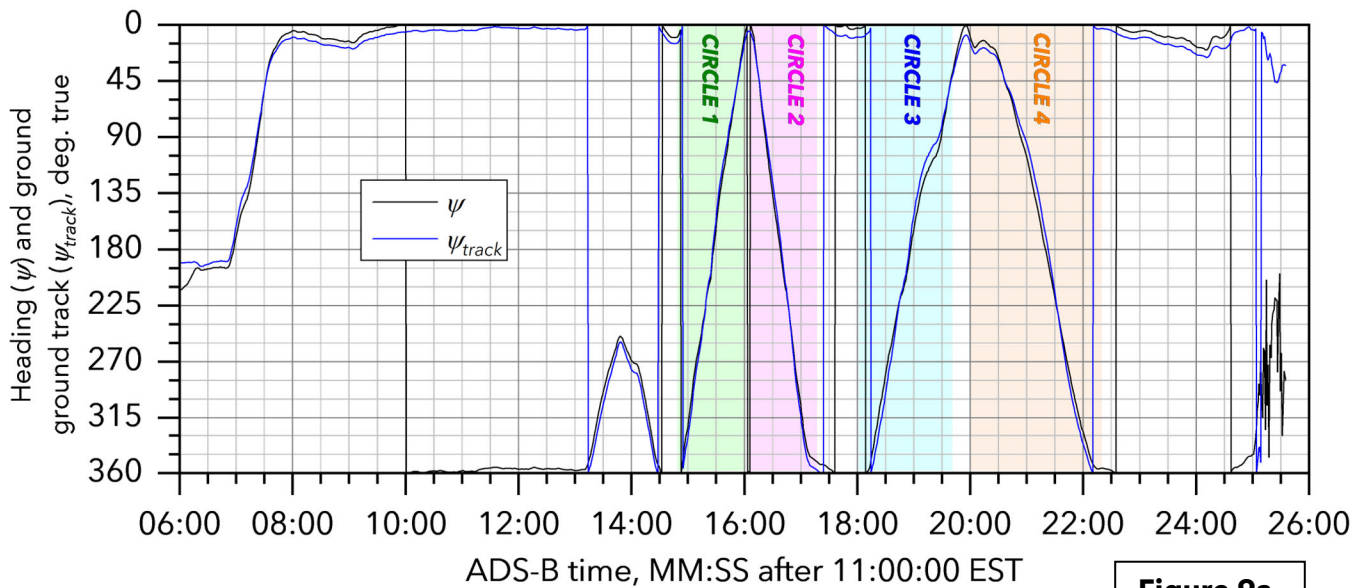
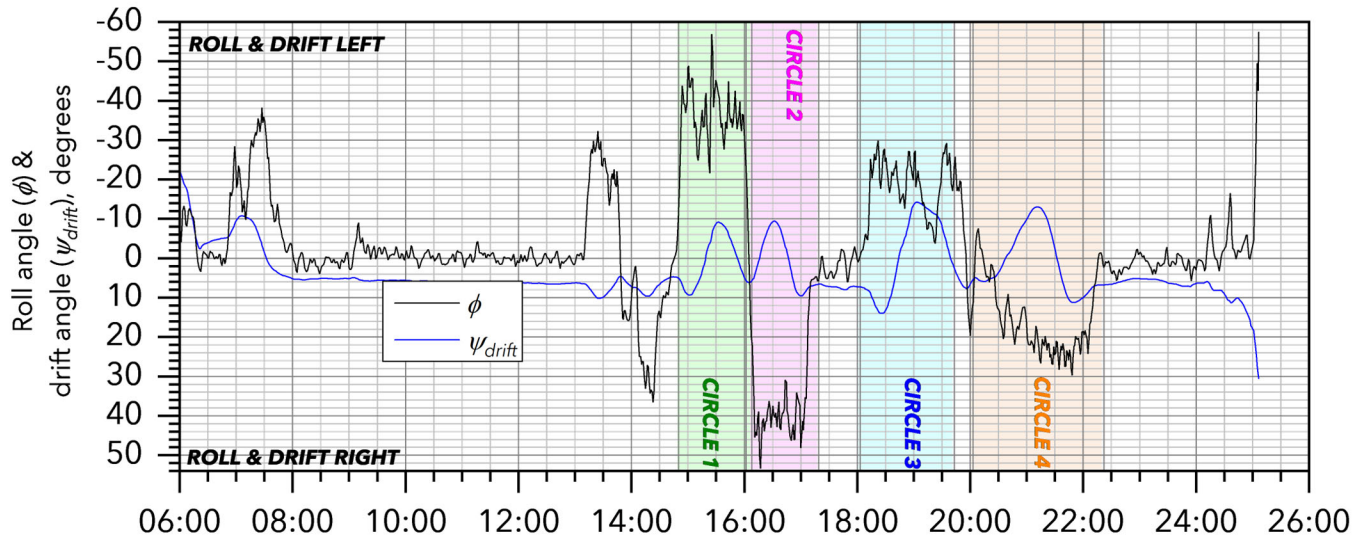
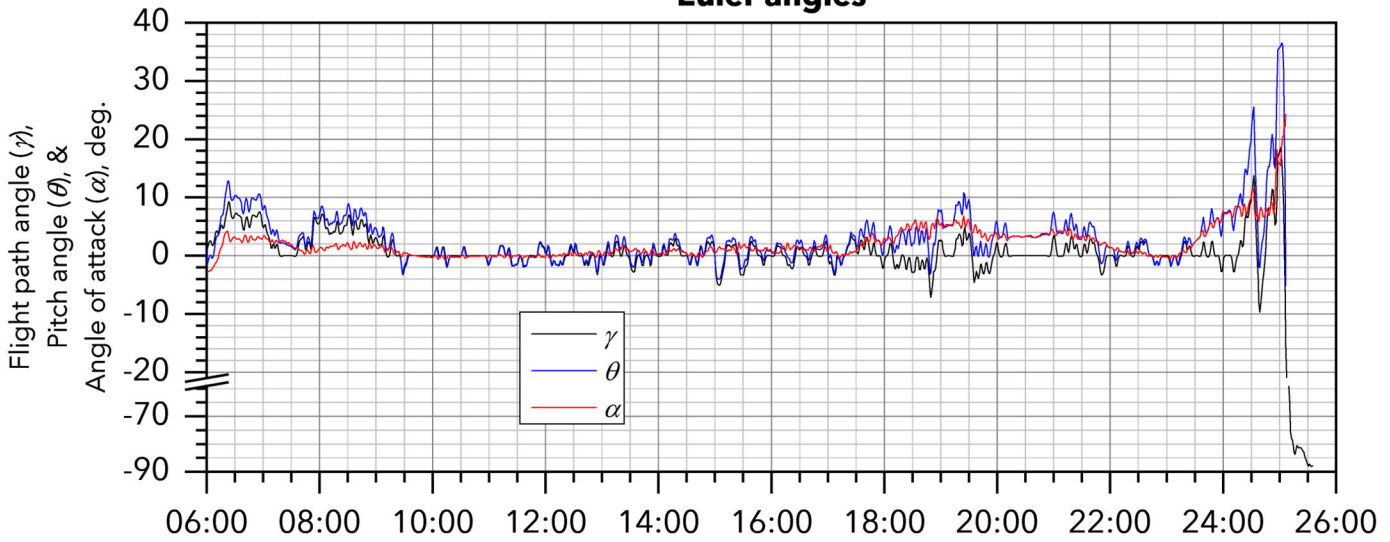


Figure 8b.

ERA24FA088: Beech 95-B55, N7345R, Leyden, MA 01/14/2024

Euler angles



ADS-B time, MM:SS after 11:00:00 EST

Figure 9a.

ERA24FA088: Beech 95-B55, N7345R, Leyden, MA 01/14/2024

Euler angles (detail)

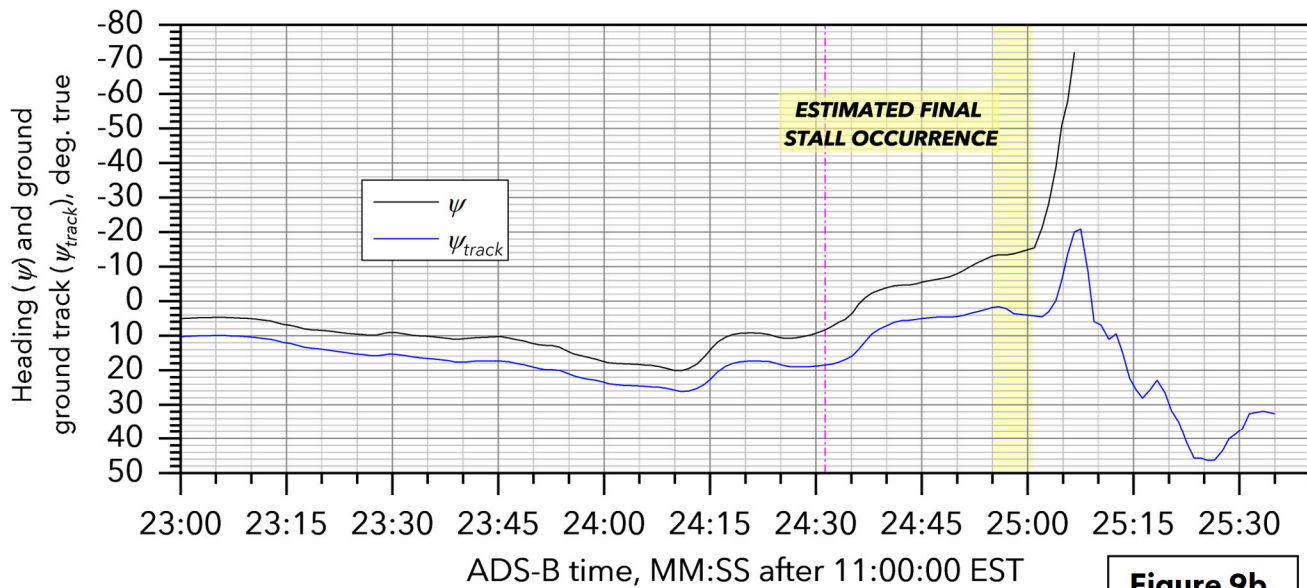
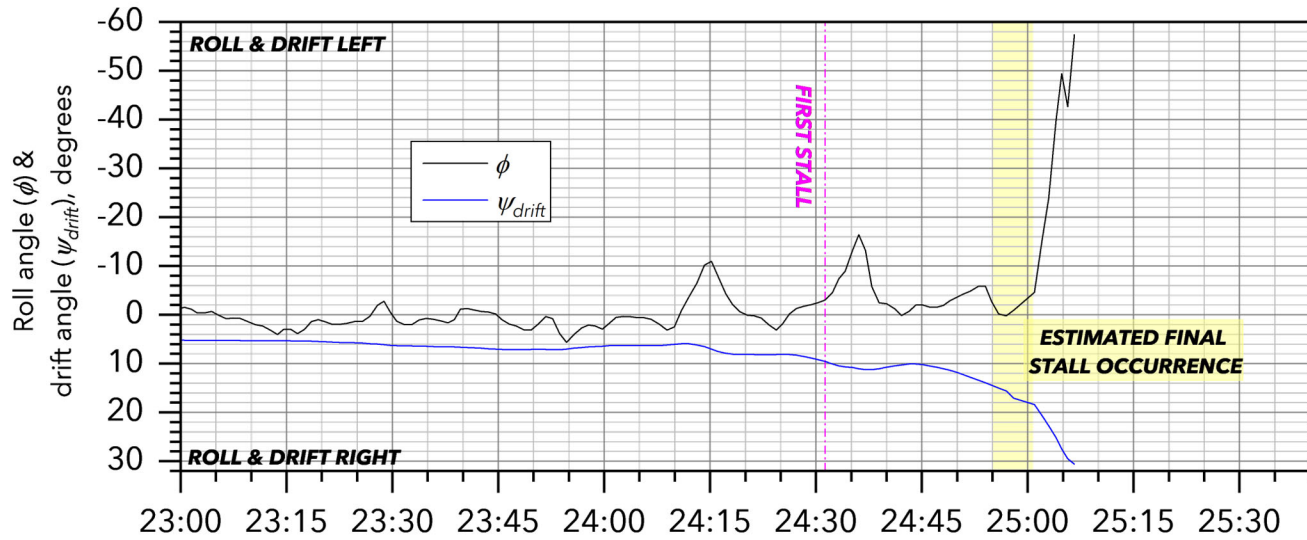
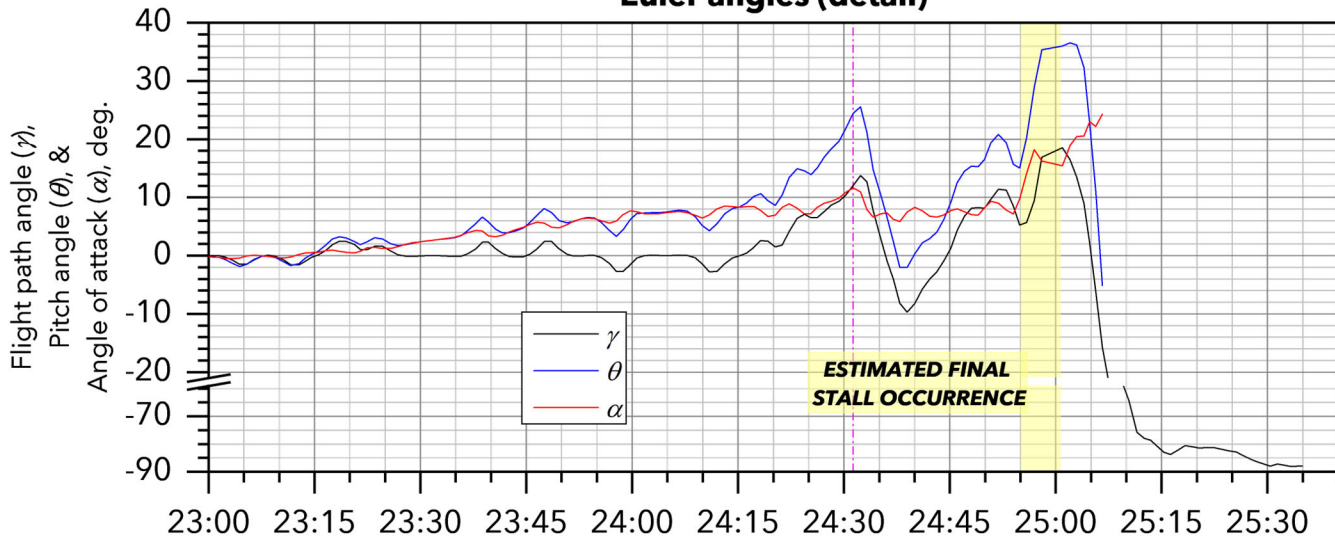


Figure 9b.

ERA24FA088: Beech 95-B55, N7345R, Leyden, MA 01/14/2024

Load factors

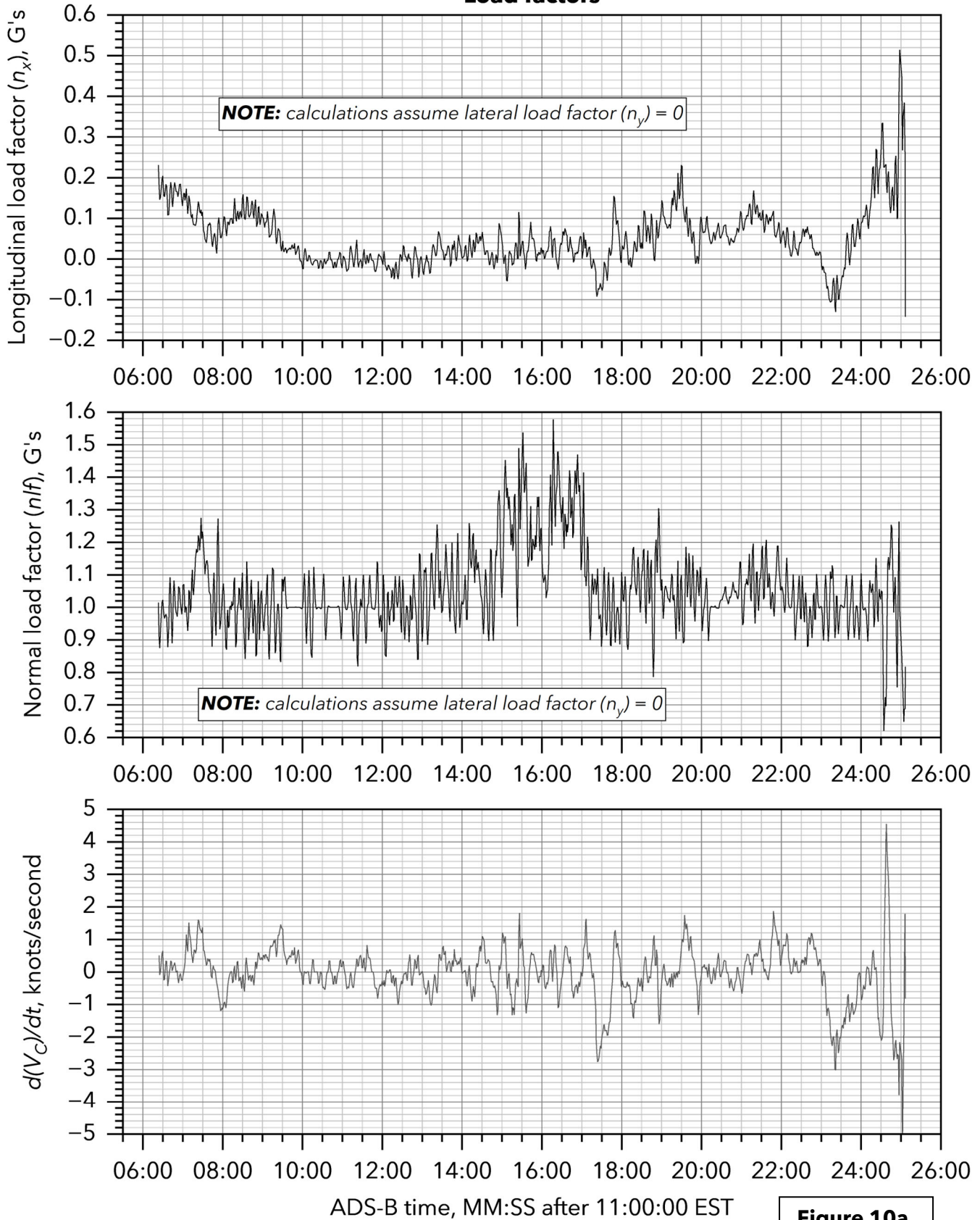
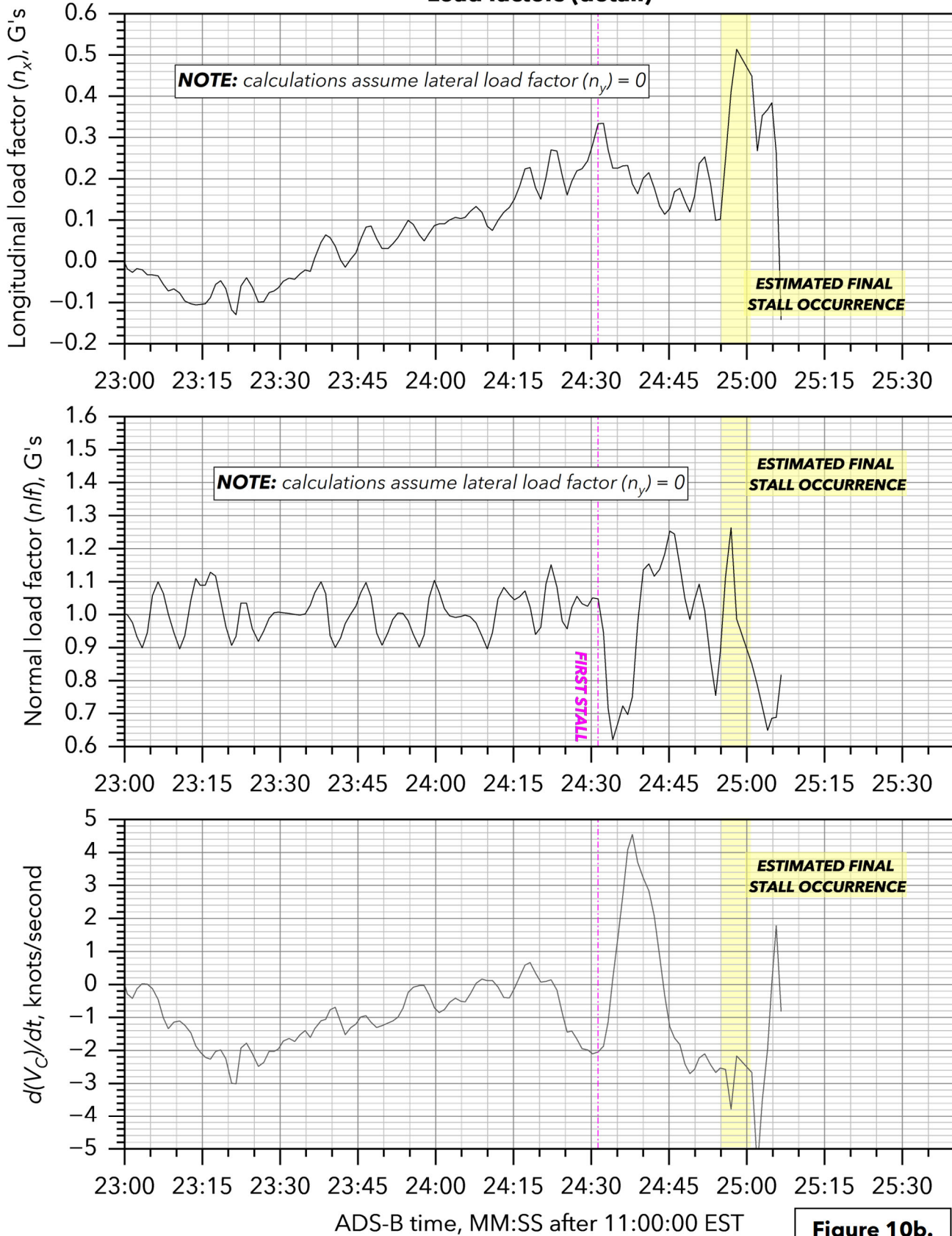


Figure 10a.

ERA24FA088: Beech 95-B55, N7345R, Leyden, MA 01/14/2024

Load factors (detail)



ERA24FA088: Beech 95-B55, N7345R, Leyden, MA 01/14/2024

Calibrated airspeed and C_L

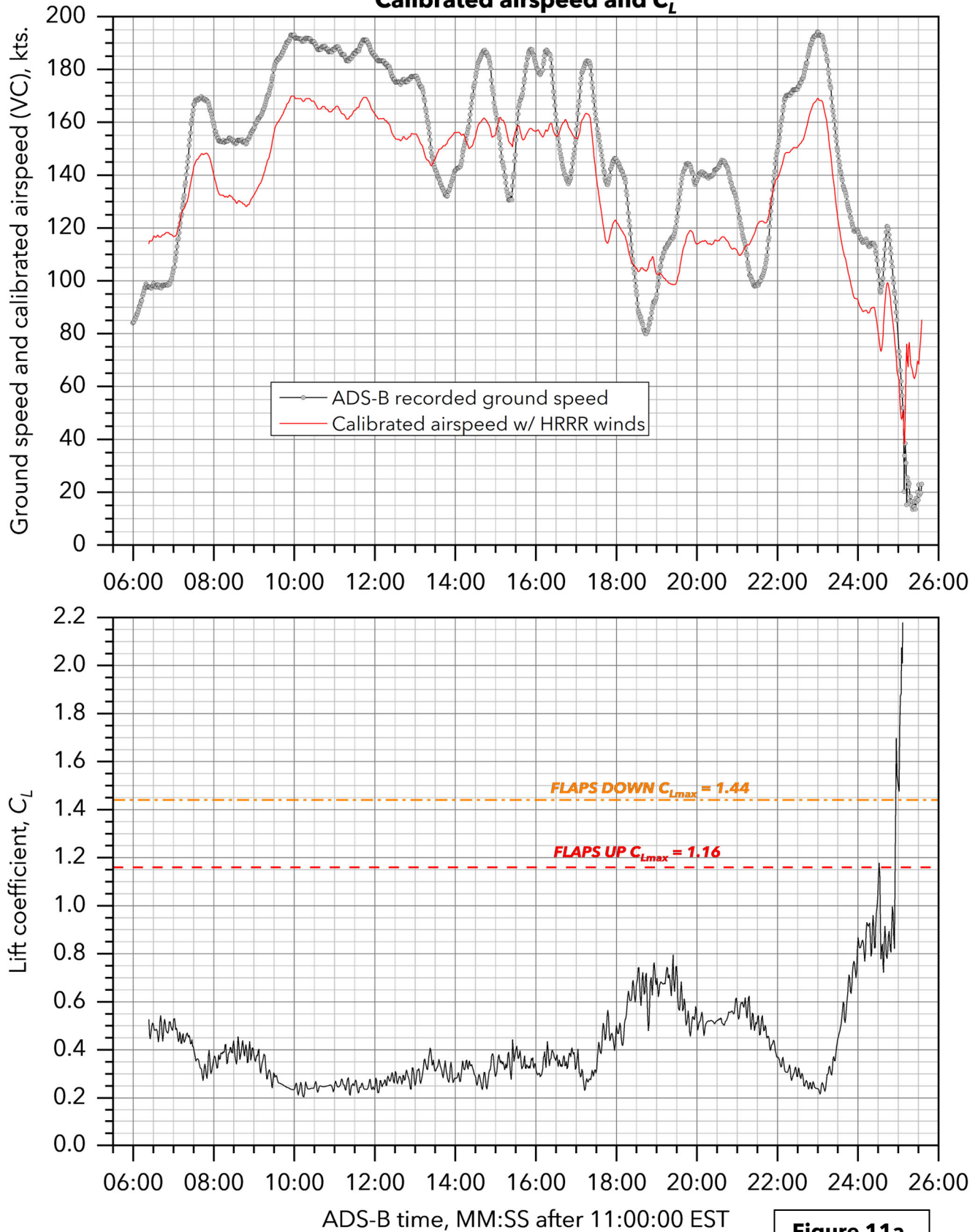


Figure 11a.

ERA24FA088: Beech 95-B55, N7345R, Leyden, MA 01/14/2024

Calibrated airspeed and C_L (detail)

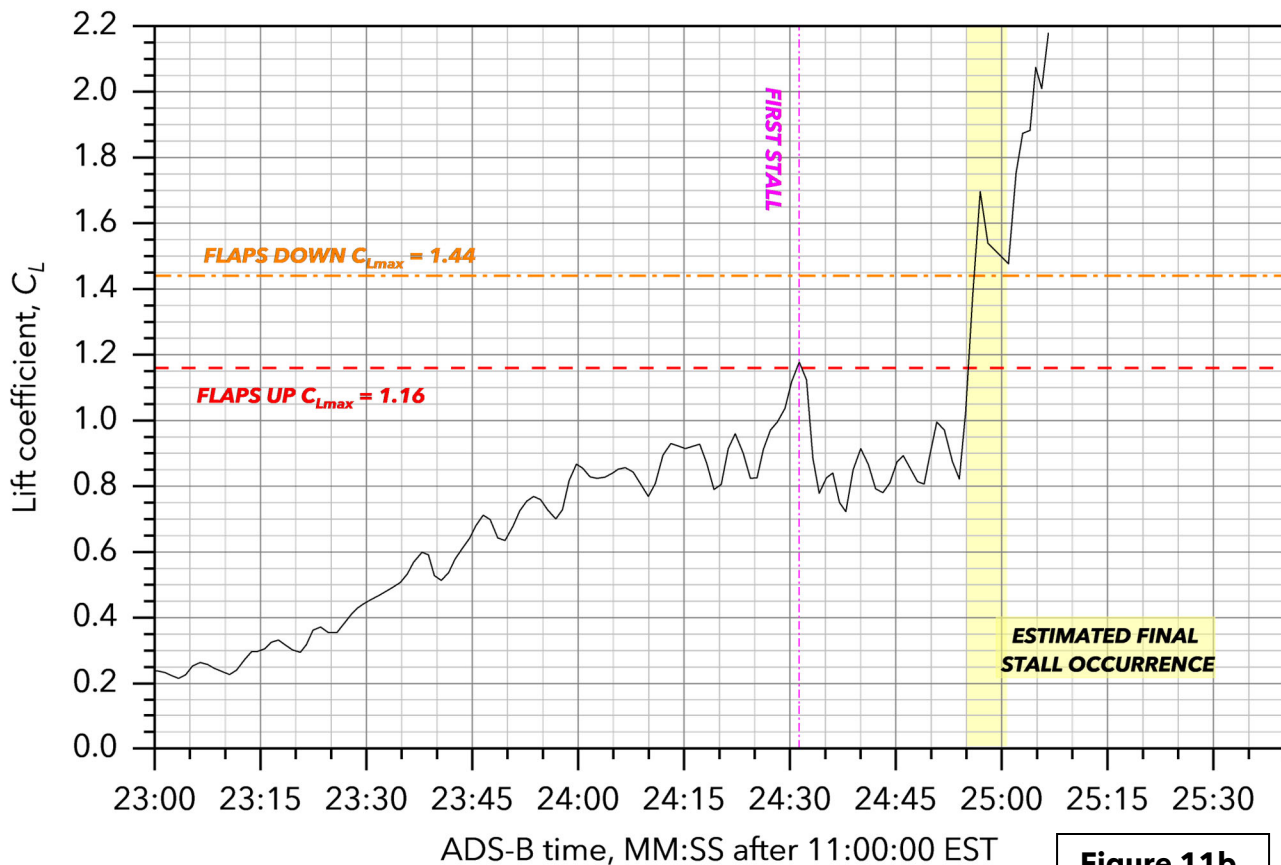
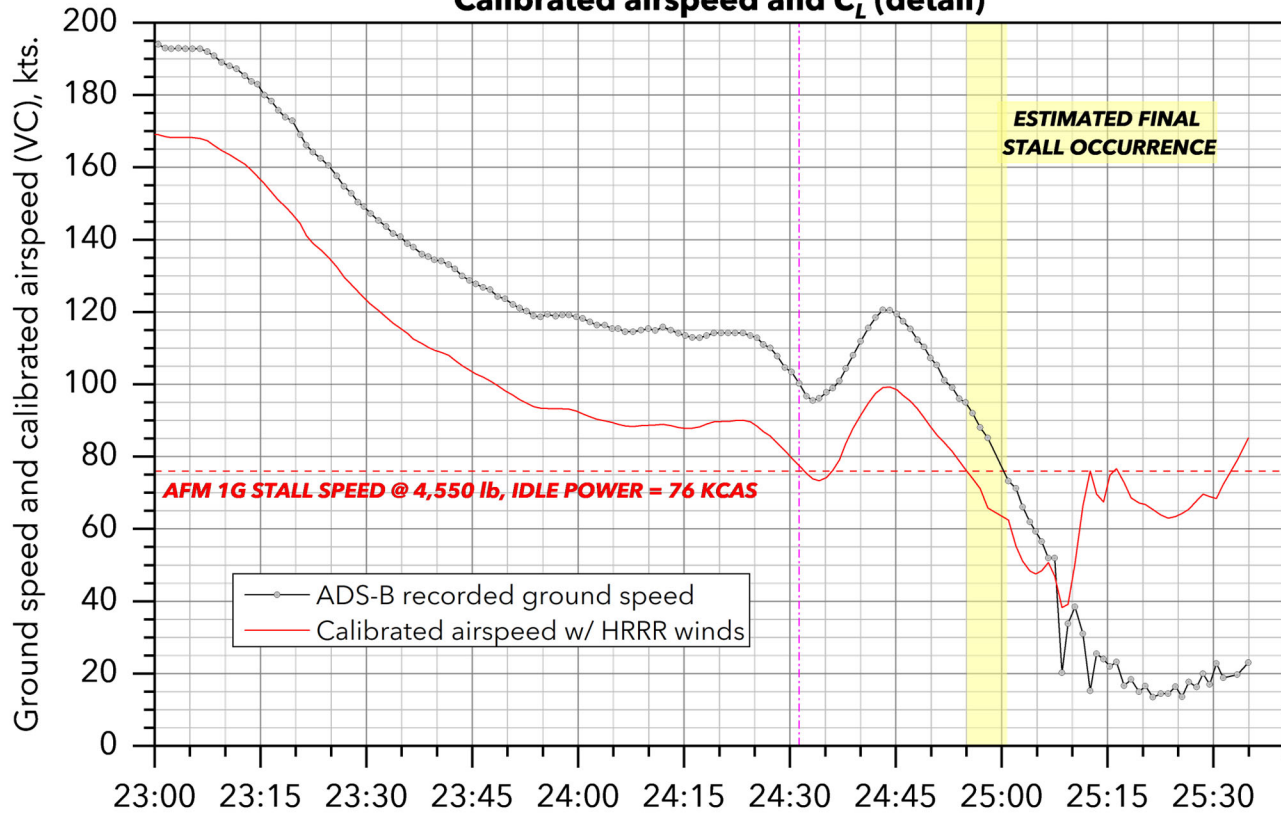


Figure 11b.

ERA24FA088: Beech 95-B55, N7345R, Leyden, MA 01/14/2024

Thrust and power

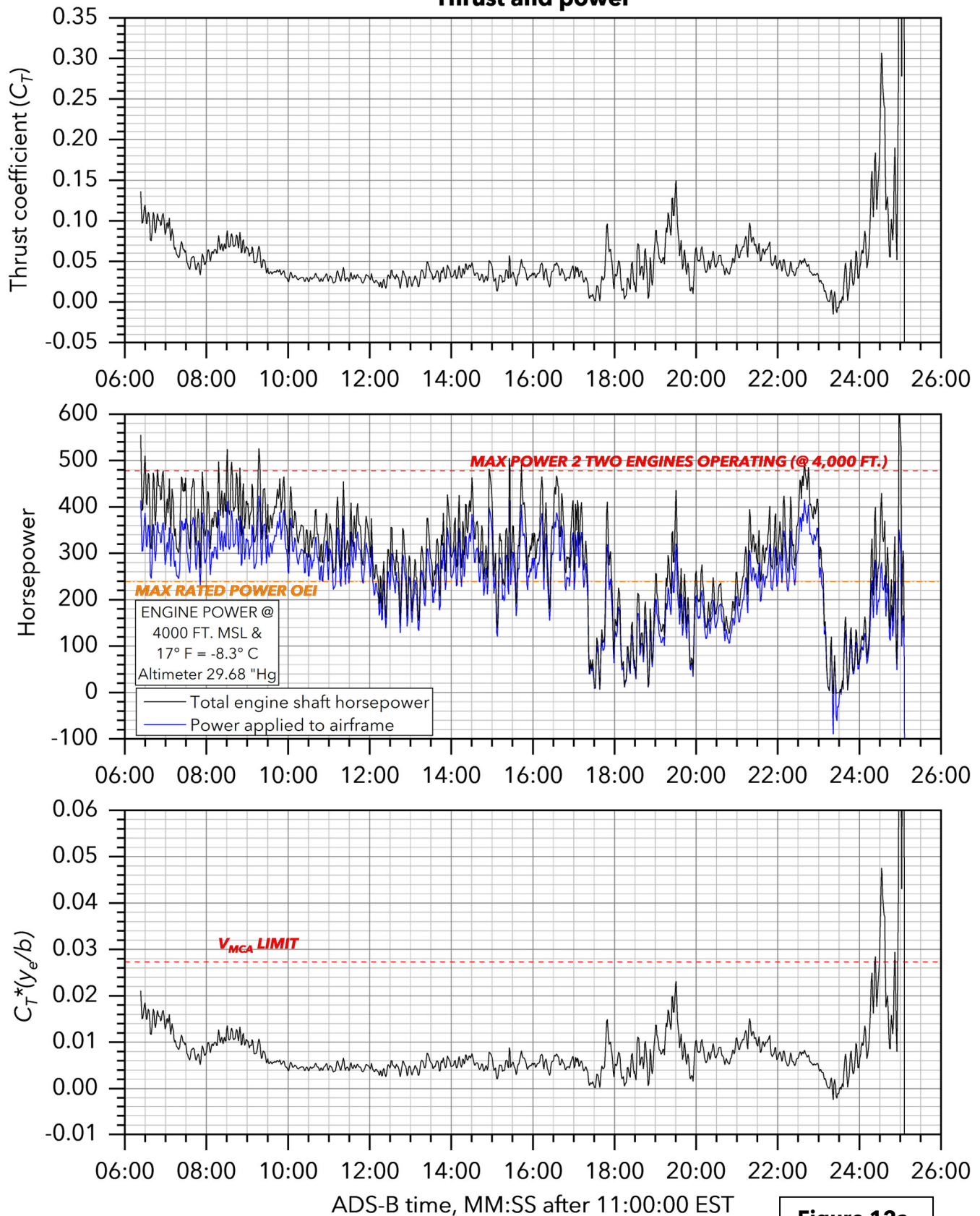


Figure 12a.

ERA24FA088: Beech 95-B55, N7345R, Leyden, MA 01/14/2024

Thrust and power (detail)

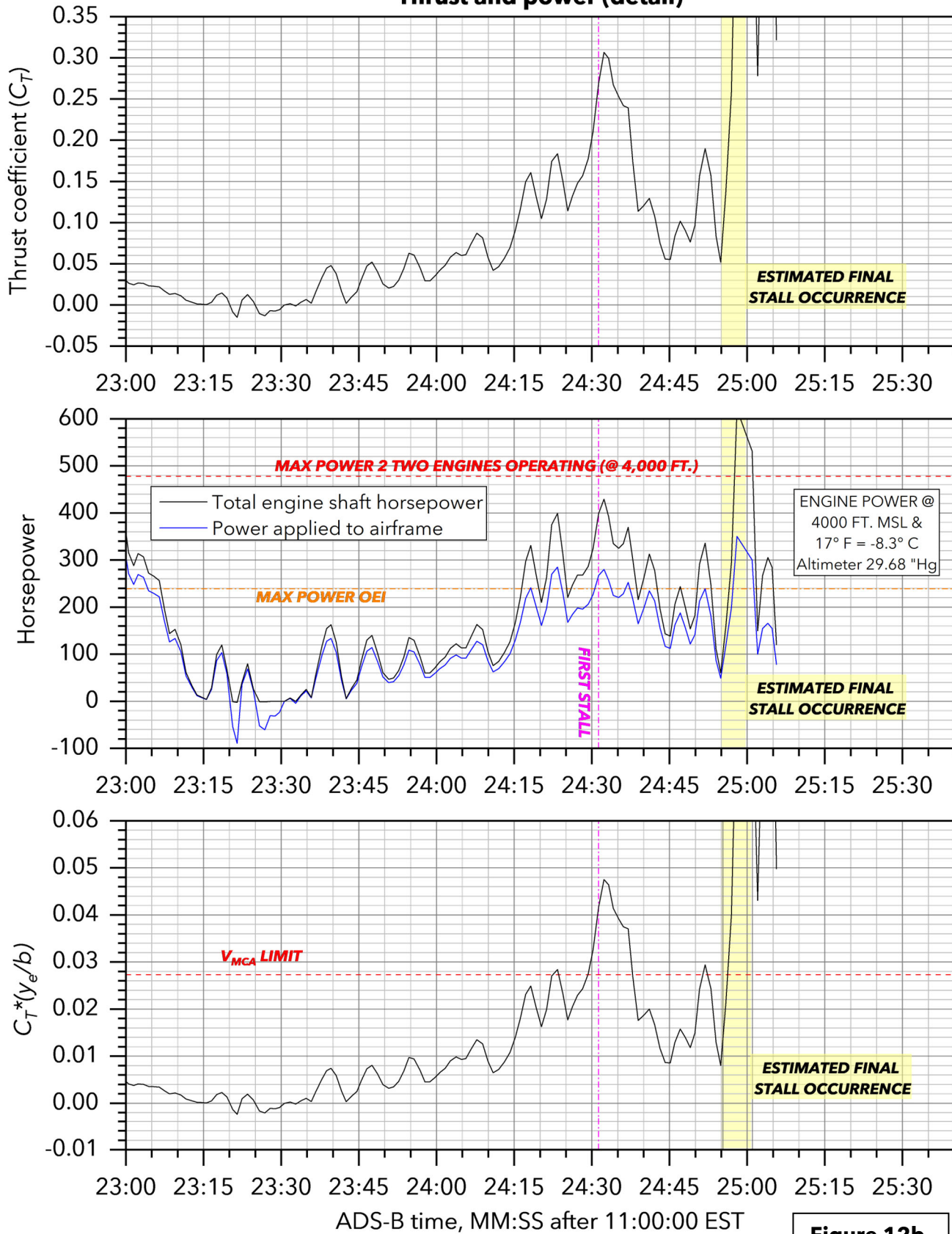


Figure 12b.