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AIRCRAFT PERFORMANCE STUDY

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A. ACCIDENT

Location: Heyburn, Idaho
Date: April 13, 2022
Time: 08:32 Mountain Daylight Time (MDT)
14:32 Coordinated Universal Time (UTC)
Airplane: Cessna 208B, registration N928JP

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 April 13, 2022, about 08:32 MDT,¹ a Cessna 208B Grand Caravan, N928JP, was destroyed after impacting an exhaust stack in Heyburn, Idaho while on approach to the Burley Municipal Airport in Burley, Idaho (KBYI). The pilot was fatally injured. The airplane was operated by Gem Air, LLC as a Title 14 *Code of Federal Regulations* Part 135 cargo flight. According to the operator, the pilot was transporting cargo on an instrument flight rules (IFR) flight from the Salt Lake City International Airport (KSLC), Salt Lake City, Utah, to KBYI.

A review of air traffic control (ATC) communication with the pilot revealed the approach controller issued the pilot the current altimeter setting and verified that the pilot had the current weather and notices to airmen reports for KBYI. Subsequently, the controller cleared the pilot for the RNAV runway 20 approach via the MALTT transition at KBYI (see Figure 1). The pilot reported passing the initial approach fix, and about 4 minutes later reported a missed approach (surveillance video at KBYI shows the airplane flying low over the runway at 08:12:23). The controller then instructed the pilot to execute the published missed approach procedure and to report established (in the hold) at IREME, and to expect the same approach.

After the pilot reported established at IREME, the controller cleared the pilot for the approach. About 1 minute later, the controller asked the pilot if she had crossed the initial approach fix. The pilot initially replied negative, then subsequently replied that

¹ All times in this *Study* are in MDT unless noted otherwise. MDT = UTC - 6 hours.

she had crossed the fix. The controller then approved a change to the KBYI advisory frequency.

Video footage recovered from a security camera located on a processing plant revealed a view of the rooftop of the processing plant, along with an exhaust stack supported by steel framework on the roof. Snow was observed falling. About 08:32:25, the airplane came into view in a wings-level, nose-high descent. The airplane struck the exhaust stack at 08:32:26.6 and fell to the rooftop.

According to a witness located about one quarter mile away, he first heard, then observed the airplane descend out of the clouds then immediately go into a steam cloud, which was produced from a set of six exhaust stacks located on the same roof. The witness heard the engine increase in sound and saw the nose lift shortly before the airplane struck the exhaust stack and descend to the rooftop.

The airplane came to rest on its right side. Both wings, the propeller assembly, belly pod, and the nose wheel separated from the fuselage. All major components of the airplane remained on the rooftop. First responders recovered about 40 gallons of jet fuel which had spilled from both wings.

A KBYI special automated weather report 8 minutes after the accident reported 2.5 mile visibility in light snow, broken layer at 3,000 ft above ground level (AGL), overcast at 4,700 ft AGL, temperature -3°C, dew point temperature -6°C, barometric pressure 29.97 inches of mercury. An Airmen's Meteorological Information (AIRMET) advisory was active for icing and mountain obscurations for areas that included KBYI.

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 portions of the flight, and determine the airplane's response to control inputs, external disturbances, ground forces, and other factors that could have affected its trajectory.

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

- Automatic Dependent Surveillance - Broadcast (ADS-B) data.
- Air Traffic Control (ATC) communications.
- Surveillance video recordings.
- Wreckage location and condition.
- Weather information.
- Airplane performance information in the Airplane Flight Manual.

- Supplemental performance information obtained from simulation.

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 control inputs, engine power, speed, and acceleration of the airplane during its two approaches to KBYI runway 20 could not be determined with precision. However, the airplane's altitude, position, and airspeed during the initial portions of its two approaches to KBYI runway 20 could be computed from ADS-B and winds aloft data. No ADS-B data was available for the airplane below an altitude of about 4,800 ft. MSL (660 ft. AGL), but surveillance video from the accident site provides the altitude and time of impact with the exhaust stack, which allows the airplane's speed and flight path between the last ADS-B point and the impact point to be estimated. Similarly, the speed and flight path between the last ADS-B point and the airplane's pass over the runway during the first (missed) approach can be estimated from timing information obtained from surveillance video at KBYI.

Simulator matches of the trajectories constructed based on the ADS-B and surveillance video information indicates that the estimated trajectories for the portions of the flight where ADS-B data is unavailable are feasible, and provide estimates of additional performance parameters, such as engine power, during the approaches. The airplane position and attitude parameters derived from the accident approach trajectory are also used to estimate the visibility of the exhaust stack from the cockpit during that approach.

C.3. Summary of results

In this *Study*, N928JP's two approaches to KBYI runway 20 are considered separately, and then compared.

C.3.1. First approach to KBYI runway 20

N928JP contacted the Twin Falls ATC Tower (Twin Falls Approach) at 07:53:08, while 23.7 nm southeast of KBYI and level at 12,000 ft. Twin Falls Approach told N928JP to "expect [the] RNAV runway 20 to Burley and report 10 miles from [the] MALTT [waypoint]." N928JP reported 10 miles from MALTT at 07:56:45, and ATC cleared the airplane for the KBYI RNAV runway 20 approach "via the MALTT transition at MUTOE."

N928JP reported passing the MALTT and MUTOE waypoints along the published approach, and at 08:07:27 and 7,000 ft. reported at IREME, the Intermediate Fix (IF) for the approach (see Figure 2). ATC provided N928JP with instructions for cancelling the flight's Instrument Flight Rules (IFR) flight plan, and at 08:08:08 cleared N928JP to switch to the KBYI airport advisory frequency.

After turning onto the final approach course at IREME, N928JP maintained about 7,000 ft. indicated altitude until 08:08:30, about 2.5 nm past IREME and about 8.5 nm from the runway 20 displaced threshold. The airplane then began to descend at about 200 ft./min. (fpm) until about 08:09:30 and 6,800 ft. indicated altitude, where the airplane intercepted a 3.75° glide slope to runway 20 about 6 nm from the threshold. During this initial descent, the airspeed was between about 128 and 132 knots calibrated airspeed (KCAS).

After 08:09:30, N928JP remained approximately on the 3.75° glide slope, while the rate of descent increased to between 1,000 and 1,100 fpm, and the airspeed increased, peaking at about 156 KCAS at 08:10:40. The airspeed then started to decrease continuously, reaching 141 KCAS as the airplane descended below ADS-B coverage² at about 08:11:27 and 4,800 ft. MSL (660 ft. AGL) near the JAMID waypoint (1.6 nm from the displaced threshold). Between 08:10:55 and 08:11:27, the rate of descent decreased from about 1,100 to about 960 fpm.

There is no recorded ADS-B data for N928JP between 08:11:27 and 08:13:17, and so the position, speed, and rate of climb of the airplane are not known during this time. The airplane climbed back into ADS-B coverage at 08:13:17 following its missed approach, and remained in ADS-B coverage until descending below it at 08:31:41 during the accident approach.

At 08:12:23, a surveillance video at KBYI recorded the airplane flying level with the flaps up past a point about 2,328 ft. from the runway 20 displaced threshold. The airplane's ground speed at this time, based on an analysis of the video, is about 91 knots, and the airplane appears to be about 20 ft. above the runway.

As described below, the airplane's position, altitude, and speed between 08:11:27 and 08:12:23 is estimated based on the known values of these parameters at these endpoints, and on assumptions of one value of constant deceleration during the descent, and second value of constant deceleration during the flight above the runway. The airplane is also assumed to remain on the 3.75° glide slope during the descent, and to level off at the displaced threshold. Based on these assumptions, the airplane reached the displaced threshold at about 08:12:12 with a ground speed of about 115 knots. A simulation of the approach indicates that these assumptions are feasible.

N928JP contacted ATC at 08:13:56 and reported executing a missed approach, and ATC instructed the pilot to execute the published missed approach procedure.

² Here, "ADS-B coverage" refers to the recording of ADS-B data transmitted by N928JP by FAA ADS-B ground stations, which must have an unobstructed line-of-sight to the airplane to receive its ADS-B transmissions. At a low enough altitude, the line-of-sight from the ground stations to the airplane will be obscured by terrain and / or other obstructions, and ADS-B reception from the airplane will be lost.

C.3.2. Accident approach to KBYI runway 20

After N928JP declared a missed approach, ATC asked the pilot to state her subsequent intentions. The pilot responded that she would like to attempt the approach again, and ATC instructed her to report established in the hold at IREME (consistent with the published missed approach procedure) and to expect the RNAV runway 20 approach.

At 08:19:46 N928JP reported established in the hold at IREME. ADS-B data indicates that at that time the airplane was at 6,921 ft. MSL on a track of 25° true, on the outbound leg of the hold (see Figure 3)³. ATC cleared the pilot for the RNAV runway 20 approach, and instructed her to cross IREME inbound at 7,000 ft., and to report crossing IREME inbound. N928JP reported crossing IREME inbound at 08:26:33. ADS-B data indicates that at the time N928JP was about 0.8 nm northeast of IREME, level at 6,945 ft. MSL, and on a track of 218° true and ground speed of 122 knots.

N928JP started an approximately 120 fpm descent at about 08:27:30, about 10 nm from the runway 20 displaced threshold (and 1 nm past IREME). At 08:28:30, about 8 nm from the displaced threshold, the rate of descent increased to about 500 fpm. Between 08:28:25 and 08:30:05, the computed calibrated airspeed increased from about 114 KCAS to about 134 KCAS as the airplane descended from about 6,830 ft. MSL to about 6,000 ft. MSL.

At 08:30:10, at about 6,000 ft. MSL and 4.5 nm from the displaced threshold, N928JP intercepted the 3.75° glide path to the runway. The rate of descent then decreased momentarily to zero before increasing again to about 900 fpm, resulting in the airplane deviating above the 3.75° glide path, and then descending back towards it. N928JP intercepted the 3.75° glide path at 08:31:12, about 2.4 nm from the displaced threshold, and remained approximately on that glide path until reaching the JAMID waypoint at 08:31:36 (1.6 nm from the displaced threshold), after which ADS-B data was not recorded (because the airplane descended below ADS-B coverage). Between 08:30:10 and 08:31:36, the computed calibrated airspeed decreased from 133 KCAS to 100 KCAS. The last ADS-B point was recorded at 08:32:17; at that point, N928JP was 0.6 nm from the displaced threshold at about 4,387 ft. MSL (245 ft. above the displaced threshold), on the nominal 3.75° glide path to the runway, at an estimated calibrated airspeed of about 85 KCAS.

As during the first approach, there is no recorded ADS-B data for N928JP after the airplane passed JAMID, and so the position, speed, and rate of climb of the airplane are not known after this time. However, a surveillance video at the impact site recorded

³ 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 airplane impacting the exhaust stack. Consequently, the time (08:32:26.6), altitude (4,242 ft. MSL) and location (2,632 ft. / 0.43 nm from the displaced threshold) of the impact are known. As described in more detail below, the state of the airplane at the last ADS-B point, and the location and time of the impact as recorded by the video, can be used to estimate the state of the airplane in between the last ADS-B point and the impact point. The estimated trajectory has N928JP descending below the nominal 3.75° glide slope to the runway after passing JAMID, and impacting the exhaust stack at an airspeed of about 84 KCAS. A simulation of the accident approach indicates that this estimated trajectory is feasible. The pitch angle computed from the ADS-B data and estimated trajectory indicates that it is unlikely that the pilot could have seen the exhaust stack over the nose of the airplane until just before impact.

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 Cessna 208B Grand Caravan airplane

The Cessna 208B Grand Caravan (C208B) is a fixed-gear, high-wing airplane powered by a 675 SHP Pratt and Whitney PT6A-114A turboprop engine, with a maximum ramp weight of 8,785 lbs. N928JP, serial #208B2428, was manufactured in 2013 (per FAA registration records), and was configured with seating for the pilot and co-pilot. The aft portion of the cabin was configured for cargo. N928JP was also configured with a belly cargo pod.

Figure 4 is a pre-accident photograph of N928JP. Figure 5 shows a three-view diagram of the C208B, taken from Reference 1. Table 1 provides some dimensions of the airplane, as well as the estimated weight of N928JP at the times of the first and accident approaches (8,085 lb. and 7,968 lb., respectively).

Item	Value
Wing area	279.4 ft. ²
Wing span	52.08 ft. (see Figure 5)
Weight at departure from KSLC	8,512 lb. (as estimated by Textron per Ref. 2)
Fuel burn from takeoff to first approach	427 lb. (1.18 hrs @ 363 lb./hr.)
Weight estimate for first approach	8,085 lb.
Fuel burn between first approach and accident	117 lb. (0.33 hrs @ 350 lb./hr.)
Weight estimate for accident approach	7,968 lb.

Table 1. Cessna 208B dimensions and N928JP weight estimates.

Information about the airplane's aerodynamic characteristics, such as the lift coefficient (C_L) as a function of angle of attack (α), are needed to estimate the airplane's Euler angles (pitch roll, and heading) throughout the flight (the Euler angles are needed to evaluate the visibility of the exhaust stack from the cockpit). For this *Study*, the aerodynamic characteristics for the C208B were extracted from the NTSB's engineering simulation model of the C208B. The simulation model, and simulation matches of N928JP's two approaches to KBYI, are described in Section D.8.

During an investigation of a mid-air collision involving a C208B in 2016, the NTSB measured the interior and exterior geometry of an exemplar C208B using a laser scanner (see Reference 3). These measurements are used in this *Study* to estimate the visibility of the exhaust stack from the cockpit, as described in Section D.12.

D.2. Impact site

Figure 6 depicts several frames from a surveillance video taken from a potato processing plant that recorded N928JP flying through wisps of cloud or steam and impacting the exhaust stack mounted on the roof of the plant. The last frame shows N928JP contacting the stack at 08:32:26.6.

The elevation of the processing plant and the height of six of the plant's exhaust stacks ("drum" stacks) above the ground were measured during a survey requested by the NTSB. The latitude and longitude of the exhaust stack impacted by N928JP (the "agglomerator stack") was determined from satellite imagery of the plant in *Google Earth*. An "aeronautical study" of the potato plant exhaust stacks conducted by the FAA in 2016 indicates that the drum stacks and the agglomerator stacks are the same height, and the elevations and heights noted in the FAA study are consistent (within 2 ft.) with the results of the survey requested by the NTSB.

Based on this information, the location and height of the agglomerator stack struck by N928JP are as listed in Table 2:

Item	Value
Latitude	N 42° 33' 05.96"
Longitude	W 113° 45' 34.61"
KBYI runway 20 x coordinate (see definition below)	-2,632 ft. (-0.4332 nm)
Ground elevation	4,156 ft. MSL
Rooftop elevation:	4,190 ft. MSL
Height of stack above ground	100 ft.
Elevation of top of stack	4,256 ft. MSL
Elevation of impact point (see below)	4,242 ft. MSL
Time of impact	08:32:26.6 MDT

Table 2. Coordinates of impact site.

Based on Figure 6c, N928JP struck the agglomerator stack at a point about 78% of its height above the rooftop, corresponding to an elevation of 4,242 ft. MSL, or 86 ft. AGL. In this *Study*, it is convenient to express the position of N928JP during its approaches to KBYI runway 20 in terms of runway axes aligned with runway 20. The runway 20 *x* axis originates at the displaced threshold and extends down the runway (southwest) to the threshold of runway 2. The runway 20 *y* axis originates at the displaced threshold and extends to the right (northwest) normal to the centerline of the runway. To convert latitude and longitude coordinates into runway coordinates, the latitude, longitude, and elevation of the runway coordinates origin (the displaced threshold) are required, as well as the true bearing of the runway. These items are listed in Table 3.

Item	Value
Latitude	N 42° 32' 45.26"
Longitude	W 113° 45' 55.86"
Elevation	4,142 ft. MSL
True bearing	217.3°

Table 3. Coordinates of KBYI runway 20 displaced threshold (origin of the runway axes system).

Figure 7 depicts a profile view of the position of the agglomerator stack relative to runway 20, and several dimensions of interest. Of note, a 3.75° glide path to the displaced threshold would clear the agglomerator stack by about 98 ft.

D.3. ADS-B data

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.⁴ ADS-B data broadcast from N928JP during its approaches to KBYI runway 20 was received and recorded by Federal Aviation Administration (FAA) ADS-B ground stations while the airplane was in ADS-B coverage (above about 4,800 ft. MSL or 660 ft. AGL). No ADS-B data was received from the airplane below this altitude.

ADS-B latitude and longitude are determined using Global Navigation Satellite System (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 4). 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.

⁴ For more information about ADS-B, see https://www.faa.gov/air_traffic/technology/adsb.

The recorded ADS-B data includes the following parameters:

- UTC time of the ADS-B report, in hours, minutes, and seconds.
- 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.⁵ In this *Study*, GNSS altitudes are corrected to MSL altitude by adding 46 ft.⁶
- 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 where N928JP is at altitude (above about 5,400 ft. MSL) is about 1 second. Below 5,400 ft., gaps in the ADS-B returns start to appear, and some of the ADS-B messages become incomplete (e.g., altitude and / or ground speed are missing and are recorded as zero). Because the ADS-B ground stations rely on radio line-of-sight to the airplane to receive data broadcasts from the airplane, they will not receive data once the line-of-sight becomes obscured by terrain or other obstructions. The last complete ADS-B record from N928JP on the accident approach was received at 08:31:41, 1.49 nm from the runway 20 displaced threshold, at an altitude of 4,796 ft. MSL, ground speed of 100 knots, and rate of descent of 512 fpm. The last ADS-B record from N928JP (containing position and rate of descent information but no altitude or ground speed information) was received at 08:32:17, 0.64 nm from the displaced threshold, at a descent rate of 512 fpm.

The ADS-B data is presented in several Figures and discussed throughout the *Study*. To convert the ADS-B latitude and longitude coordinates to the runway x and y coordinates defined above, latitude and longitude are first transformed into east and north coordinates from the threshold using the WGS84 ellipsoid model of the earth, and the coordinates of the runway 20 displaced threshold listed in Table 3.

The east / north coordinates are then transformed into runway x and y coordinates by rotating them through the true heading of runway 20 (217.3°).

⁵ "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.)

⁶ Per <https://geographiclib.sourceforge.io/cgi-bin/GeoidEval>, the geoid at the accident site is 14 m (46 ft.) below the surface of the WGS84 ellipsoid.

D.4. Surveillance video data

As described above, surveillance video from a camera mounted to an outside wall of the potato processing plant struck by N928JP recorded the airplane's approach to and impact with the agglomerator exhaust stack on the roof of the plant, providing the time and location of the impact (see Table 2). During the investigation, the time stamp recorded in the surveillance video was confirmed to be synchronized with the GNSS time stamp associated with the ADS-B data by taking a photograph of the security camera video display together with a mobile phone displaying the official GNSS time from the U. S. Naval Observatory at www.time.gov (see Figure 8a). As shown in the Figure, the time shown in the security camera image is the same as that displayed on the phone.

N928JP's first approach to KBYI runway 20 is also of interest, since on this approach the airplane overflowed the potato plant exhaust stacks successfully. Surveillance video from a camera at the airport captured the airplane making a low pass over runway 20, and this recording is used in this *Study* to determine the airplane's ground speed and position at a particular time in the video. This information is then used to estimate the airplane's trajectory and performance from the last ADS-B position recorded on the first approach to the time that the airplane passed through the field of view of the airport camera. The airplane's performance on the first approach can be compared to its performance on the second approach, which might reveal key differences between the conduct of each approach. The time stamp of the airport video was confirmed to be aligned with the ADS-B GNSS time using the same method that was used for the potato plant video. Figure 8b shows that the time displayed by the airport video is aligned with the U.S. Naval Observatory time. Figure 9 depicts selected frames from the KBYI surveillance video.

The location and ground speed of N928JP at 08:12:23 as determined from the airport video is presented in Table 4. The ground speed was estimated by triangulating the position of the airplane over the runway at two different times, and dividing the distance between these positions by the difference in time.

Item	Value
Time	08:12:23.19 MDT
Runway x coordinate	2,328 ft.
Ground speed	91 knots
Height above runway (estimate)	20 ft.
Altitude	4,162 ft.

Table 4. Position and speed of N928JP during low pass over runway 20, as determined from video.

D.5. Meteorological data

The NTSB *Meteorology Specialist's Factual Report* (Reference 5) presents meteorological data for this accident, collected from official National Weather Service sources. Items in Reference 5 most relevant to this *Study* are the altimeter setting, static temperature, visibility, ceiling, winds, and precipitation at KBYI and on the approach to runway 20 during the time N928JP was in the area. This information is provided to aviators for flight planning through Aviation Routine Weather Reports (METAR) and Aviation Select Special Weather Reports (SPECI)⁷, and in the air via Automatic Terminal Information System (ATIS) broadcasts over VHF frequencies. The data for KBYI in these reports is recorded by the Automated Surface Observation System (ASOS) located at the airport.

The METAR and SPECI reports for KBYI at the times surrounding the accident are duplicated here in Table 5.

Report Type Time (MDT)	METAR 07:53	SPECI 08:01	SPECI 08:10	SPECI 08:40
Wind direction (°true)	200	200	190	210
Wind speed (knots)	6	8	8	8
Visibility (statute miles)	7	2.5	1	2.5
Present weather ⁸	Light snow	Light snow Mist	Light snow Mist	Light snow
Sky condition (ft. AGL)	1,900 few 2,400 broken 3,300 overcast	2,600 broken 3,300 overcast	2,300 broken 2,800 overcast	3,000 broken 4,700 overcast
Temperature (°C)	-3	-3	-3	-3
Dew point (°C)	-6	-5	-5	-6
Altimeter setting ("Hg)	29.96	29.96	29.96	29.97
Precipitation (inches) ⁹	< 0.01	< 0.01	< 0.01	< 0.01

Table 5. METAR and SPECI reports based on KBYI ASOS data, from Reference 5. N928JP reported a missed approach at 08:13:56 and impacted the exhaust stack at 08:32:27.

Reference 5 also presents winds-aloft data for the KBYI area at 09:00 MDT based on a High Resolution Rapid Refresh (HRRR) numerical model retrieved from the National Oceanic and Atmospheric Administration (NOAA) Air Resources Laboratory. Table 6 presents the HRRR model wind speed, wind direction, and static air temperature up to an altitude of 8,000 ft. MSL (covering the approach segment from IREME to the runway).

⁷ Per Reference 6, "METAR is the primary observation code used in the United States to satisfy requirements for reporting surface meteorological data," and a SPECI is an unscheduled report taken when certain criteria (defined in Reference 6), such as wind shifts or low visibility, are observed.

⁸ Per Reference 6, the intensity of snow is based on the reported surface visibility. "Light" snow corresponds to visibility > 0.5 statute mile.

⁹ The recorded precipitation is that accumulated since the previous hourly METAR report was issued.

Altitude (ft. MSL)	Wind speed (knots)	Wind direction (°true)	Air temperature (°C)
4147	8	210	-3.0
4207	10	211	-3.3
4357	11	212	-3.8
4599	11	214	-4.6
4965	12	219	-5.7
5428	13	226	-7.1
5992	12	230	-8.3
6597	10	235	-9.8
7280	10	245	-11.0
8045	11	253	-12.8

Table 6. HRRR model of winds aloft at KBYI, from Reference 5. In this table, the HRRR wind is increased by 1 knot and the wind direction reduced by 12° to match the KBYI SPECI report at 8:40 MDT.

D.6. Air Traffic Control (ATC) communications

The FAA provided the NTSB with an audio recording of the radio communications between ATC and N928JP in file “Distribution N928JP - Certified Working copy.wav,” available in the public docket for this accident. The author of this *Study* created a transcript of these communications from this file, as shown in Table 7a. Tables 7b and 7c are subsets of Table 7a that contain selected communications during N928JP’s first and accident approaches to runway 20, respectively. The “plot content” items in Tables 7b and 7c are also depicted in Figures 2 and 3, indicating the position of N928JP at the times they occurred.

Time MDT	Source	Full Content
07:53:08	N928JP	Twin Falls Approach N928JP 12,000
07:53:16	TFATCT	N928JP Twin Falls Approach altimeter 29.97 verify you have Burley weather and NOTAM ¹⁰
07:53:25	N928JP	9.97 we have the weather and NOTAM N928JP
07:54:27	TFATCT	N8JP expect RNAV runway 20 to Burley and report 10 miles from MALTT
07:54:38	N928JP	OK expect RNAV 20 and we'll report 10 miles from MALTT 8JP
07:56:45	N928JP	Approach N8JP is 10 miles from MALTT
07:57:03	TFATCT	N8JP roger after MALTT ... correction your cleared via ... cleared to RNAV runway 20 via the MALTT transition at MUTOE. Cleared approach, report MALTT.
07:57:17	N928JP	OK we are cleared to RNAV 20 from MALT, MUTOE for 928JP
07:57:56	TFATCT	N8JP report MALTT
07:57:59	N928JP	Report MALTT 8JP

Table 7a. Transcript of communications between the Twin Falls Air Traffic Control Tower non-radar approach position (TFATCT) and N928JP (continued on next page).

¹⁰ Per Reference 2, prior to the accident, the FAA had published Notice to Air Mission (NOTAM) flight data center (FDC) 2/5029 that included the following information:
DELETE NOTE: VGS1 AND DESCENT ANGLES NOT COINCIDENT (VGS1 ANGLE 3.00/TCH 37).

Time MDT	Source	Full Content
08:01:30	N928JP	Falls approach N928JP MALTT
08:01:34	TFATCT	N8JP roger report MUTOE, say altitude leaving
08:01:39	N928JP	Report MUTOE ... one zero thousand eight hundred 8JP
08:05:58	N928JP	Falls Approach Caravan 8JP is [?]
08:07:22	N928JP	Falls Approach Caravan 928JP is now IREME
08:07:27	TFATCT	N928JP report IFR cancellation in the air on this frequency or on the ground with flight services or with Twin Falls Tower ... and verify you have Twin Falls Tower's phone number
08:07:41	N928JP	I don't have their phone number could you give that to me 8JP?
08:07:45	TFATCT	8JP Twin Falls Tower phone number is 208-734-7160 extension 211
08:07:54	N928JP	What was that for 734 8JP
08:07:57	TFATCT	8JP that's 7160 extension 211
08:08:03	N928JP	208-734-7160-211 8JP thanks
08:08:08	TFATCT	8JP change to advisory frequency approved
08:08:12	N928JP	Frequency approved 8JP
08:13:56	N928JP	Falls Approach Caravan 928JP is going missed
08:14:08	TFATCT	N8JP say altitude
08:14:12	N928JP	5000 feet 8JP
08:14:19	TFATCT	98JP execute published missed approach
08:14:22	N928JP	[?] missed approach 8JP
08:15:30	TFATCT	N8JP report established at IREME
08:15:34	N928JP	Report established at IREME 8JP
08:15:38	TFATCT	N8JP say intentions after the missed
08:15:42	N928JP	I would like to just shoot that same approach again 8JP
08:15:52	TFATCT	N8JP roger report established in the hold at IREME and you can expect the RNAV runway 20
08:15:58	N928JP	OK we'll expect 20 and we'll let you know when we're established in the hold 8JP
08:19:46	N928JP	Falls Approach Caravan 928JP established in the hold at IREME
08:19:52	TFATCT	N8JP cross IREME at 7000 cleared straight in RNAV runway 20 approach report IREME
08:20:00	N928JP	OK we'll cross IREME 7000 cleared for the ILS 20 in ... I'm sorry not the ILS the RNAV 20 into Burley
08:24:17	TFATCT	N8JP report IFR cancellation in the air or on the ground correction in the air on this frequency or on the ground with Twin Falls Tower
08:24:27	N928JP	'K we'll report either with you or with Twin Falls Tower on the ground 8JP
08:24:31	TFATCT	N8JP did you cross IREME?
08:24:34	N928JP	Negative, not yet 8JP
08:24:36	TFATCT	Roger
08:26:33	N928JP	Twin Falls Approach Caravan 8JP is at IREME
08:26:47	TFATCT	N8JP say altitude
08:26:50	N928JP	[?] thousand 8JP
08:26:55	TFATCT	8JP roger ... change to advisory frequency approved
08:27:00	N928JP	[?] change approved 8JP

Table 7a (concluded). Transcript of communications between the Twin Falls Air Traffic Control Tower non-radar approach position (TFATCT) and N928JP. For brevity, spoken numbers and letters from the phonetic alphabet are depicted as their single-character symbols (e.g., "eight" is depicted as "8," and "November" as "N").

Time MDT	Source	Full Content	Plot Content
08:05:58	N928JP	Falls Approach Caravan 8JP is [?]	[N928JP] @ [?MUTOE?]
08:07:22	N928JP	Falls Approach Caravan 928JP is now IREME	[N928JP] @ IREME
08:08:08	TFATCT	8JP change to advisory frequency approved	[TFATCT] freq chg aprvd
08:13:56	N928JP	Falls Approach Caravan 928JP is going missed	[N928JP] going missed
08:15:30	TFATCT	N8JP report established at IREME	[TFATCT] report IREME
08:19:46	N928JP	Falls Approach Caravan 928JP established in the hold at IREME	[N928JP] in hold

Table 7b. Transcript of selected communications between the Twin Falls Air Traffic Control Tower non-radar approach position (TFATCT) and N928JP during the first approach to KBYI.

Time MDT	Source	Full Content	Plot Content
08:24:31	TFATCT	N8JP did you cross IREME?	[TFATCT] crossed IREME?
08:26:33	N928JP	Twin Falls Approach Caravan 8JP is at IREME	[N928JP] @ IREME
08:26:55	TFATCT	8JP roger ... change to advisory frequency approved	[TFATCT] freq chg aprvd

Table 7c. Transcript of selected communications between the Twin Falls Air Traffic Control Tower non-radar approach position (TFATCT) and N928JP during the accident approach to KBYI.

D.7. Estimates of airplane performance based on ADS-B and video data

Airplane performance parameters of interest for both of N928JP's approaches to KBYI runway 20 include the airplane's position and altitude, flight path angle, airspeed, ground speed, and rate of descent. These parameters can be compared to the expected trajectory depicted by the RNAV (GPS) runway 20 approach plate (Figure 1), and to the operational approach procedures provided by the operator (Gem Air). In addition, the pitch angle of the airplane, and corresponding visibility over the nose, is of interest, in order to determine whether the exhaust stack would have been visible to the pilot before it was struck. These performance parameters can be computed from the recorded ADS-B data (where available) and winds aloft. Below ADS-B coverage, the performance parameters can be estimated such that they match the both the last available ADS-B points during each approach, and the time and position information gleaned from the video recordings at KBYI and at the potato plant. In addition, Section D.8 describes engineering simulations of the airplane's two approaches that confirm the feasibility of the trajectories computed from the ADS-B data and estimated from the video information.

D.7.1. Performance estimates based on ADS-B and winds aloft data

If the position (latitude, longitude, and altitude) of an airplane is known as a function of time, then its velocity relative to the Earth can be computed. The airplane velocity relative to the air mass can also be computed if the motion of the air mass relative to the Earth (i.e., the wind) is known. Finally, the airplane's pitch (θ), roll (ϕ), and heading (ψ) angles (i.e., the Euler angles) can be estimated as long as the following are true:

- 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 (i.e., coordinated flight).

The following information is used in the performance calculations presented here:

- N928JP's position and altitude from ADS-B data where available, and estimates of position and altitude consistent with surveillance video information where ADS-B data is not available (see below).
- Winds aloft from the HRRR model as presented in Table 6.
- The C208B flaps-up lift curve (C_L vs. α) extracted from the NTSB's simulation model of the C208B (the surveillance videos from the potato plant and KBYI airport indicate that the N928JP's flaps were up during both approaches).
- Gross weights of 8,085 lb. and 7,968 lb. during the first and accident approaches to runway 20, respectively (see Table 1).

The recorded ADS-B positions are GNSS-based and very accurate, but still contain some error or uncertainty. This uncertainty, combined with the relatively high sample rate of the data (1 Hz), results in spurious "noise," or unrealistic spikes and variations, in the ground speed computed from the ADS-B positions (see Figures 19 & 20). If not removed or otherwise corrected, the noise in the computed ground speed propagates into all the other performance calculations.

As noted above, the north-south and east-west components of ground speed, as computed by on-board avionics, are included in the ADS-B messages. These speed components are very smooth and can be combined to produce a smooth total ground speed. They can also be integrated over time to produce "smooth" positions. While in general the positions obtained in this way do not match the recorded ADS-B positions perfectly, in this case the agreement is very good, and no further corrections or adjustments to the integrated positions are required. These integrated positions are used as the basis for ground speed and other performance calculations.

Similarly, the ADS-B data includes both pressure and geometric altitudes, and rate of climb. The altitudes are recorded to the nearest 25 ft., and computing the rate of climb from these data produces noisy results. A "smooth" altitude can be computed by integrating the recorded rate of climb data.

The results of the ADS-B based performance calculations are presented in Figures 2, 3 and 10-25. Figures 2 and 10-15 correspond to the first approach to KBYI, and Figures 3 and 16-22 correspond to the accident approach. The simulation "target tracks"

shown in Figures 2, 3, 10 and 16 are the results of integrating the recorded ADS-B north and east ground speed components, as described above. The square symbols in these plots are the recorded ADS-B positions. Figures 2 and 3 provide plan views of N928JP's position relative to the KBYI runway 20 displaced threshold, and Figures 10 and 16 plot the airplane's north and east coordinates relative to the displaced threshold as a function of time. The excellent agreement between the integrated and recorded positions is evident in these Figures. In the area where N928JP is below ADS-B coverage, the "target tracks" are based on the last ADS-B point and information obtained from the security videos, as described below.

Figures 11 and 17 plot N928JP's altitude vs. time during the first and accident approaches, and Figures 12 and 18 plot altitude vs. the runway 20 x coordinate during the two approaches. The ADS-B pressure altitudes have 37 ft. added to them to account for an altimeter setting of 29.96" Hg (the result is indicated altitude in ft. MSL). In addition, 46 ft. have been added to the ADS-B GNSS altitudes to account for the height of the geoid above the WGS84 ellipsoid at KBYI (the result is GNSS altitude in ft. MSL). The indicated and GNSS altitudes diverge as altitude increases because of the non-standard atmospheric lapse rate of temperature and pressure over KBYI on the day of the accident.

For the first approach, the "altitude target for simulation" is the result of integrating the ADS-B rate of climb data and fitting the result to the ADS-B GNSS MSL altitude where available. Below ADS-B coverage, the altitude is based on the last ADS-B point and KBYI surveillance video information, as described below.

For the accident approach, the "altitude target for simulation" is the result of integrating the ADS-B rate of climb data and fitting the result to the GNSS MSL altitude at IREME, and blending this solution into the ADS-B pressure altitude + 37 ft. (the indicated altitude) at JAMID. At JAMID, the indicated altitude is about 34 ft. lower than the GNSS MSL altitude (for unknown reasons; the difference is only 15 ft. at the same point in the first approach). The indicated altitude is selected as the target altitude for the simulation at JAMID because the lower altitude requires less of a "dive" near the end of the flight to impact the exhaust stack at the time indicated by the potato plant surveillance video (see the steepening of the flight path angle (γ) and increase in descent rate near the end of the data in Figures 19-22).

Figures 13 and 19 present speed data vs. time for the first and accident approaches, respectively, and Figures 14 and 20 present speeds vs. the runway 20 x coordinate for the first and accident approaches, respectively. The computed ground speeds and airspeeds are based on the simulation "target tracks" discussed above, and on the HRRR winds aloft data in Table 6. The simulation "target rate of climb" lines are the time-derivatives of the "altitude target for simulation" data discussed above. The ADS-B ground speed and rate of climb data are presented as square symbols.

Figure 15 presents the computed flight path angle γ , angle of attack α , and pitch angle θ vs. time for the first approach. Figure 21 presents these parameters vs. time for the accident approach, and Figure 22 presents them vs. the runway 20 x coordinate for the accident approach. The engine torque parameter presented in these Figures is the output of simulation matches of the target trajectories, as discussed in Section D.8.

D.7.2. Estimated trajectories below ADS-B coverage based on video information

As noted above, on both approaches to runway 20 N928JP was below ADS-B coverage after descending through an altitude of about 4,800 ft. MSL (660 ft. AGL), and so no measurements of the airplane's position or performance are available below that altitude. However, the KBYI video recording of N928JP making a low pass over runway 20, and the potato plant video recording of the airplane impacting the exhaust stack, provide the position of the airplane at those times. In addition, a ground speed estimate of the airplane over runway 20 on the first approach can also be made using the KBYI video. (Due to the distorted "fish eye" lens of the camera at the potato plant, the angle at which N928JP is approaching the camera, and a lack of background references in the video images, no estimate of the ground speed upon impact with the exhaust stack was made using the plant video.) The video points and the last available ADS-B points on each approach provide "boundary conditions" that, together with assumptions about the management of speed and flight path angle, can be used to estimate the position and altitude of the airplane with time between these points.

For the first approach, the following is assumed regarding the trajectory of N928JP below ADS-B coverage:

- N928JP continues to follow the 3.75° glide path to the displaced threshold.
- N928JP crosses the threshold at 40 ft. AGL, and then levels off at 20 ft. AGL.
- The deceleration of N928JP is approximately constant at about -0.5 kt./s. between the last ADS-B point and the level-off point, and constant at -2 kt./s. between the level-off point and the point captured in the KBYI surveillance video (see Table 4). These decelerations result in a trajectory that provides continuity in position, speed, and acceleration between the last ADS-B point and the point specified in Table 4, as shown in Figures 10-14.

During the accident approach, the last ADS-B messages provided position information but not ground speed information. However, the ground speed can be computed from the position data, though this calculation contains inherent "noise" as described above (and as shown in Figures 19 & 20). Nonetheless, the calculated ground speed indicates that N928JP continued to decelerate to approximately 78 kt. ground speed. This

ground speed and the winds in Table 6 result in a true airspeed of about 89 KTAS.¹¹ The corresponding calibrated airspeed is about 85 KCAS, which is consistent with the flaps 10° landing speed specified in the C208 S-1 Icing Supplement (Reference 12).

The time and distance increments between the last ADS-B position and the impact with the exhaust stack indicate that N928JP's ground speed between these points remained close to the last computed ground speed value (about 78 kt.), as shown in Figure 19. The estimated ground speed at impact with the exhaust stack is about 76 kt.

As shown in Figures 17 and 19, although the last few ADS-B points did not contain altitude information, they did contain rate of climb information. The integration of the rate of climb data provides a computed change in altitude. This altitude increment, along with the indicated altitude at the last ADS-B point where altitude is available, and the known impact elevation at the stack (see Table 2), are used to construct the altitude profile depicted in Figures 17 and 18. If the ADS-B rate of climb data are correct, then the rate of descent and flight path angle near the impact site had to steepen relatively quickly in the last few seconds of flight in order to impact the exhaust stack, as shown in Figures 19-22.

The altitudes, speeds, flight path angles, and lift coefficients (C_L) computed from the estimated trajectories and simulations of the first and accident approaches are compared as function of the runway x coordinate in Figures 23-25. The airspeed during the first approach is appreciably higher (by 25 to 50 KCAS) than during the accident approach, and the C_L is correspondingly lower. On the accident approach, the C_L increases into the range in which the stall warning horn can be activated about 1 nm from the displaced threshold.¹² This suggests that the lowering of the pitch angle (and consequent steepening of the flight path angle) near the end of the flight might have been the result of the pilot reacting to the activation of the stall warning horn.

The airplane's ability to fly the approaches recorded by the ADS-B data and the estimated trajectories below ADS-B coverage (for both the first and accident approaches) was confirmed by using an engineering simulation of the C208B to approximately match these flight paths. These simulations are described below.

¹¹ KTAS = knots true airspeed; KCAS = knots calibrated airspeed; KIAS = knots indicated airspeed. Indicated airspeed and calibrated airspeed are identical, except for airspeed indicator calibration errors. True airspeed and calibrated airspeed diverge with altitude.

¹² The description of the stall warning system in the C208B POH/AFM notes that the "vane in the wing senses the change in airflow over the wing, and operates the warning horn at airspeeds between 5 and 10 knots above the stall in all configurations." The maximum and stall warning C_L values plotted in Figure 25 are computed based on the flaps-up stall speed published in the POH/AFM, and the 5-10 knot buffer specified for the stall warning. It is uncertain where in the 5-10 knot buffer the warning horn will activate; if the horn does not activate until the C_L exceeds 1.2, for example, then it would not have activated on the accident approach.

D.8. Engineering simulations of N928JP's two approaches to KBYI runway 20

To confirm the consistency of the estimated trajectories of the airplane below ADS-B coverage with the airplane's performance capabilities, six degree-of-freedom (6-DOF) simulations of the approaches were performed. The objective of the simulations was to obtain physics-based computations of the airplane's trajectory and orientation that are consistent with the performance capabilities of the Cessna 208B, and with the ADS-B and video information described above.

The aerodynamic, propulsion, and flight controls models for the simulation were obtained from Kohlman Systems Research (KSR). KSR's models for the C208B meet the qualification standards for a Level D Full Flight Simulator specified in 14 Code of Federal Regulations (CFR) Part 60.

An airplane gross weight of 8,085 lb. was used in the simulation of the first approach, and a weight of 7,968 was used in the simulation of the accident approach (see Table 1). A flap setting of 0° (flaps up), and the winds specified in Table 6, were used in both simulations.

The simulations use a "math pilot" to generate flight control and throttle inputs that result in approximate matches of the target trajectories described in section D.7 (that is, the trajectories defined by the ADS-B data and video information).

The results of the simulation are presented in Figures 10-25 together with the corresponding parameters computed from the ADS-B and video data. The generally good agreement between the simulated and computed positions, speeds, and Euler angles indicates that the estimated trajectories, including those portions below ADS-B coverage, are consistent with the performance capabilities of the airplane.

D.9. ADAS engine monitor data

N928JP was equipped with a Pratt & Whitney (P&W) Air Data Acquisition System (ADAS), which records various engine parameters as well as the airspeed and altitude presented to the pilot on the Garmin G1000 displays in the cockpit.¹³ The ADAS was

¹³ Per an email from P&W to the author on 07/06/2023.

recovered after the accident and sent to P&W for readout. P&W then provided the recovered data to the NTSB.

The ADAS records data at 3-5 Hz, but the time associated with the recorded data cannot be correlated to any real-world time. Further, the position of the airplane (latitude and longitude) is not recorded. Consequently, associating the recorded data with any particular flight is not straightforward. Furthermore, differences between the altitudes from the last flight recorded on the ADAS and the ADS-B altitudes for the accident flight make it unlikely that the last flight recorded on the ADAS corresponds to the accident flight.

The altitude data from the 18 flights recorded on the ADAS are compared to the ADS-B altitudes for N928JP's last three flights in Figure 26. Each ADAS flight was identified in the altitude data based on an initial low-level altitude followed by a climb, descent, and final low-level altitude (together with corresponding time gaps between candidate flights). For each ADAS and ADS-B flight in Figure 26, the time parameter is shifted so that an elapsed time of 0 seconds corresponds to the takeoff time, making it easier to compare the altitude profiles.

None of the ADAS altitude profiles match the ADS-B altitude profiles from any of N928JP's last three flights. To highlight just one difference, N928JP's known flights cruise at 11,000-12,000 ft. MSL, and only ADAS flight 3 shows cruise at these altitudes, and its duration is much shorter than the known flights. Based on these results, it appears that the ADAS data do not correspond to any of N928JP's last three flights, and so are not relevant to the accident. The reason why the ADAS did not record data for these flights is unknown.

D.10. Operational guidance to pilots provided by Gem Air

D.10.1. Gem Air Operations Specifications and Flight Operations Manual

The certification of air carriers and commercial operators in the USA is governed by 14 CFR §119.33(b)(3), which states that "a person other than a direct air carrier may not conduct any commercial passenger or cargo aircraft operation for compensation or hire under part 121 or part 135 of this chapter unless that person ... obtains operations specifications that prescribe the authorizations, limitations, and procedures under which each kind of operation must be conducted." The content of operations specifications is defined in §119.49.

Gem Air, LLC holds operations specifications (OpsSpecs) for its operations conducted under Parts 91 and 135. Gem Air's *Flight Operations Manual* (FOM, Reference 7), Section 4, "Introduction," states that

This manual has been prepared in accordance with Federal Aviation Regulations Part 61, 91, 119, 135 and NTSB part 830. The procedures and policies contained herein supplement the regulations and are considered essential to good operational practices and safety. If a question of applicability arises the FARs shall prevail.

This manual is used for guidance of Management, Flight, Ground, and Maintenance personnel in the conduct of company operations of aircraft in compliance with FARs 91, 135, and the FAA issued Operations and Maintenance Specifications.

There are other references, publications, and manuals to be used by company personnel in the conduct of its operations. These items are properly identified in the appropriate sections of this manual. Sections of this manual are pertinent only to air carrier operations (i.e., Operations Specifications), while the rest of the manual may be used for any Part 91 operations. This manual is used as a guidance for all company operations, and the standards set forth within this manual shall be adhered to whenever practical in day-to-day operations.

...

The instructions contained in this manual are designed to aid the pilot and crewmembers in the operation of aircraft. However, in no situation shall this Operations Manual be regarded as a complete guide to all company procedures. Specifically, *it will not be utilized as a replacement for good judgment in daily operation* [emphasis in original].

Regarding the conduct of IFR approaches, the FOM Section 12, "Flight Operations," under the heading of "IFR Approach Procedures," lists several actions a two-pilot crew should take over the course of planning and executing an IFR approach. The FOM does not specify stabilized approach criteria *per se*, but does specify call outs that the pilot not flying (PNF) must make to the pilot flying (PF) during the final approach segment. Among these call outs are "descent rate in excess of 1,000 fpm after passing the FAF [Final Approach Fix]" and "airspeed deviations of +10 or -0 knots from target V-REF." These call outs imply stabilized approach criteria of no more than 1,000 fpm descent rate, and a +10 / -0 kt. tolerance on airspeed.

While these procedures are intended for two-pilot operations, the "Departure Procedures" section of the FOM states that "the following are procedures specifically for two-pilot crews. On single-pilot flights the pilot is responsible for cockpit and flight procedures that conform to the following guidance." If same policy applies to the "IFR

Approach Procedures” section of the FOM, then the rate of climb and airspeed tolerances cited above would also apply to single-pilot approaches.

Approach guidance specific to the Cessna 208B is provided in the “Flight Maneuver Descriptions” (FMD) document included as part of Gem Air’s pilot training program (Reference 9).

D.10.2. C208B approach procedures described in the Gem Air Training Program

The RNAV runway 20 approach to KBYI is a non-precision instrument approach (that is, an instrument approach with horizontal but no vertical navigation guidance). The “Non-Precision Approach” procedures section in the FMD document states that “if you are approaching an airport without current weather reports, even if the approach is straight-in, you may wish to plan on circling over the airport to check the winds and runway condition.” Considering this statement, N928JP’s first approach to KBYI (which ended in a low pass over the runway and a missed approach) might have been intended by the pilot to “check the winds and runway condition” before making a landing attempt on the second approach. Another possibility is that on the first approach, N928JP arrived at the runway threshold at a speed too high to touch down and land safely, prompting a go-around.

The FMD document states that “during or prior to completion of the procedure turn, or equivalent,” the aircraft configuration should be flaps 10° (in non-icing conditions) at an airspeed of 120 KIAS (procedures in icing conditions are discussed below). The FMD document continues:

After passing the FAF inbound, begin descent to MDA or step down fix, if applicable. Descent should be approximately 1,000 fpm to insure that you are level at the next required altitude. Failure to make the descent to MDA in a timely manner may result in missing the opportunity to visually identify the airport in time to continue a normal descent to landing.

Notably, here the recommended descent rate after passing the FAF is “approximately 1,000 fpm.” As noted above, the “IFR Approach Procedures” section of the FOM specifies a “descent rate in excess of 1,000 fpm after passing the FAF” as one of the conditions requiring a “callout” from the PNF. The unstated implication, considering both documents, is that the descent rate on a non-precision approach should approach, but not exceed, 1,000 fpm.

Per the FMD document, the airplane configuration after passing the FAF should be flaps 10° (no ice) at an airspeed of 120 KIAS. This configuration is maintained to the MDA or until the airport is visually acquired. If the airport is visually acquired at or before the MDA, a visual final approach can be executed; if the airport is not visually acquired by the MDA, a missed approach must be executed. The "Visual Approach and Landing" section of the FMD document states that "this procedure is accomplished either from [Visual Flight Rules] traffic patterns or as the last step in an IFR arrival." Hence, the visual approach and landing procedure would have applied as the last part of the RNAV runway 20 approach to KBYI, assuming that the runway environment was acquired visually before N928JP reached the MDA (this is likely the case, given the ceiling and visibility conditions indicated in Table 5 and depicted in Figures 17 & 18).

The FMD document specifies that for a straight-in visual approach (such as the final part of the accident approach), the "descent" part of the procedure should start "at about the one mile [from the runway] point." The specified configuration (in non-icing conditions) for the final approach is flaps 30 and airspeed 75-85 KIAS. The "acceptable performance guidelines" for the maneuver include "airspeed: ± 5 [knots]" and "landing within first 1/3 of the runway."

Although the RNAV runway 20 approach to KBYI is a non-precision approach with no GNSS-based vertical guidance, the vertical navigation features of the Garmin 1000 avionics suite installed in N928JP include the ability to generate a descending target path based on a prescribed "Flight Path Angle" (FPA) from a specified waypoint (such as the FAF of a non-precision approach) or the vertical path defined by the altitudes at two waypoints (such as the FAF and the runway threshold crossing height). Deviations from the target vertical path are displayed on the primary flight display in a manner similar to the way deviations from an instrument landing system (ILS) glide slope would be displayed. The ability of the G1000 system to present vertical guidance for the RNAV runway 20 approach at KBYI was tested by the Operations Group in an Advanced Airplane Training Device (AATD), as documented in Reference 11.

As shown in Figure 12, on the first approach N928JP intercepted the nominal 3.75° glide path to runway 20 about 6.2 nm from the displaced threshold, and remained on the glide path throughout the descent recorded by the ADS-B data. The match of the nominal glide path while the airspeed and rate of descent varied (see Figures 13 & 14), together with the absence of visual vertical guidance to the runway, suggest that the pilot might have been following FPA guidance provided by the G1000 on this

approach, as opposed to maintaining a nominal airspeed and rate of descent (for example, 120 KIAS and 1,000 fpm) in an attempt to descend to the MDA well before reaching the runway.

On the accident approach, Figure 18 indicates that N028JP intercepted the nominal glide path at about 4.5 nm from the displaced threshold, but then deviated above it and had to descend more steeply to intercept it again (at about 2.4 nm from the displaced threshold). Notably, on the accident approach N928JP started a 500 fpm descent about 8 nm from the displaced threshold, well before the glide path intercept, whereas on the first approach the significant increase in rate of descent started at 6 nm from the displaced threshold, roughly coincident with the glide path intercept. This raises the possibility that the pilot used different vertical navigation strategies on the two approaches, and that perhaps the G1000 FPA guidance was used on the first approach but not on the accident approach (though it cannot be known for certain what strategies were employed on either approach, or whether the G1000 FPA functionality was used at all).

The airplane flap and speed configurations for non-precision approaches and the visual final approach segment, specified in the Gem Air FMD document cited above, correspond to flight in non-icing conditions. In icing conditions, the flap and speed configurations to be used are specified in the Cessna 208B POH/AFM S-1 Icing Supplement (Reference 12). This Supplement is covered in the annual training provided to Gem Air's IFR Caravan pilots through the Cessna E-learning website (Cessna requires this training annually before flying the aircraft into icing conditions). The Supplement is also referenced in airplane checklists and cockpit placards.

D.10.3. Guidance for operations in icing conditions

The Cessna 208B POH/AFM S-1 Icing Supplement must be included in the POH/AFM of airplanes, such as N928JP, equipped with both the TKS Ice Protection System and a cargo pod. The information contained in the document supplements or supersedes the basic POH/AFM in specified areas; those areas not addressed in the Supplement are governed by the basic POH/AFM.

The Icing Supplement lists a number of airplane limitations that are in effect in icing conditions. "Icing conditions" are defined in the Supplement as "visually detected ice, or the presence of visible moisture in any form at an OAT [Outside Air Temperature] of 5° C (41° F) or below." N928JP's two approaches to runway 20, conducted in

temperatures below 5° C in light snow, met this definition of “icing conditions,” and consequently the limitations listed in the S-1 Supplement applied.

The limitations listed in the Icing Supplement include:

- Minimum airspeeds of 95 KIAS flaps up, and 85 KIAS at flaps 10°-20°
- Maximum 20° flap setting for landing

The “Landing” portion of the “Normal Procedures” section of the Supplement recommends a flap setting of 10° and airspeed of 85 KIAS for landing (a maximum of 20° of flaps may be used, but the minimum airspeed is still 85 KIAS). Per Figures 19 & 20, on the accident approach the airspeed decreased to between 84 and 86 KCAS and remained there for about 26 seconds before impact, though the flaps remained fully retracted (the minimum flaps-up airspeed cited in the Icing Supplement is 95 KIAS).

The “Airplane Systems and Descriptions” section of the Icing Supplement describes the “Low Airspeed Awareness System:

The Low Airspeed Awareness (LAA) system is designed to warn the pilot when airspeed falls below 97.5 ± 2.2 knots while operating in icing conditions. The system consists of an annunciator with a white or amber background and black letters, which reads BELOW ICING MIN SPD.

This annunciator is mounted in the instrument panel directly in front of the pilot, and is activated by an airspeed switch plumbed off the pilot's pitot and static lines. A remote mounted relay box provides logic for the annunciator, and for the stall warning horn, which provides an aural alert. Power is supplied from the LEFT PITOT HEAT and RIGHT PITOT HEAT circuit breakers and through the P/S HEAT/LOW A/S AWARE switch. This switch has two positions, ON and OFF and the Low Airspeed Awareness System is powered only when the P/S HEAT/LOW A/S AWARE switch is ON and at least one of the two circuit breakers is IN.

When the P/S HEAT/LOW A/S AWARE switch is turned ON prior to takeoff, the BELOW ICING MIN SPD annunciator will be illuminated white, indicating that the airspeed is below $97.5 + 2.2$ knots. Once the airspeed exceeds $97.5 + 2.2$ knots, the BELOW ICING MIN SPD annunciator will extinguish. If the airspeed falls back below $97.5 + 2.2$ knots, the BELOW ICING MIN SPD annunciator will flash between amber and white and the stall warning horn will sound intermittently until the airspeed is increased above $97.5 + 2.2$ knots. Pressing the flashing BELOW ICING MIN SPD annunciator, which incorporates a momentary switch, silences the stall warning horn and causes the annunciator to stop flashing. The annunciator will remain illuminated solid white as long as the airspeed is below $97.5 + 2.2$ knots. The autopilot must be disengaged when the flashing amber and white annunciation is activated. Once the flashing annunciator is acknowledged the autopilot may be re-engaged.

The "Before Landing" portion of the "Normal Procedures" section of the Icing Supplement contains the following note alerting pilots to anticipate both longer landing distances and the LAA warning when slowing to land in icing conditions:

NOTE

- Multiply normal POH/AFM landing distance by 2.1 for WING FLAPS 10°.
- If the shortest landing distance is required due to field length, WING FLAPS 20° (maximum) may be used. Multiply normal POH/AFM landing distance by 2.0.
- When slowing for landing, expect the BELOW ICING MIN SPD annunciator to flash and aural warning to sound.
- The pilot may fly a higher speed to avoid repeated LAA warnings.

The surveillance video from the potato plant indicates that the N928JP's flaps were fully retracted at impact, suggesting that the entire approach was flown with the flaps up. The video from KBYI, which captured N928JP's low pass over the runway following the first approach, also indicates that the flaps were up at that time. Flying the entire approach with the flaps up would be consistent with the instruction in the Icing Supplement to avoid full flaps (30°) in icing conditions, but would not be consistent with the normal approach flap setting of 10° specified in the FMD document and allowed by the Icing Supplement. The Supplement specifies flaps 10° (or a maximum of 20°) for landing in icing conditions; it only forbids flaps 30° in these conditions. If the accident pilot kept the flaps fully retracted out of concern over the icing conditions, then she might also have activated the TKS ice protection system and the pitot/static system heat.¹⁴ If the P/S HEAT/LOW A/S switch was turned on, then the LAA light and warning horn likely activated (intermittently) on the accident approach as the airspeed decreased below 100 KCAS. However, the Icing Supplement alerts pilots to expect (and ignore) this warning when slowing to land.

The Icing Supplement advises pilots to multiply the required landing distance by 2.1 for landing with wing flaps 10° and 85 KIAS airspeed, and by 2.0 when landing with flaps 20° at the same speed. No multiplier is provided for flaps up, implying that the Supplement assumes at least 10° of flaps for landing.

The "Performance" section of the C208B POH/AFM contains tables listing the "Short Field Landing Distance" required on a "paved, level, dry runway." The POH/AFM

¹⁴ Per Textron's Field Notes for this accident, the switches associated with the TKS system and pitot/static heat were found "off" in the airplane wreckage. However, the landing light switches were also found "off," but the surveillance video indicates that the landing lights were on. Consequently, the positions of the switches in the wreckage are not reliable indicators of their positions prior to impact.

provides no information about how to increase the landing distance to account for the reduced wheel braking friction coefficient on a wet or snow-covered runway.¹⁵ For the approximate accident conditions (8,000 lb. gross weight, 4,000 ft. pressure altitude, and 0° C), the POH/AFM specifies a total landing distance of 1,735 ft. For a flaps 10° landing at 85 KIAS, the Icing Supplement indicates that the required landing distance would be $(2.1) \times (1,735 \text{ ft.}) = 3,644 \text{ ft.}$ The available landing distance on runway 20 (considering the displaced threshold) is 3,787 ft., or only 143 ft. more than the distance required by the Supplement. Considering that the landing distance on a wet or snow-covered runway would be considerably longer than that required on a dry runway, it is unlikely that the airplane could have landed and stopped on runway 20 at flaps 10° and 85 KIAS given the performance indicated in the POH/AFM and Icing Supplement.

D.11. Exhaust plume effects on airplane performance

The Aeronautical Information Manual (AIM) published by the FAA (Reference 8) contains the following information about the hazards presented by exhaust plumes:

7-6-16. Avoid Flight in the Vicinity of Exhaust Plumes (Smoke Stacks and Cooling Towers)

a. Flight Hazards Exist Around Exhaust Plumes. Exhaust plumes are defined as visible or invisible emissions from power plants, industrial production facilities, or other industrial systems that release large amounts of vertically directed unstable gases (effluent). High temperature exhaust plumes can cause significant air disturbances such as turbulence and vertical shear. Other identified potential hazards include, but are not necessarily limited to: reduced visibility, oxygen depletion, engine particulate contamination, exposure to gaseous oxides, and/or icing. Results of encountering a plume may include airframe damage, aircraft upset, and/or engine damage/failure. These hazards are most critical during low altitude flight in calm and cold air, especially in and around approach and departure corridors or airport traffic areas.

Whether plumes are visible or invisible, the total extent of their turbulent [e]ffect is difficult to predict. Some studies do predict that the significant turbulent effects of an exhaust plume can extend to heights of over 1,000 feet above the height of the top of the stack or cooling tower. Any effects will be more pronounced in calm stable air where the plume is very hot and the surrounding area is still and cold. Fortunately, studies also predict that any amount of crosswind will help to dissipate the effects. However, the size of the tower or stack is not a good indicator of the predicted effect the plume may produce. The major effects are related to the heat or size of the plume effluent, the ambient air temperature, and the wind speed affecting the plume. Smaller aircraft can expect to feel an effect at a higher altitude than heavier aircraft.

¹⁵ The Gem Air FOM states that "the Aircraft Flight Manual will be strictly adhered to for computations of runway required for landings on contaminated surfaces" and that "no landings will be made if the runway braking action is reported to be 'NIL.'"

b. When able, a pilot should steer clear of exhaust plumes by flying on the upwind side of smokestacks or cooling towers. When a plume is visible via smoke or a condensation cloud, remain clear and realize a plume may have both visible and invisible characteristics. Exhaust stacks without visible plumes may still be in full operation, and airspace in the vicinity should be treated with caution. As with mountain wave turbulence or clear air turbulence, an invisible plume may be encountered unexpectedly. ...

Pilots are encouraged to exercise caution when flying in the vicinity of exhaust plumes. Pilots are also encouraged to reference the Chart Supplement U.S. where amplifying notes may caution pilots and identify the location of structure(s) emitting exhaust plumes.

It is notable that while the AIM advises pilots to “avoid flight in the vicinity of exhaust plumes” and that the hazards from plumes are “most critical during low altitude flight in calm and cold air, especially in and around approach and departure corridors or airport traffic areas,” airplanes on approach to runway 20 at KBYI will inevitably fly in close proximity to exhaust plumes at low altitude when the exhaust stacks at the potato plant are in operation.

The primary hazards of exhaust plumes identified by the AIM are “turbulence and vertical shear.” It is not known whether N928JP experienced turbulence or shear on either of the approaches to runway 20, but the fact that the pilot elected to attempt the approach a second time suggests that any turbulence she might have encountered on the first approach was insufficient to prompt her to divert to another airport.

The AIM identifies other potential hazards from exhaust plumes as “reduced visibility, oxygen depletion, engine particulate contamination, exposure to gaseous oxides, and/or icing.”

As shown in Figure 21, the simulation results for the accident approach indicate a power reduction starting at about 4 nm from the displaced threshold, when N928JP was at about 5,900 ft. MSL, or about 1,650 ft. above the exhaust stack (per Figure 17). This power reduction occurs just after N928JP intercepts the 3.75° glide path to the runway, and was likely an intentional power reduction in order to steepen the flight path angle and keep the airplane on the 3.75° glide path. Figure 21 shows the power reducing further at about 1.5 nm from the displaced threshold, just after passing the JAMID waypoint and descending through 4,800 ft. MSL (about 550 ft. above the stack). The reason for this second power reduction is unknown. One possibility considered in the investigation is that the hot exhaust steam from the stack decreased the density altitude of the air surrounding the airplane, decreasing its performance (which would

appear as a power reduction in the simulation that assumes ambient air temperature and density altitude). To examine whether the effects of the steam exhaust on density altitude might account for a loss of performance, the effects of the exhaust plume on the air temperature (and density altitude) in the area of the exhaust stack were estimated using the Exhaust Plume Analyzer (EPA) software developed by the MITRE corporation.

MITRE's website¹⁶ describes the EPA software as follows:

Exhaust plumes emanating from smoke stacks at power plants or other industrial facilities can have adverse impacts on local aviation during periods of calm winds. Adverse impacts can exacerbate if the temperature is low or the atmosphere is unstable. While low oxygen concentrations and elevated temperatures inside the plume can be detrimental to slow-flying or hovering helicopters, the turbulence generated from the upward motion of the plume is the main potential hazard to light, fixed-wing aircraft at low altitudes.

The Exhaust Plume Analyzer consists of three main parts: a convective flow model describing the mean flow of the plume, two aircraft response models judging the required vertical gust to achieve severe turbulence or aircraft upset, and a turbulence model computing the probability of experiencing a gust capable of causing severe turbulence or aircraft upset.

MITRE provided the NTSB with a special version of the EPA software that also outputs exhaust plume properties, such as temperature and pressure, in the vicinity of the exhaust stack. Using these outputs, the density of the air as a function of distance from the stack could be computed. The results indicate that the temperature of the exhaust plume drops to that of the surrounding air very quickly, so that 200 ft. above the stack the density altitude in the plume is 99.7% of that of the surrounding air. Hence, the power (or equivalent performance) reduction in the simulation passing JAMID (550 ft. above the stack) is not likely the result of an increase in density altitude associated with elevated temperatures produced by the exhaust plume. Note also that no steepening of the glide path as N928JP passed through JAMID is observed on the first approach (see Figure 12).

¹⁶ See <https://www.mitre.org/our-impact/intellectual-property/exhaust-plume-analyzer>.

D.12. Visibility of the exhaust stack from the cockpit

D.12.1. Overview: visibility angle definitions & flight recreation in FSX

Given the collision of N928JP with the exhaust stack, it is of interest to determine if and when the stack might have been visible to the pilot during the accident approach. The elevation of the top of the stack was 4,256 ft., or 304 ft. below the RNAV runway 20 approach minimum descent altitude (MDA) of 4,560 ft. Per regulation, in order to descend below the MDA, the pilot has to be able to see specified elements of the runway environment. Presumably, if the pilot can see these elements, obstacles between the runway and the airplane would also be visible. This section of the *Study* examines the visibility of the stack based on the position and orientation of N928JP computed from the accident approach trajectory described in section D.7.

According to the FAA Instrument Approach Procedures (IAP) handbook (Reference 10), the MDA on a non-precision approach (such as the RNAV runway 20 approach to KBYI) is defined as:

MDA—the lowest altitude, expressed in feet MSL, to which descent is authorized on final approach or during circle-to land maneuvering in execution of a standard instrument approach procedure (SIAP) where no electronic glideslope is provided.

The IAP handbook also notes that

Pilots are cautioned to fully understand and abide by the guidelines set forth in 14 CFR §91.175(c) regarding proper identification of the runway and runway environment when electing to continue any approach beyond the published [Decision Altitude (DA) / Decision Height (DH)] or MDA.

The referenced guidelines in 14 CFR §91.175(c) are as follows:

Operation below DA/DH or MDA. Except as provided in § 91.176 of this chapter, where a DA/DH or MDA is applicable, no pilot may operate an aircraft, except a military aircraft of the United States, below the authorized MDA or continue an approach below the authorized DA/DH unless—

(1) The aircraft is continuously in a position from which a descent to a landing on the intended runway can be made at a normal rate of descent using normal maneuvers, and for operations conducted under part 121 or part 135 unless that descent rate will allow touchdown to occur within the touchdown zone of the runway of intended landing;

(2) The flight visibility is not less than the visibility prescribed in the standard instrument approach being used; and

(3) Except for a Category II or Category III approach where any necessary visual reference requirements are specified by the Administrator, at least one of the following visual references for the intended runway is distinctly visible and identifiable to the pilot:

- (i) The approach light system, except that the pilot may not descend below 100 feet above the touchdown zone elevation using the approach lights as a reference unless the red terminating bars or the red side row bars are also distinctly visible and identifiable.
- (ii) The threshold.
- (iii) The threshold markings.
- (iv) The threshold lights.
- (v) The runway end identifier lights.
- (vi) The visual glideslope indicator.
- (vii) The touchdown zone or touchdown zone markings.
- (viii) The touchdown zone lights.
- (ix) The runway or runway markings.
- (x) The runway lights.

To evaluate the visibility of the exhaust stack and the runway environment from the cockpit of N928JP, the location of the stack in the pilot's field of view, defined by the stack's "visibility angles," were computed.

The visibility angles correspond to the angular coordinates of the line of sight from the airplane to the stack, measured in a coordinate system fixed to the airplane's body axis system, and consist of the azimuth angle and elevation angle (see Figure 27). The azimuth angle is the angle between the airplane's x -axis and the projection of the line of sight onto the x - y plane. The elevation angle is the angle between the line of sight itself, and its projection onto the x - y plane. At 0° elevation, 0° azimuth is straight ahead, and positive azimuth angles are to the right. 90° azimuth would be out the right window parallel to the y axis of the airplane. At 0° azimuth, 0° elevation is straight ahead, and positive elevation angles are up. 90° elevation would be straight up parallel to the z axis. The azimuth and elevation angles depend on both the positions (east, north, and altitude coordinates) of the airplane and stack, and the orientation (yaw, pitch, and bank angles) of the airplane.

The position of the exhaust stack is known and fixed. The position and orientation of the airplane used here are those derived from the complete trajectory of the accident approach, as described in section D.7 and presented in Figures 16-22.

Assuming adequate atmospheric visibility, the stack will be visible from the airplane unless a non-transparent part of the airplane's structure lies along the line of sight between the airplane and the stack. To determine if this is the case, the azimuth and elevation coordinates of the boundaries of the airplane's transparent structures (windows) must be known, as well as the coordinates of the airplane's structure visible from the cockpit (such as the wings, nose, and wing struts). If the line of sight passes through a non-transparent structure (such as the instrument panel, a window post, or a wing), then the stack will be obscured from the airplane.

For this *Study*, the azimuth and elevation angles of the windows and structures of the Cessna 208B were determined from the interior and exterior dimensions of an exemplar airplane, as measured using a FARO laser scanner during a previous investigation. The laser scanner produces a "point cloud" generated by the reflection of laser light off objects in the laser's path, as the scanner sweeps through 360° of azimuth and approximately 150° of elevation. The 3-dimensional coordinates of each point in the cloud are known, and the coordinates of points from multiple scans (resulting from placing the scanner in different positions) are "merged" by the scanner software¹⁷ into a common coordinate system. By placing the scanner in enough locations so that the scanner can "see" every part of the airplane, the complete exterior and interior geometry of the airplane can be defined.

In the previous investigation, the scanner was placed in several locations to scan the exterior of the airplane, and in the pilot seat to scan the interior of the airplane. The scanner software was then used to identify the points defining the outline of the cockpit windows (from the interior scans) and exterior structures visible from the cockpit (from the exterior scans). The coordinates were transformed into the airplane's body axis system and, ultimately, into azimuth and elevations angles from the pilot's eye position. The transformation method is described in Appendix A of Reference 3.

The azimuth and elevation angles of the airplane's windows and other structures are very sensitive to the pilot's eye location in the cockpit. If the pilot moves her head forward or aft, or from a position centered over her seat to one close to a window surface, the view out the window (and the azimuth and elevation angles of all the airplane's structures) change significantly. This potential variability in the pilot's eye position, and the consequent variability in the location of the window edges and

¹⁷ FARO SCENE software: see <http://faro-3d-software.com/>.

airplane structures in her field of view, is a source of uncertainty as to whether the top of the stack is obscured or not at a given time.

To evaluate the effect of varying eye position on the visibility of the stack, the azimuth and elevation angles of the cockpit windows and other airplane structures were computed for three different eye heights in the cockpit, as described below. In the absence of better information, it is assumed that the pilot would have adjusted the seat and pedal positions to place her eyes in a position similar those of the pilot that was seated in the exemplar airplane at the time it was scanned.

In addition to the calculation of the visibility angles, this *Study* presents recreations of possible views from the cockpit (including simulation-based depictions of the outside world) created in the *Microsoft Flight Simulator X (FSX)* simulation program, using sky and terrain graphics inherent in *FSX*, and assuming the nominal eye position as defined above. The exhaust stack was modeled in *FSX* and placed appropriately relative to the KBYI runway using the tools included in the *FSX Software Development Kit*.

The cockpit structure as seen from the nominal pilot's eye position (based on the laser scans) was constructed in *FSX* as a semi-transparent panel that "masks" the view from the cockpit (see Appendix B in Reference 3 for more information about the creation of such panels in *FSX*). The cockpit geometry built into the C208B airplane model that comes with *FSX* was not used. The azimuth and elevation coordinates of the laser scan points and the resulting panel mask are depicted in Figure 28.

The position (latitude, longitude, and altitude) and attitude (heading, pitch, and roll) of N928JP were recreated in *FSX* using the *FS Recorder* program developed by Matthias Neusinger,¹⁸ based on the accident approach trajectory described in section D.7.

FSX contains inherent options to customize the time, date, and weather depiction in the simulation. The time and date were set to those of the accident (08:32:30 MDT on April 13, 2022), which results in the correct placement of the sun in the sky. The weather options were set to a broken ceiling at 2,300 ft. AGL and 2 miles visibility in light snow, per the weather conditions near the time of the accident listed in Table 5 (a visibility of 2 miles was used as an estimate between the reported visibilities at 08:10 (1 mile) and

¹⁸ This program used to be available at <http://www.fs-recorder.net/>, but the website is no longer operational.

08:40 (2.5 miles); the accident occurred at about 08:30). Screenshots from the *FSX* recreation are presented and discussed below.

D.12.2. Results: azimuth and elevation angle calculations

The azimuth and elevation angles from the nominal eye position in the cockpit to the top and bottom of the exhaust stack during the last minute before impact are shown as a function of time (in seconds before impact) in Figure 29. The top plot presents the azimuth angles, and the bottom plot presents the elevation angles. Since the airplane is on a steady final approach course heading, the azimuth angle up to a second before impact is small (between about 0° and 2°), and is relatively constant. As a consequence of this relatively constant azimuth angle, only a very narrow slice of the airplane structure in the pilot's horizontal field of view needs to be considered for potential obstructions to the visibility of the exhaust stack.

Figure 28 shows that at the nominal eye position, between an azimuth angle of 0° and 2° the elevation angle of the top of the engine cowl is between about -10° and -11° . Consequently, the top of the stack is obscured below the nose of the airplane whenever its elevation angle is less than about -10° ; this is depicted by the "nominal" green band in Figure 29 and the red-shaded area labeled "stack obscured at nominal eye height." At the nominal eye height, the stack would have been obscured from about 29.5 to 3.3 seconds before impact.

As noted above, variations in the height of the pilot's eyes will affect the elevation angles of the top of the cowl and instrument panel. The green bands labeled '1" lower' and '1" higher' in Figure 29 show this effect; raising or lowering the pilot's eyes shifts the elevation angle of the top of the panel by about 1° , which in turn affects the times at which the exhaust stack is obscured by the cowl and / or instrument panel.

D.12.3. Results: accident approach recreation in *FSX*

Screenshots of the cockpit view recreation in *FSX* are presented in Figures 30a-i. The times of the screenshots and corresponding altitudes and distances from the runway 20 displaced threshold are listed in Table 8.

Figure #	Time, HH:MM:SS MDT	Time to impact, seconds	MSL altitude, feet	Height above displaced threshold, ft.	Distance from displaced threshold, nm
30a	08:31:46.6	40	4,695	553	1.33
30b	08:31:51.6	35	4,638	496	1.21
30c	08:31:56.6	30	4,585	443	1.09
30d	08:32:01.6	25	4,537	395	0.97
30e	08:32:06.6	20	4,489	347	0.86
30f	08:32:11.6	15	4,441	299	0.76
30g	08:32:16.6	10	4,391	249	0.65
30h	08:32:21.6	5	4,326	184	0.54
30i	08:32:24.6	2	4,277	135	0.48

Table 8. Times corresponding to FSX screenshots in Figures 30a-i.

The semi-transparent gray area in Figures 30a-i is the instrument panel “mask” described above, corresponding to areas of the cockpit and airplane structure that obscure the view from the cockpit. The location of the exhaust stack in Figures 30a-d is highlighted with the red circle.

In the FSX recreation, the following airport environment items in the list from 14 CFR §91.175(c) are depicted and are “visible” at various times:

- The runway threshold.
- The runway threshold markings.
- The threshold lights.
- The runway end identifier lights (REIL).
- The touchdown zone or touchdown zone markings.
- The runway and runway markings.
- The runway lights.

The REIL “flash” in FSX with a sudden off-to-on burst, followed by a slower on-to-off dimming. Hence, the REIL (at each corner of the runway threshold) might appear in Figures 30a-i at different brightness levels, depending on the timing of the screenshot.

Similarly, a flashing red light is located at the top of the exhaust stack, but might or might not have been illuminated when each screenshot was captured. Figure 30i depicts the illuminated red light on the stack. At that time, the light was approximately in line with the red runway threshold lights.

The obscuration of the exhaust stack depicted in Figures 30a-i is consistent with the plot of the stack elevation angles in Figure 29. Note that portions of the stack are obscured in Figures 30c-26h (corresponding to times 30 to 5 seconds before impact).

It is also notable that in Figures 30d-i (corresponding to times from 25 seconds before impact and onwards), the pitch angle of the airplane (resulting from the airspeed and flap selection) is such that the runway and runway threshold appear just above the shaded gray area corresponding to the airplane structure. This suggests the possibility that the pilot was modulating the pitch angle so as to slow the airplane (requiring a combination of increasing pitch and decreasing power) while attempting to keep the runway in sight through the windshield (limiting the amount the pitch angle could be increased). The pause in the increase in the pitch angle at 08:32:00 (1 nm from the displaced threshold) might have resulted from the pilot's desire to keep the nose low enough to maintain the runway threshold in sight. At the same time, the limited atmospheric visibility and absence of visual vertical approach guidance (such as a Visual Approach Slope Indicator, or VASI) might have made it harder for the pilot to realize that the airplane was descending below the nominal 3.75° glide path to the runway.

As noted above, the reduction in pitch angle from about 7° to 4.5° at 08:32:15 (0.7 nm from the displaced threshold) shown in Figures 21 & 22, resulting in a steepening flight path angle, might reflect the pilot's response to a possible activation of the stall warning horn as the C_L increased into the range in which the horn could be activated (see Figure 25).

Figures 29 & 30 indicate that between 60 and 30 seconds before impact, the exhaust stack would not have been obscured by the airplane structure, but might have been too small (or too distant in limited atmospheric visibility) to be noticed. Between 30 and 3.3 seconds before impact, the stack might have been totally obscured by the cockpit structure, even though the runway likely remained visible. When the top of the stack became unobscured about 3 seconds before impact, it was likely too late for the pilot to recognize the hazard and take action to avoid the collision.

As noted in section D.7, the trajectory of N928JP below ADS-B coverage was not recorded directly, but is a reconstruction designed to fit the end of the ADS-B data and the information about the airplane state available from the video recording of the impact with the stack. The simulations described in section D.8 indicate that this

reconstructed trajectory is feasible, but uncertainty about the exact trajectory of the airplane remains. There could be similar, yet distinct, combinations of altitude and position that also satisfy the constraints imposed by the ADS-B and video data. Consequently, there is also uncertainty in the speed, C_L , pitch and flight path angles, and corresponding cockpit visibility recreations presented in this *Study*. However, the solution presented here identifies one possibility, and serves to highlight the factors that might have affected N928JP's descent below the nominal 3.75° glide path and impact with the exhaust stack.

E. CONCLUSIONS

The material in this *Study* supports a number of observations and conclusions regarding the performance of N928JP during its two approaches to KBYI runway 20, and its impact with the agglomerator exhaust stack on the second approach. The airplane's position and orientation above about 4,800 ft. MSL (660 ft. AGL) on its two approaches could be computed from ADS-B and winds aloft data. No ADS-B data is available for the airplane below 660 ft. AGL, but position and time information provided by surveillance videos at the accident site and at KBYI allows the airplane's trajectory below ADS-B coverage on each approach to be estimated. Simulator matches of the resulting trajectories indicates that they are feasible, and provide estimates of additional performance parameters, such as engine power, during the approaches. The airplane position and attitude parameters derived from the accident approach trajectory are also used to estimate the visibility of the exhaust stack from the cockpit during that approach.

Sections C.3, D.7, and associated Figures of this *Study* describe the sequence of events and the results of analyses of the airplane's performance during N928JP's two approaches to runway 20. The following observations can be drawn from these sections:

- The evidence suggests that both approaches were conducted with the flaps fully retracted. The first approach was conducted at airspeeds well above the 120 KIAS approach speed specified in the Gem Air FMD document (the airplane decelerated through 120 KCAS at the displaced threshold), and the KBYI surveillance video recorded the airplane flying level over the runway with the flaps retracted. The surveillance video from the impact site shows N928JP approaching the exhaust stack with the flaps up.
- Flying the approach with the flaps up is consistent with the guidance in the C208B S-1 Icing Supplement to avoid flight in icing conditions with the flaps fully extended (30°), but is not consistent with the Supplement's recommended

approach and landing flap setting of 10°. However, it is possible that accident pilot kept the flaps fully retracted out of concern over the icing conditions.

- The Icing Supplement specifies 10° of flaps (20° maximum) and 85 KIAS for landing in icing conditions. In this configuration, the Supplement states that the required landing distance determined from the tables in the POH/AFM should be multiplied by a factor of 2.1. For the accident conditions, the resulting required distance would have been 3,644 ft., only 143 ft. less than the available runway landing length. The landing distances provided in the POH/AFM correspond to a dry runway; the required landing distance on a wet or snow-covered runway would be considerably longer, though the POH/AFM does not provide information with which to compute the increase. Consequently, it is unlikely that N928JP could have landed and stopped on the runway, if the airplane configuration and landing performance were consistent with the guidance provided in the POH/AFM and Icing Supplement.
- The estimated trajectory for N928JP's first approach indicates that the airspeed over the displaced threshold was about 120 KCAS, too fast for an attempted landing. Given this high speed, it is possible that the pilot never intended to land following the first approach, but instead only meant to "[circle] over the airport to check the winds and runway condition" as suggested in the Gem Air FMD document. However, the pilot did not communicate such an intention to ATC; an opportune time to have done so would have been at 08:07:27, after ATC transmitted IFR flight plan cancellation instructions. Instead, the pilot asked ATC for the Twin Falls Tower phone number, which suggests that she was anticipating cancelling her flight plan on the ground.
- On the first approach, N928JP intercepted the 3.75° glide path to the runway about 6.2 nm from the displaced threshold and remained on it to the runway threshold, suggesting that the pilot might have been following the FPA guidance provided by the Garmin G1000 avionics.
- On the accident approach, N028JP intercepted the nominal glide path at about 4.5 nm from the displaced threshold, but then deviated above it and had to descend more steeply to intercept it again (at about 2.4 nm from the displaced threshold). On this approach N928JP started a 500 fpm descent about 8 nm from the displaced threshold, well before the glide path intercept.

- The differences in the tracking of the nominal glide path to the runway between the two approaches raise the possibility that the pilot used different vertical navigation strategies on each, and that perhaps the G1000 FPA guidance was used on the first approach but not the second (though it cannot be known for certain what strategies were employed on either approach, or whether the G1000 FPA functionality was used at all).
- The airspeeds on the accident approach were much slower than those on the first approach (by 25 to 50 KCAS), and more consistent with an intent to land. However, the video evidence indicates that the flaps were kept fully retracted, rather than being extended to 10° as specified in the Icing Supplement.
- On the accident approach the airspeed decreased to between 84 and 86 KCAS and remained there for about 26 seconds before impact. This speed range is consistent with the 85 KIAS flaps 10° landing speed specified in the Icing Supplement. However, because the flaps were retracted, flight at this speed increased the lift coefficient into the range in which the stall warning horn could be activated.
- Estimates of the visibility of the exhaust stack from the cockpit indicate that at the nominal eye height, the stack would have been obscured below the nose of the airplane from about 29.5 to 3.3 seconds before impact.
- A recreation of the accident approach in *FSX* indicates that for much of the approach, the runway and runway threshold appear just above the nose of the airplane (while the exhaust stack is obscured beneath it). This suggests the possibility that the pilot was modulating the pitch angle so as to slow the airplane (requiring a combination of increasing pitch and decreasing power) while attempting to keep the runway in sight through the windshield (limiting the amount the pitch angle could be increased).
- The pause in the increase in the pitch angle at 08:32:00 (1 nm from the displaced threshold) might have resulted from the pilot's desire to keep the nose low enough to maintain the runway threshold in sight.
- The computed reduction in pitch angle at 08:32:15 (0.7 nm from the displaced threshold), resulting in a steepening flight path angle, might reflect the pilot's response to a possible activation of the stall warning horn.

- When the top of the exhaust stack became unobscured about 3 seconds before impact, it was likely too late for the pilot to recognize the hazard and take action to avoid the collision.

When considering these observations, it is important to remember that the trajectory of N928JP below ADS-B coverage analyzed in this *Study* was not recorded directly, but is a reconstruction designed to fit the end of the ADS-B data and the information derived from the video recording of the impact with the stack. Consequently, uncertainty about the exact trajectory of the airplane remains. There could be similar, yet distinct, trajectories that also satisfy the constraints imposed by the ADS-B and video data, and that result in somewhat different speed, C_L , pitch and flight path angles, and cockpit visibility results. However, the solution presented here identifies one possibility, and serves to highlight the factors that might have affected N928JP's descent below the nominal 3.75° glide path and impact with the exhaust stack.

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National Resource Specialist – Aircraft Performance

F. REFERENCES

1. Cessna Aircraft Company, *Model 208B G1000 Information Manual*, incorporating information issued in the Pilot's Operating Handbook and FAA approved Airplane Flight Manual at Revision 1, dated 5 June 2008 (part number 208BPHBUS-01).
2. National Transportation Safety Board, Office of Aviation Safety, *Operational Factors Specialist's Factual Report, Cessna 208B, N028JP, Heyburn, Idaho, April 13, 2022, NTSB accident # WPR22FA151* (July 23, 2022). (Available through the NTSB CAROL search tool at <https://data.nts.gov/carol-main-public/landing-page>).
3. National Transportation Safety Board, Office of Research and Engineering, *Aircraft Performance & Cockpit Visibility Study, Cessna 208B N752RV & Piper PA-18-150 N82452, Russian Mission, Alaska, August 31, 2016, NTSB accident # ANC16FA061* (November 30, 2017). (Available through the NTSB CAROL search tool at <https://data.nts.gov/carol-main-public/landing-page>).
4. 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.
5. National Transportation Safety Board, Office of Aviation Safety, *Meteorology Specialist's Factual Report, Cessna 208B, N028JP, Heyburn, Idaho, April 13, 2022, NTSB accident # WPR22FA151* (July 12, 2022). (Available through the NTSB CAROL search tool at <https://data.nts.gov/carol-main-public/landing-page>).
6. U.S. Department of Commerce / National Oceanic and Atmospheric Administration (NOAA), Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM), *Federal Meteorological Handbook No. 1: Surface Weather Observations and Reports*, document FCM-H1-2019, Washington, D.C., July 2019. Available at: https://www.icams-portal.gov/resources/ofcm/fmh/FMH1/fmh1_2019.pdf.
7. Gem Air LLC, *Flight Operations Manual*, Revision 13, 10/22/2021 (Gem Air proprietary document).
8. Federal Aviation Administration, *Aeronautical Information Manual*. Available at: https://www.faa.gov/air_traffic/publications/atpubs/aim_html/
9. Gem Air LLC, *Air Carrier Training Program Flight Maneuver Descriptions: Small Single-Engine Airplanes: Cessna 208B Caravan*, Revision 6, June 11, 2016.
10. Federal Aviation Administration, *Instrument Approach Procedures Handbook*. Available at: https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/instrument_procedures_handbook
11. National Transportation Safety Board, Office of Aviation Safety, *Operational Factors Specialist's Factual Report Attachment 12: FAA AATD Observation Field Notes: FAA AA, Cessna 208B, N028JP, Heyburn, Idaho, April 13, 2022, NTSB accident # WPR22FA151* (August 4, 2022). (Available through the NTSB CAROL search tool at <https://data.nts.gov/carol-main-public/landing-page>).
12. Cessna Aircraft Company, *Model 208B Grand Caravan 675 HP - G1000 Pilot's Operating Handbook and FAA approved Airplane Flight Manual Supplement S1: TKS Ice Protection System for Cargo Pod Equipped Airplanes*, Revision 6, dated 2 December 2016 (part number 208BPHBUS-S1-06).

G. GLOSSARY

Acronyms

ADAS	Pratt & Whitney Air Data Acquisition System
ADS-B	Automatic Dependent Surveillance – Broadcast
AFM	Airplane Flight Manual
AGL	Above ground level
AIM	Aeronautical Information Manual
ASOS	Automated Surface Observation System
ATC	Air Traffic Control
CFR	Code of Federal Regulations
FAA	Federal Aviation Administration
FAF	Final Approach Fix
FMD	Flight Maneuvers Description (document)
FOM	Flight Operations Manual
fpm	Feet per minute
FSX	Microsoft Flight Simulator X computer program
GNSS	Global Navigation Satellite System
GOM	Cape Air General Operations Manual
GPS	Global Positioning System
"Hg	Inches of mercury
HRRR	High Resolution Rapid Refresh winds-aloft model
IF	Intermediate Fix
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
KBYI	Burley Municipal Airport, Burley, Idaho
KCAS	Knots calibrated airspeed
KIAS	Knots indicated airspeed
KSLC	Salt Lake City International Airport, Salt Lake City, Utah
KTAS	Knots true airspeed
LAA	Low Airspeed Awareness system / alert
MDT	Mountain Daylight Time
METAR	Meteorological Terminal Air Report
MSL	Mean Sea Level
NOAA	National Oceanic and Atmospheric Administration
NTSB	National Transportation Safety Board
POH	Pilot's Operating Handbook
REIL	Runway End Identifier Lights
RNAV	Area Navigation
SPECI	Aviation Select Special Weather Reports
TFATCT	Twin Falls Air Traffic Control Tower
UTC	Universal Coordinated Time

Symbols

α	Angle of attack
γ	Flight path angle
θ	Pitch angle
C_L	Lift coefficient
x	Runway coordinate originating at displaced threshold and parallel to centerline
y	Runway coordinate originating at displaced threshold and normal to centerline

FIGURES

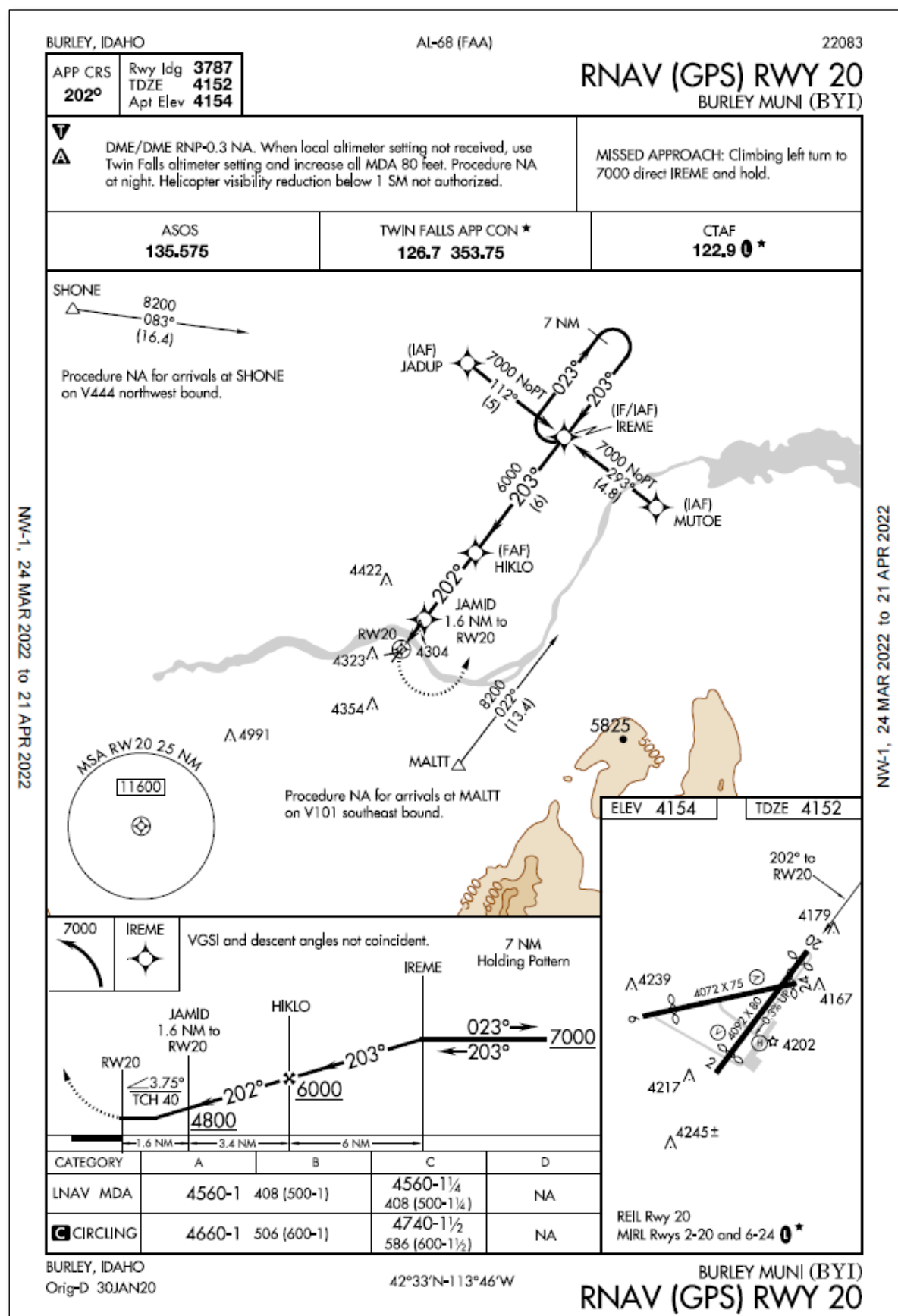


Figure 1. KBYI RNAV (GPS) runway 20 IFR approach plate.

WPR22FA151: Cessna 208B, N928JP, Heyburn, ID, 04/13/2022

Plan view of flight path during first approach to KBYI runway 20

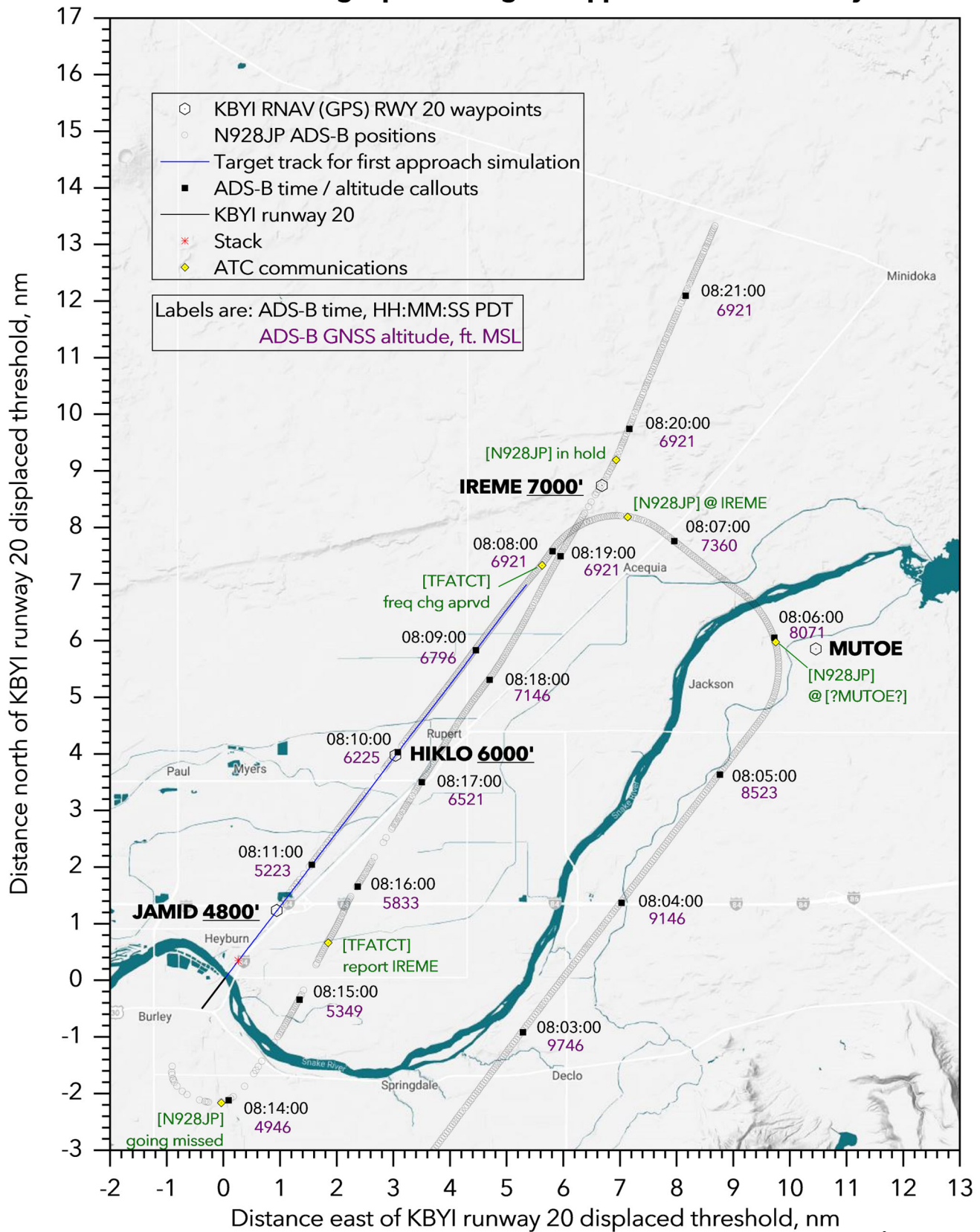


Figure 2.

WPR22FA151: Cessna 208B, N928JP, Heyburn, ID, 04/13/2022

Plan view of flight path during accident approach to KBYI runway 20

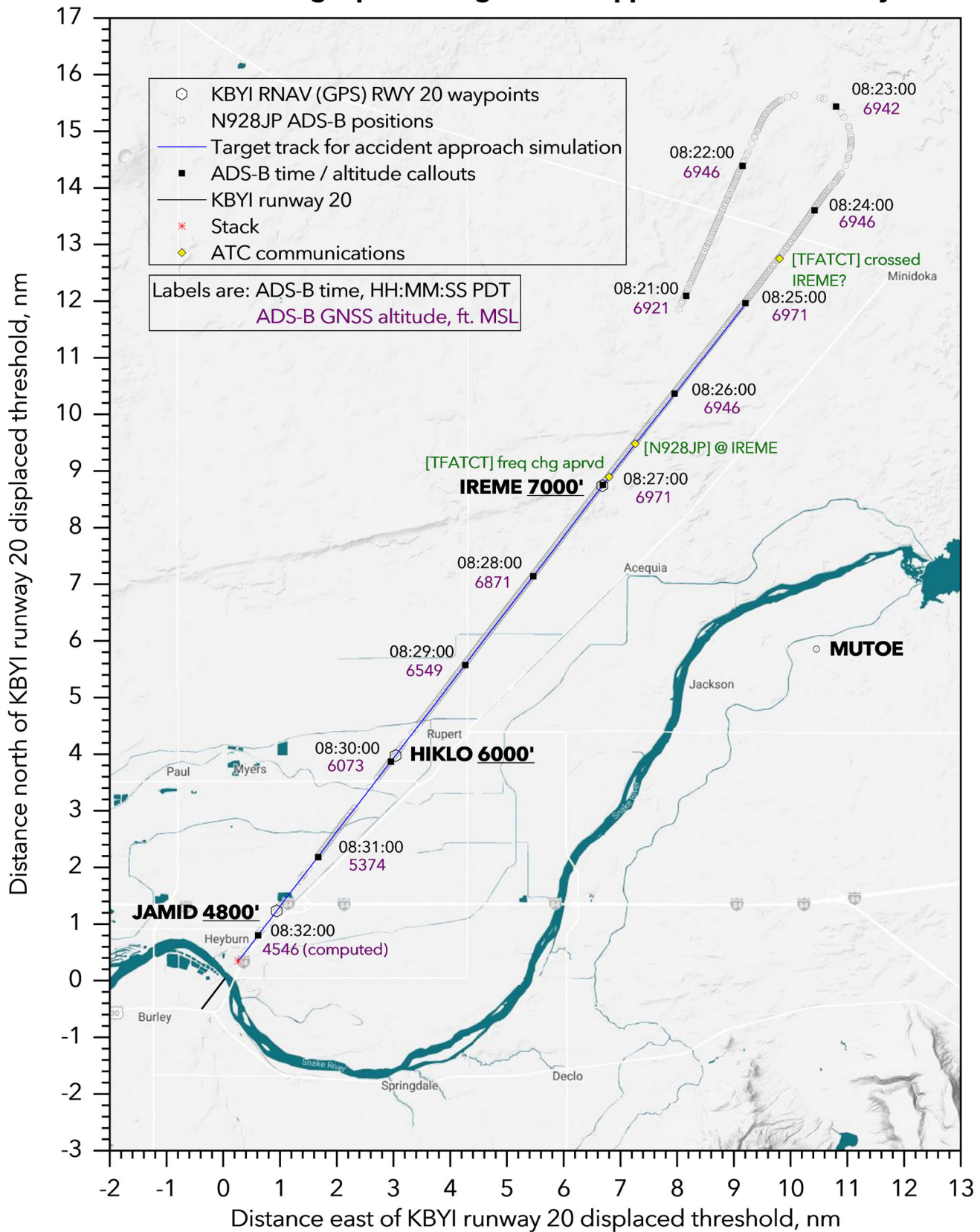


Figure 3a.

WPR22FA151: Cessna 208B, N928JP, Heyburn, ID, 04/13/2022

Plan view of flight path during accident approach to KBYI runway 20 (detail)

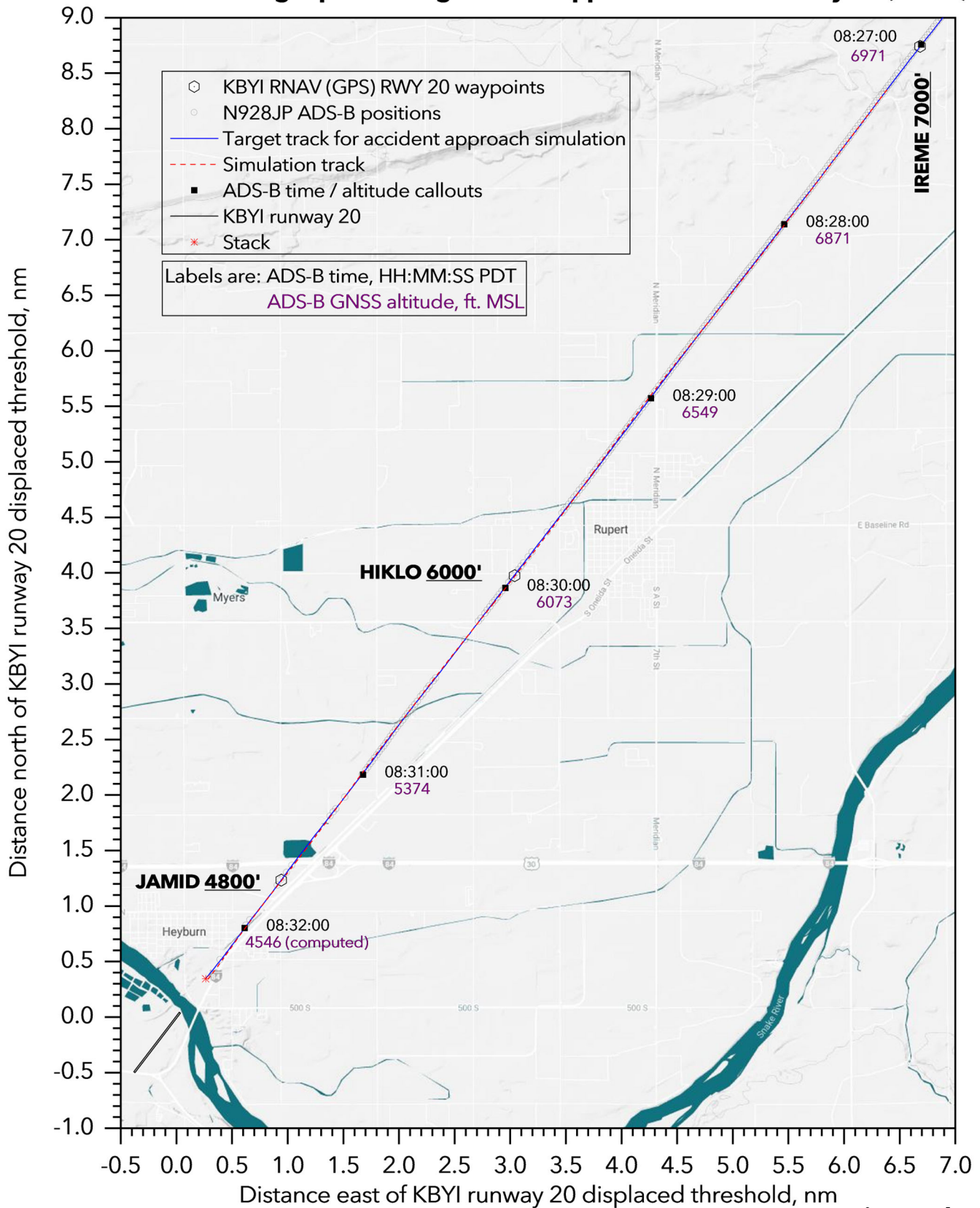


Figure 3b.



Figure 4. Pre-accident photo of N928JP (from <https://www.airport-data.com/aircraft/photo/001344396.html>).

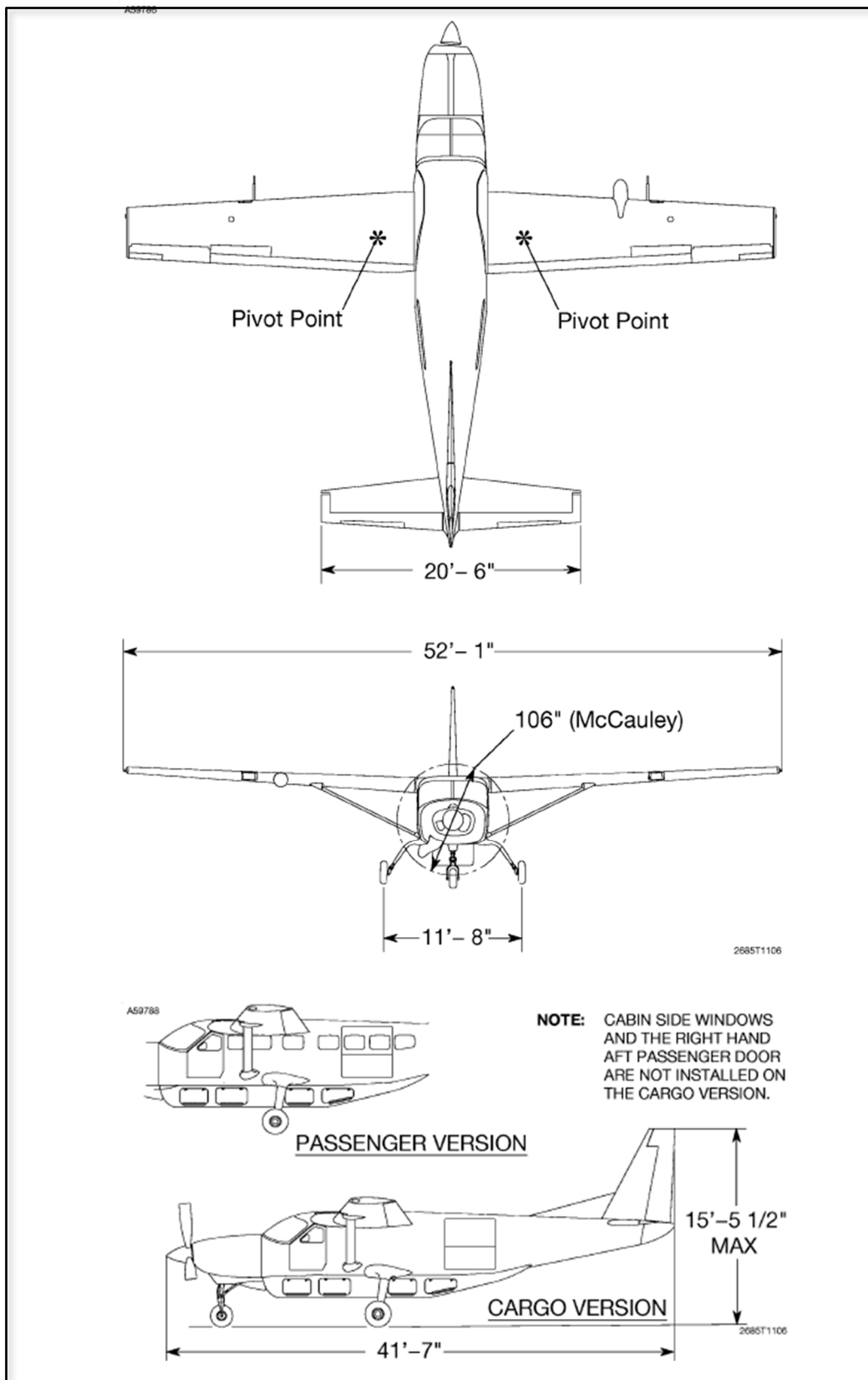


Figure 5. 3-view of the Cessna 208B airplane (from Reference 1).



(a) 08:32:25.5 MDT.



(b) 08:32:26.1 MDT.



(c) 08:32:26.6 MDT.

Figure 6. Surveillance video frames showing N928JP approaching and impacting the agglomerator exhaust stack.

Point	x (nm)	x (ft)	h (ft MSL)	Description
A	0.1004	610	4142	Glide path runway intercept
B	0.0000	0	4142	Displaced threshold
C	-0.0502	-305	4141	Threshold
D	0.0000	0	4182	Glide path threshold crossing height
E	-0.4332	-2632	4156	Agglomerator stack base
F	-0.4332	-2632	4256	Agglomerator stack top
G	-0.4332	-2632	4354	Glide path altitude at stack
H	-1.5508	-9423	4800	Glide path altitude at JAMID

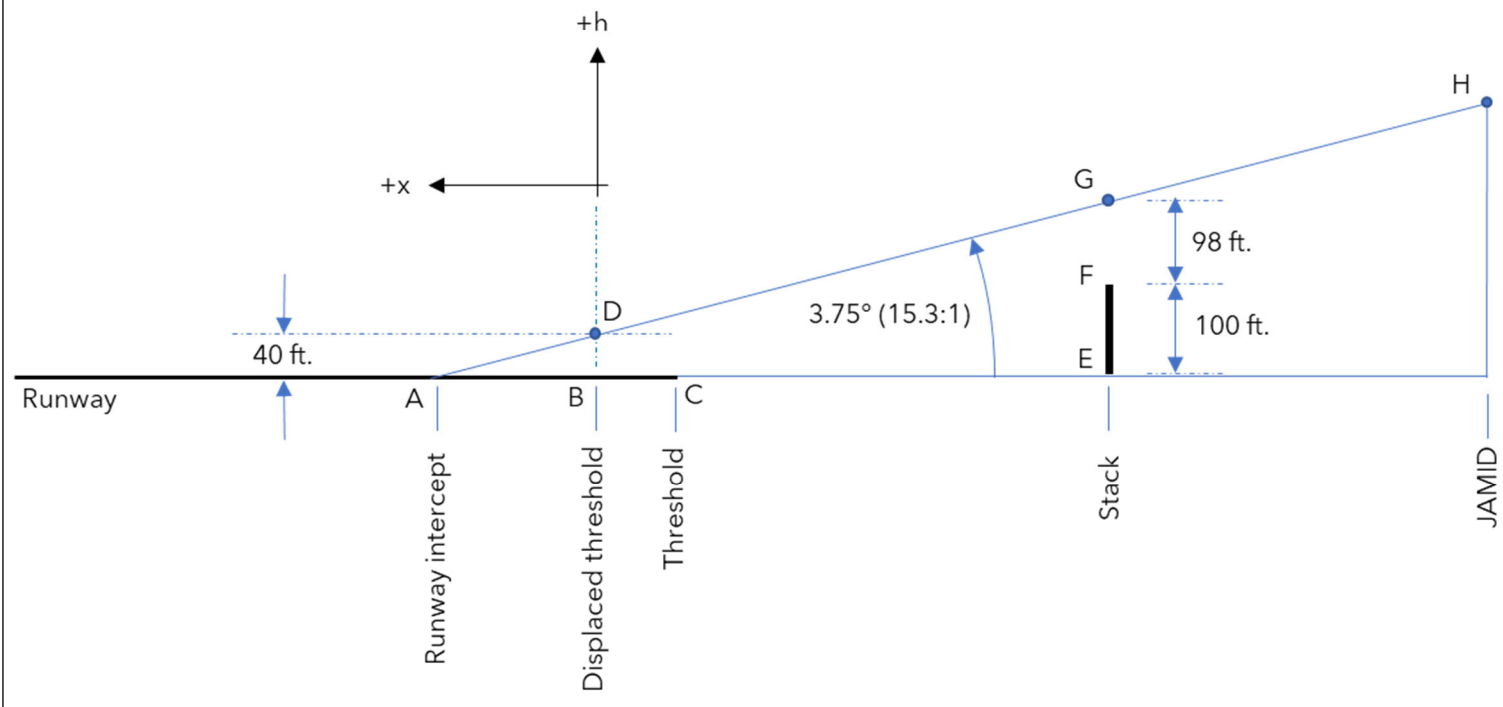


Figure 7. Profile view of runway and agglomerator exhaust stack geometry. x coordinates are from KBYI runway 20 displaced threshold.

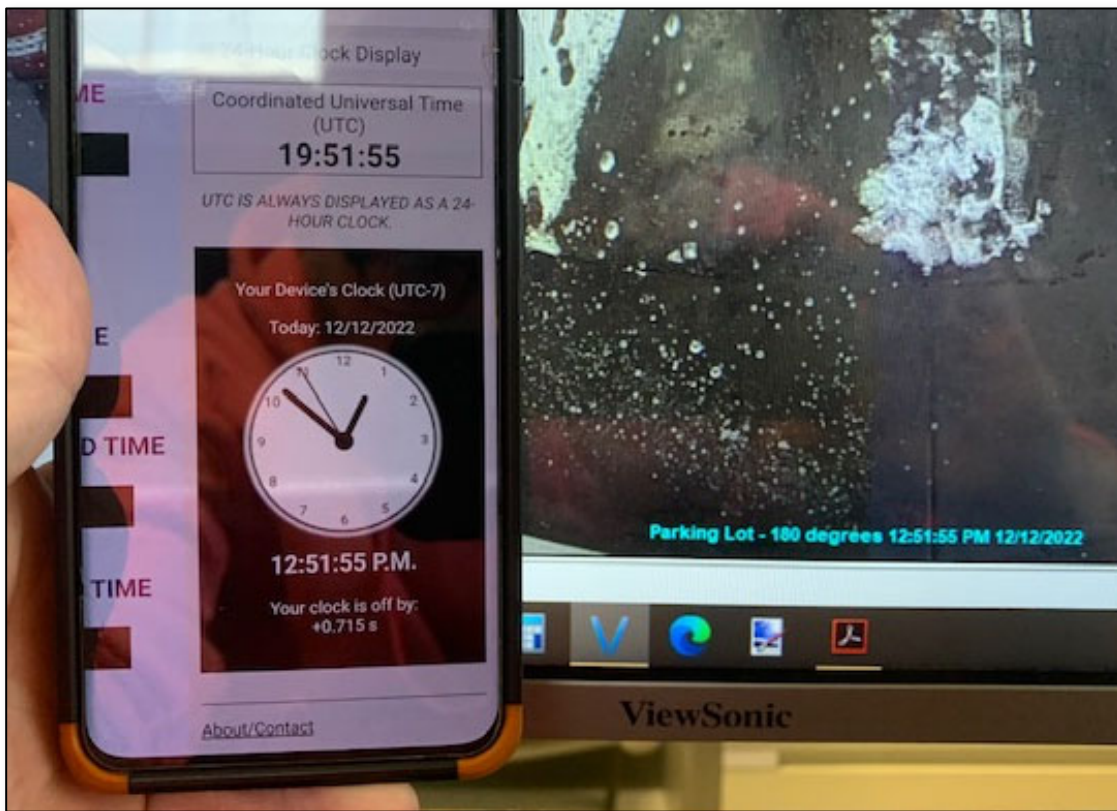


Figure 8a. Photograph showing agreement between potato plant security video time (on computer screen) and official U.S. Naval Observatory time (on mobile phone).

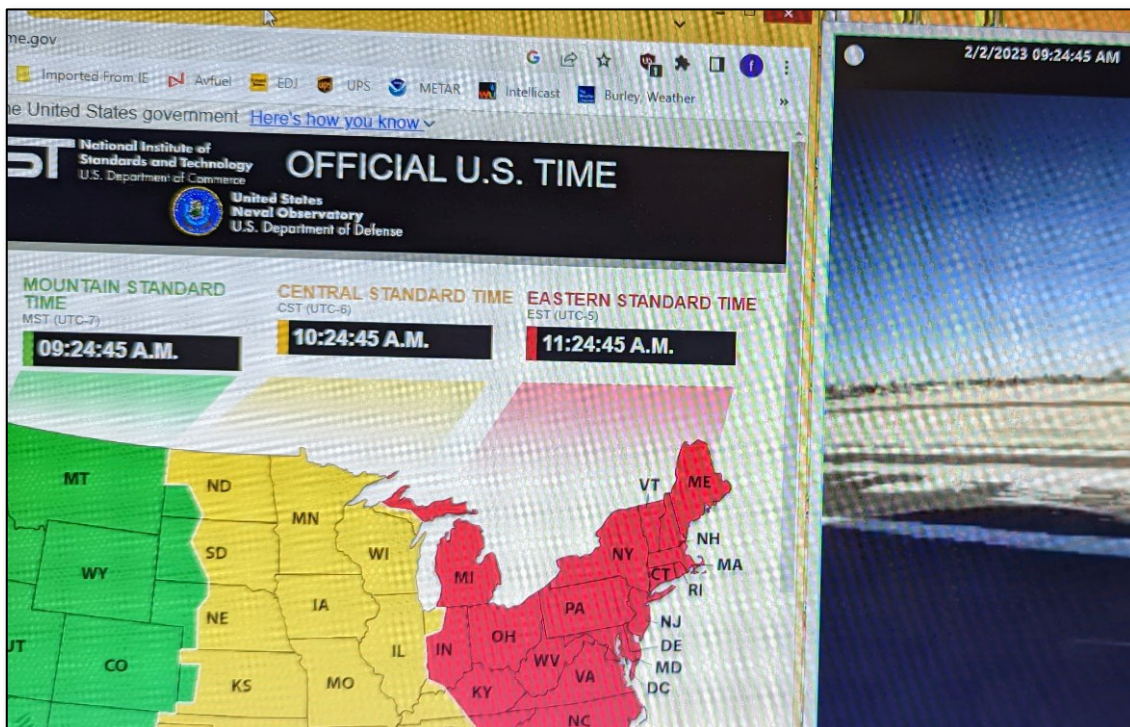


Figure 8b. Photograph showing agreement between KBYI security video time (on the right) and official U.S. Naval Observatory time (on the left).



(a) 08:12:22.59 MDT.



(b) 08:12:23.19 MDT.



(c) 08:12:24.24 MDT.

Figure 9. Surveillance video frames showing N928JP flying over KBYI runway 20.

WPR22FA151: Cessna 208B, N928JP, Heyburn, ID, 04/13/2022

North & east coordinates vs. time during first approach to KBYI runway 20

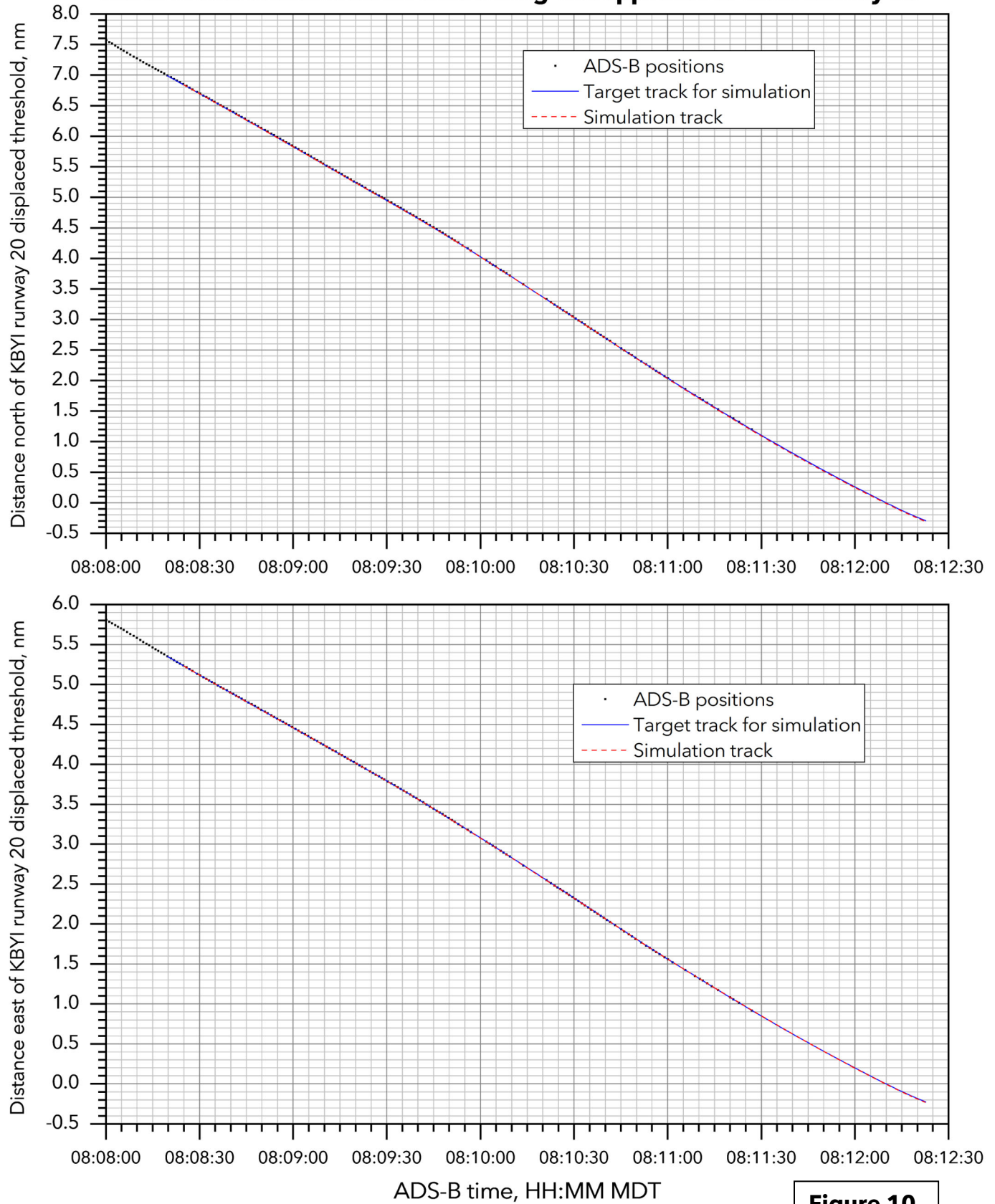


Figure 10.

WPR22FA151: Cessna 208B, N928JP, Heyburn, ID, 04/13/2022

Altitude vs. time during first approach to KBYI runway 20

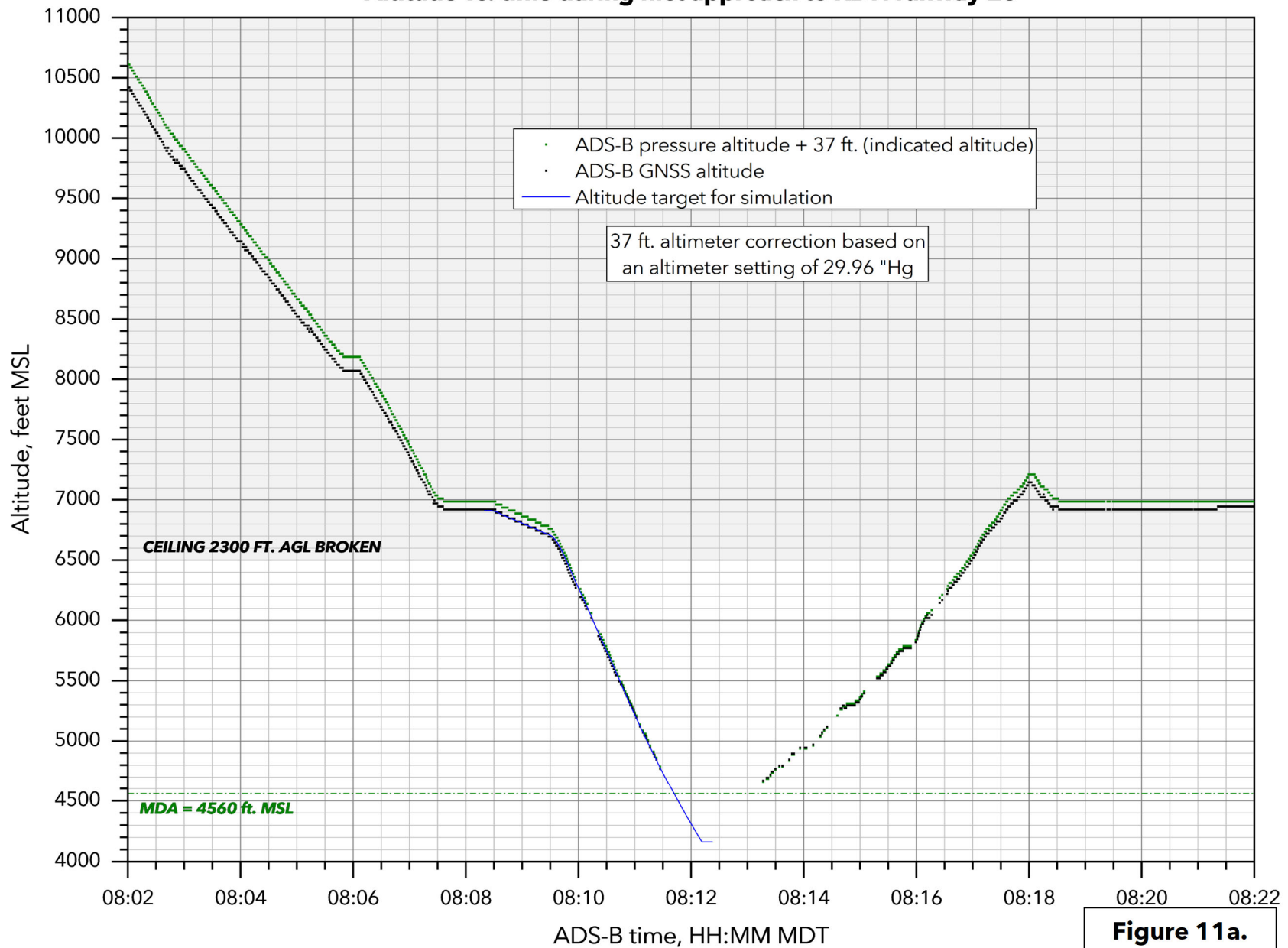


Figure 11a.

WPR22FA151: Cessna 208B, N928JP, Heyburn, ID, 04/13/2022

Altitude vs. time during first approach to KBYI runway 20 (detail)

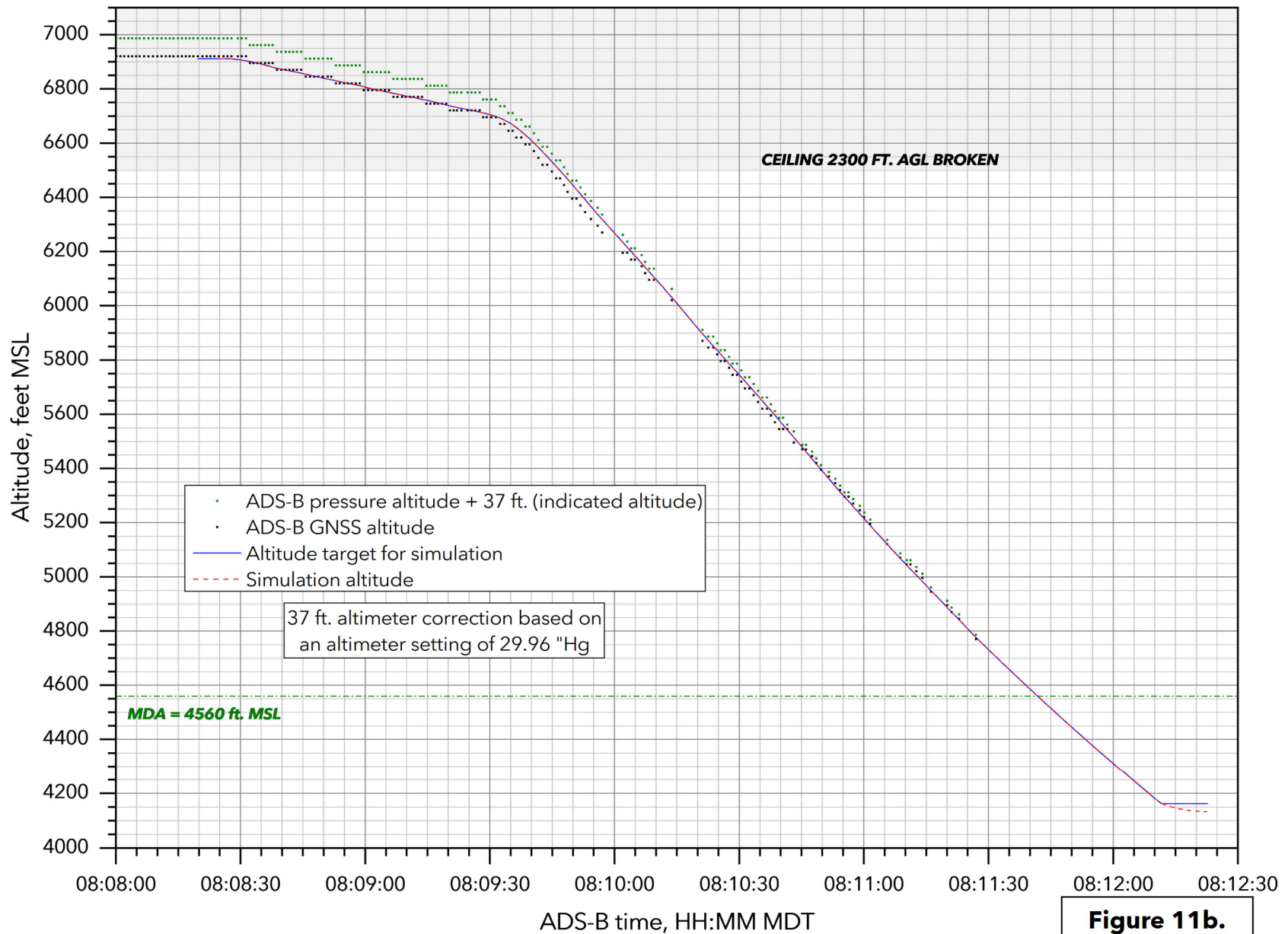


Figure 11b.

WPR22FA151: Cessna 208B, N928JP, Heyburn, ID, 04/13/2022

Altitude vs. distance during first approach to KBYI runway 20

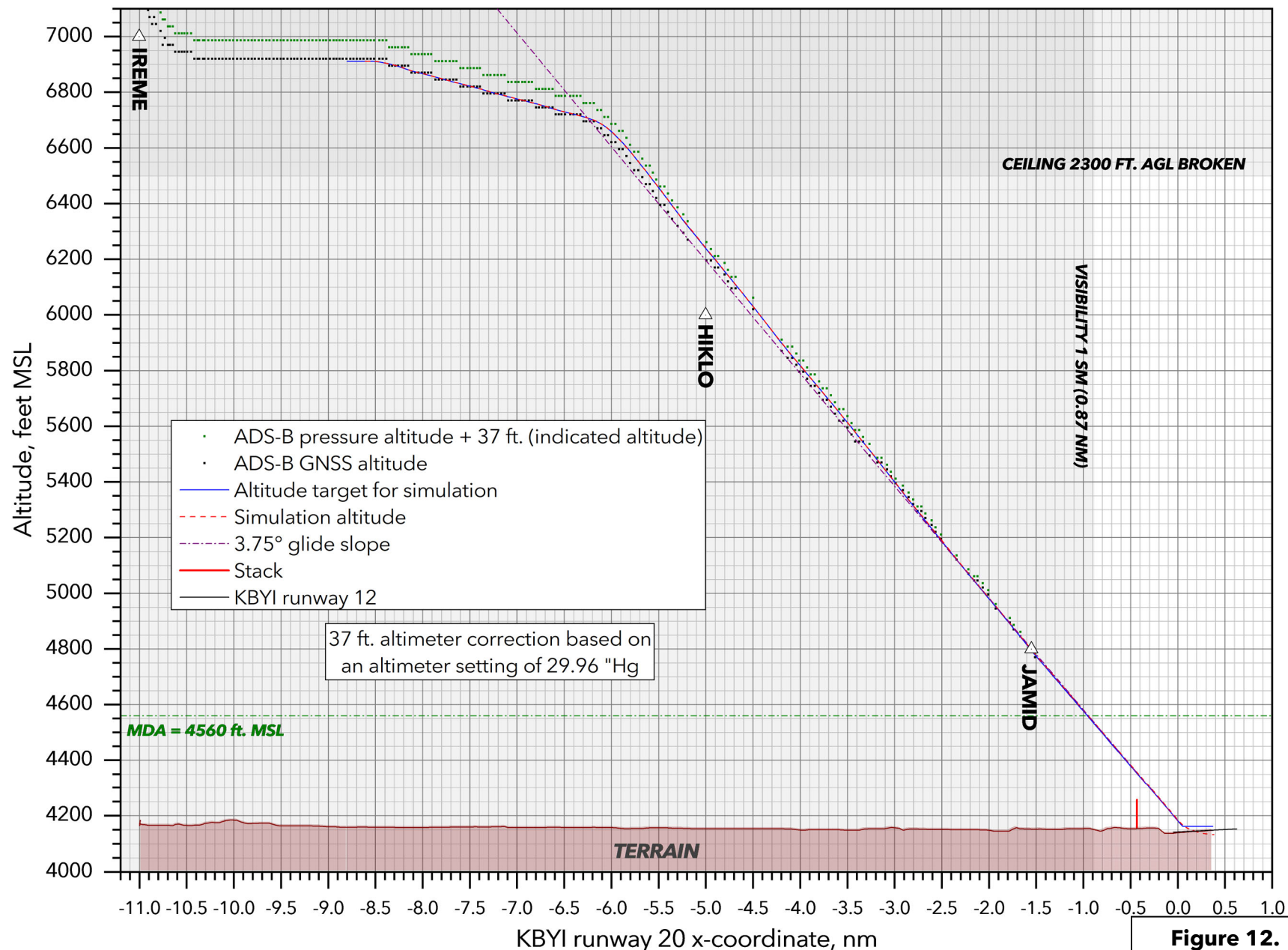


Figure 12.

WPR22FA151: Cessna 208B, N928JP, Heyburn, ID, 04/13/2022

Speeds, rate of climb, & γ vs. time during first approach to KBYI runway 20

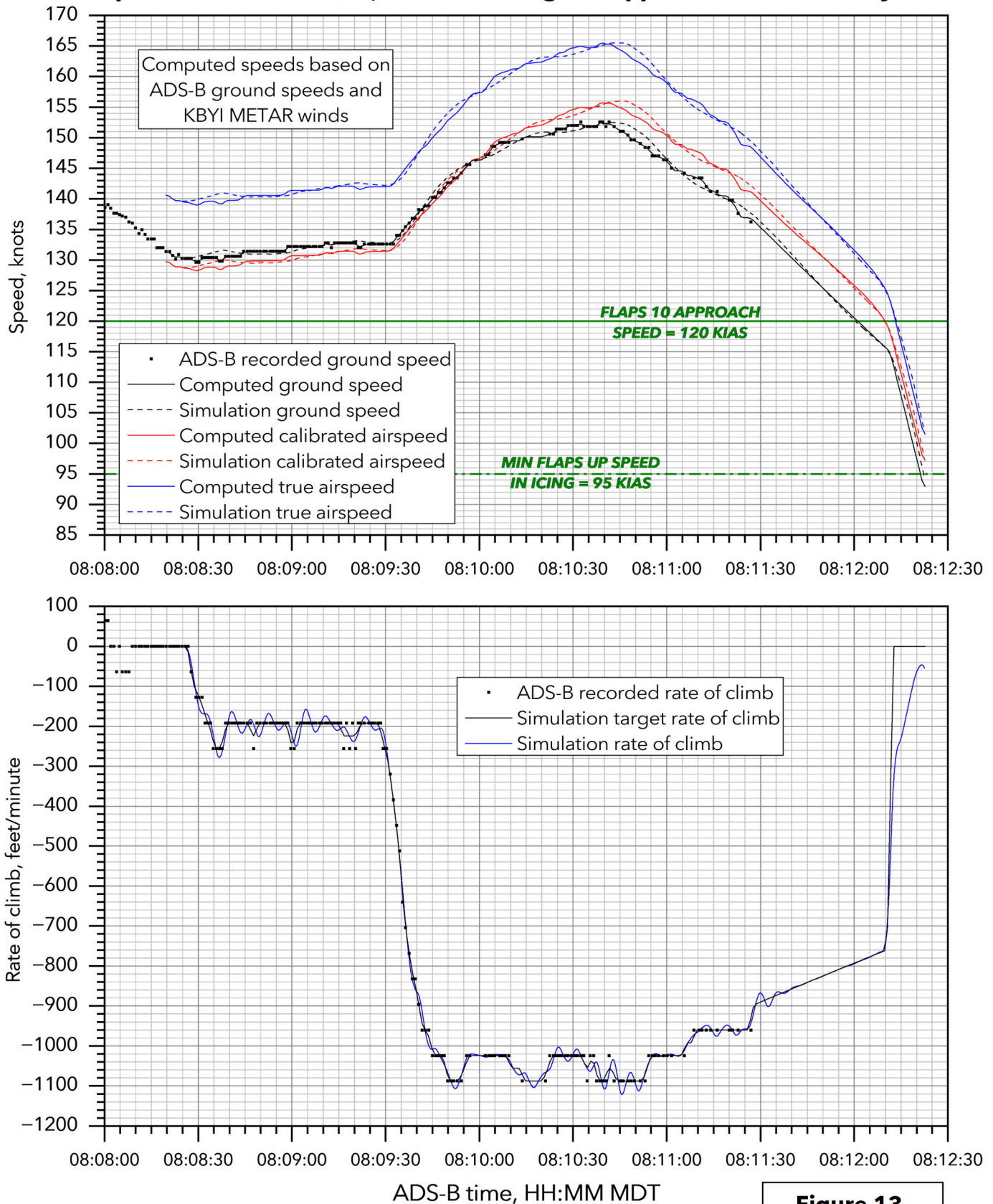


Figure 13.

WPR22FA151: Cessna 208B, N928JP, Heyburn, ID, 04/13/2022

Speeds, rate of climb, & γ vs. distance during first approach to KBYI runway 20

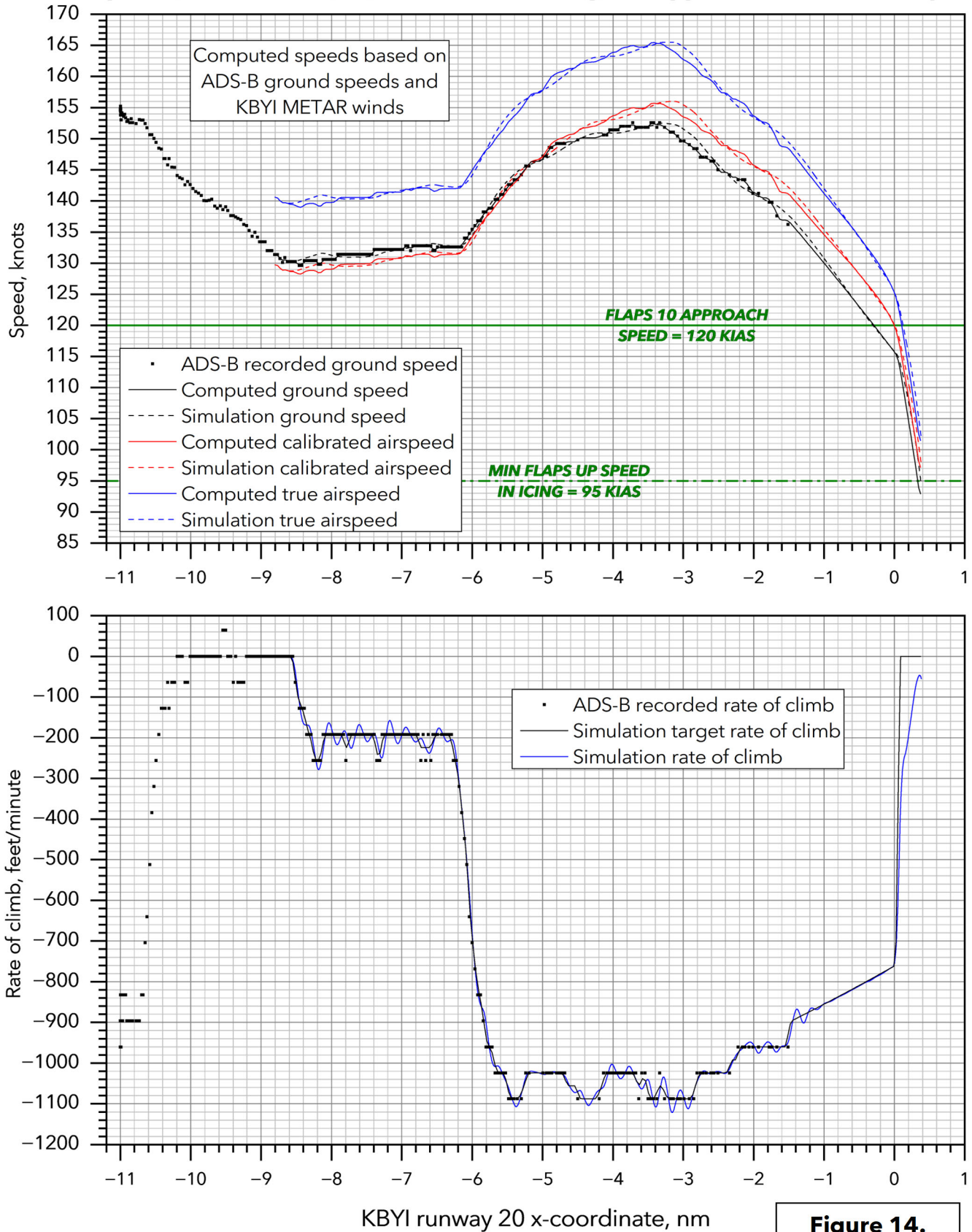


Figure 14.

WPR22FA151: Cessna 208B, N928JP, Heyburn, ID, 04/13/2022

Pitch & power vs. time during first approach to KBYI runway 20

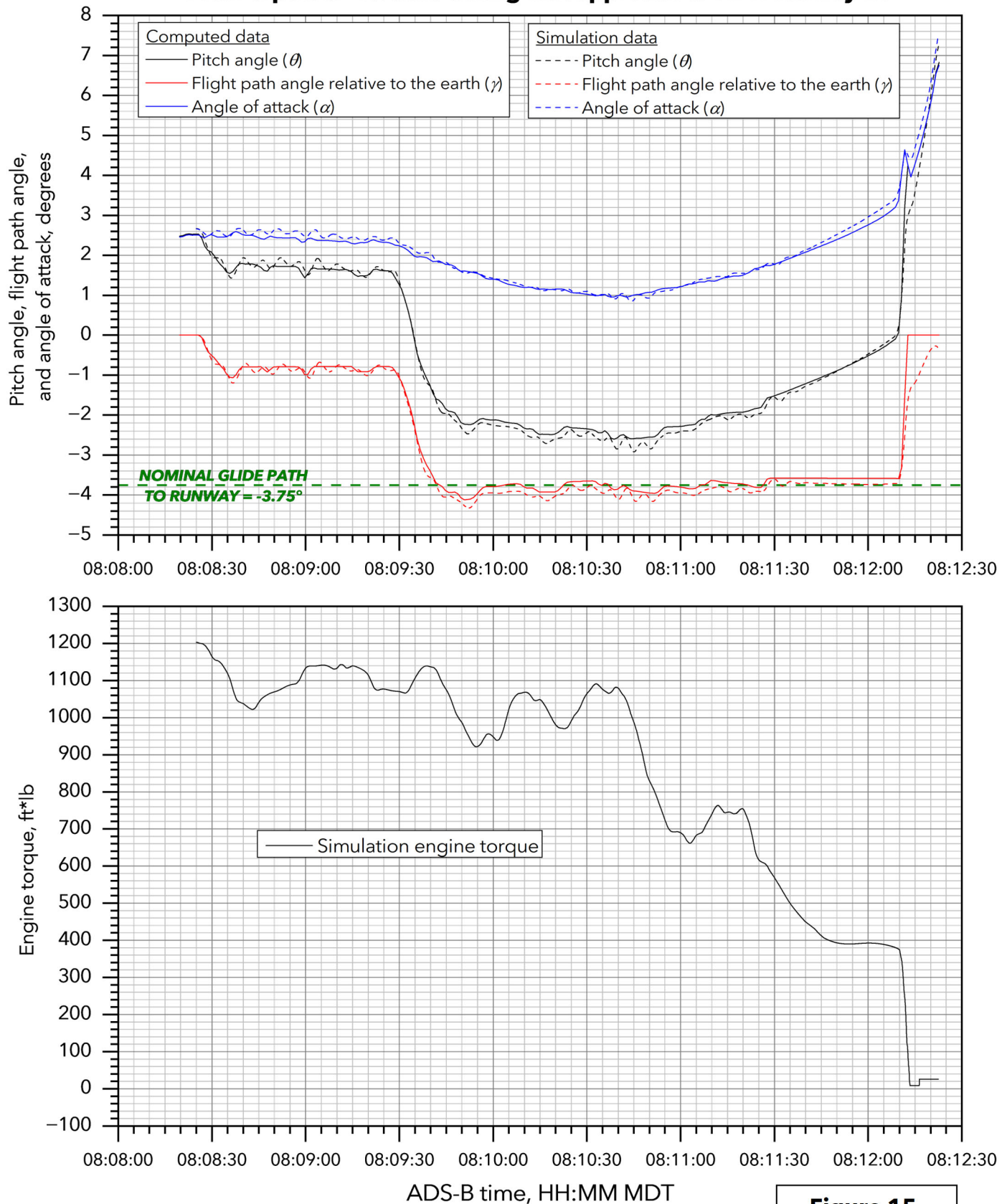


Figure 15.

WPR22FA151: Cessna 208B, N928JP, Heyburn, ID, 04/13/2022

North & east coordinates vs. time during accident approach to KBYI runway 20

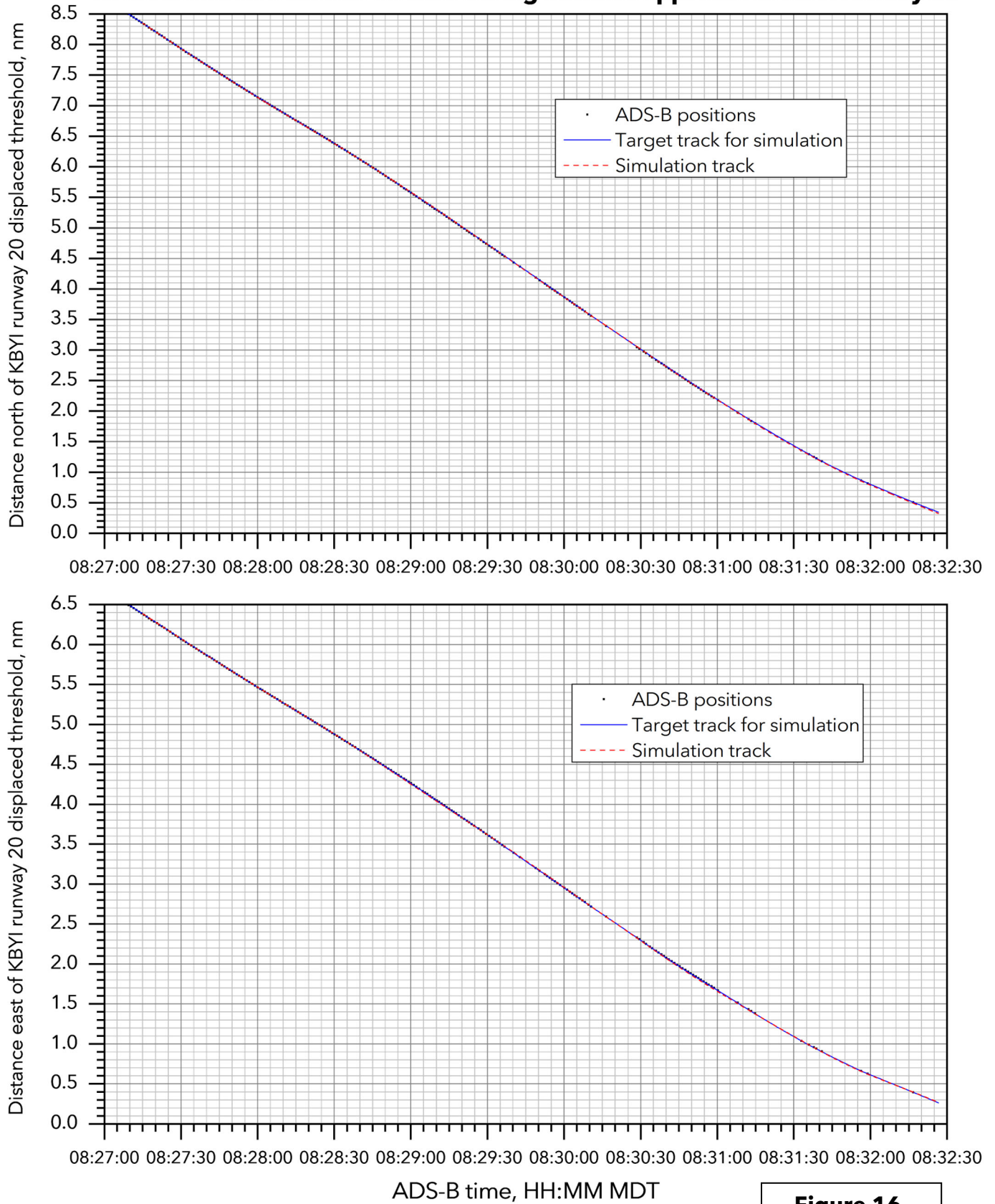
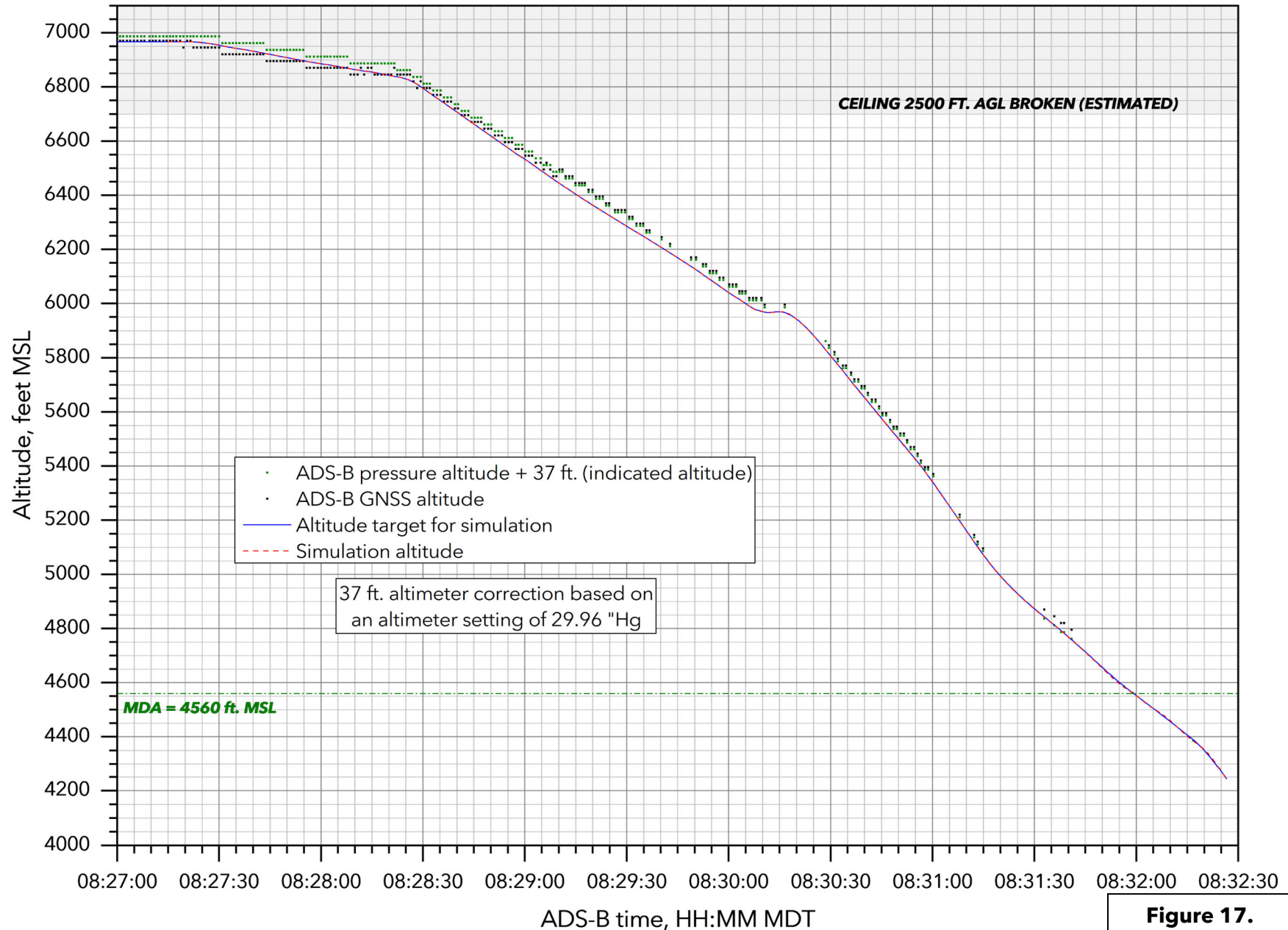


Figure 16.

WPR22FA151: Cessna 208B, N928JP, Heyburn, ID, 04/13/2022

Altitude vs. time during accident approach to KBYI runway 20



WPR22FA151: Cessna 208B, N928JP, Heyburn, ID, 04/13/2022

Altitude vs. distance during accident approach to KBYI runway 20

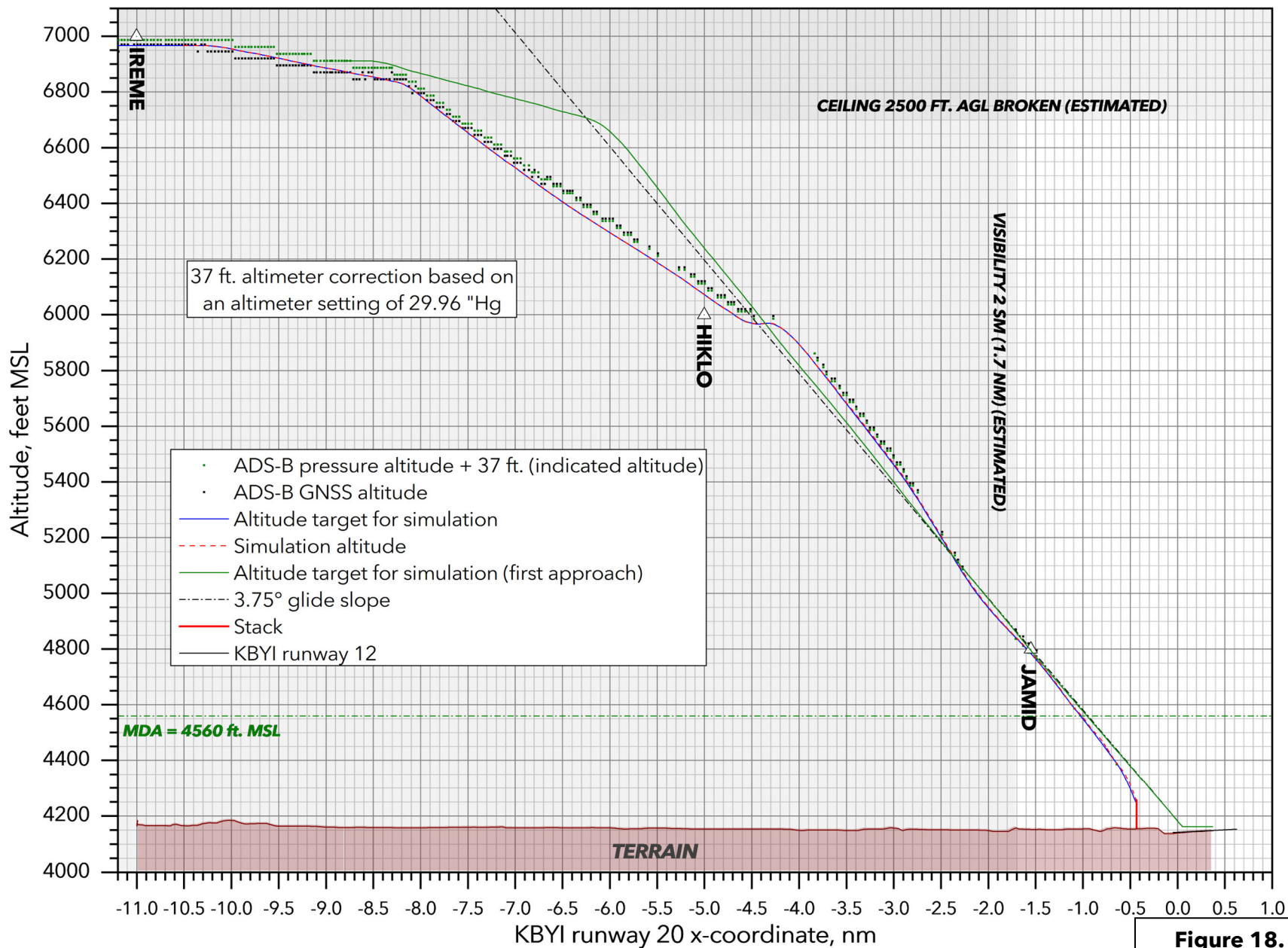


Figure 18.

WPR22FA151: Cessna 208B, N928JP, Heyburn, ID, 04/13/2022

Speeds, rate of climb, & γ vs. time during accident approach to KBYI runway 20

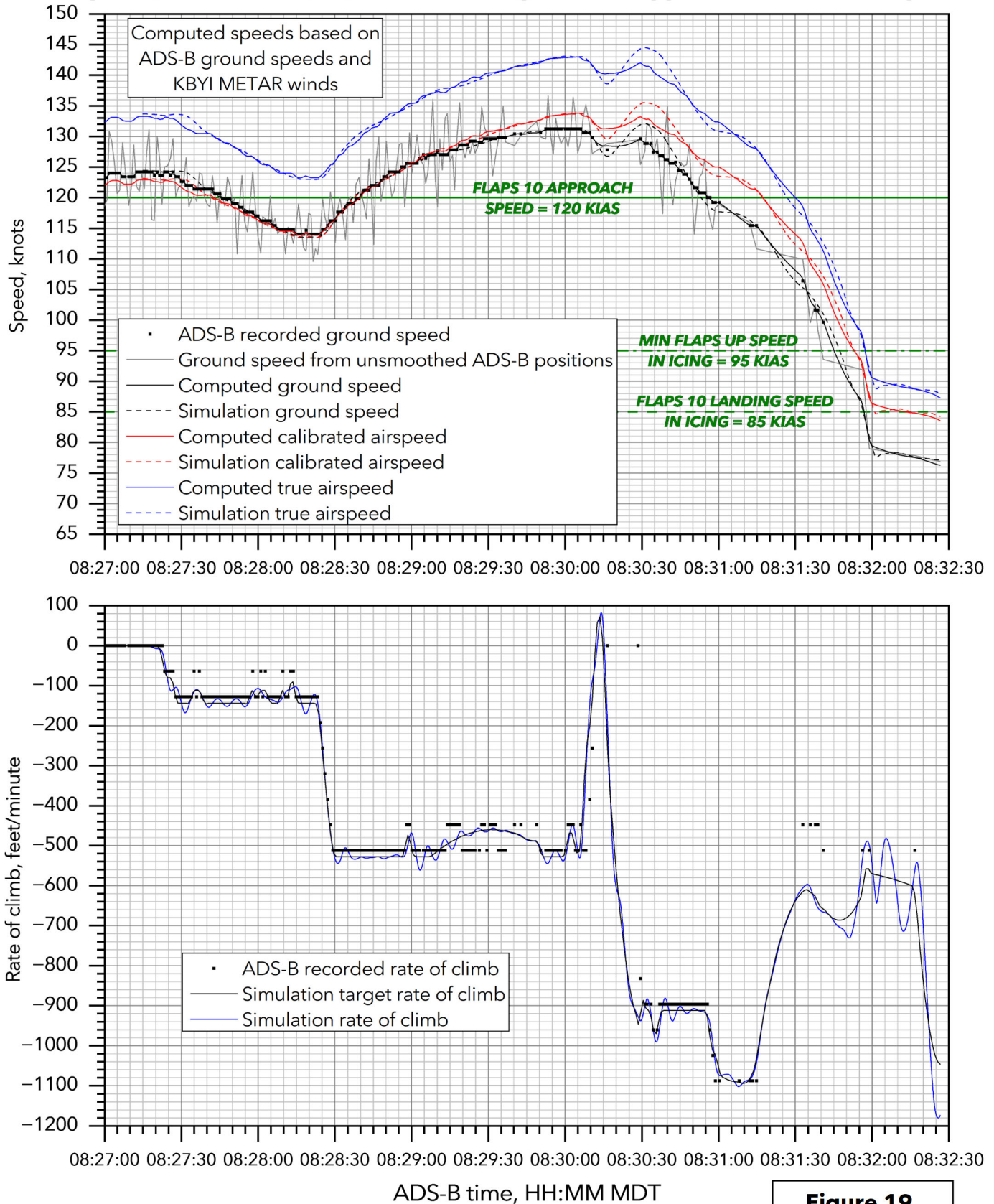


Figure 19.

WPR22FA151: Cessna 208B, N928JP, Heyburn, ID, 04/13/2022

Speeds, rate of climb, & γ vs. distance during accident approach to KBYI runway 20

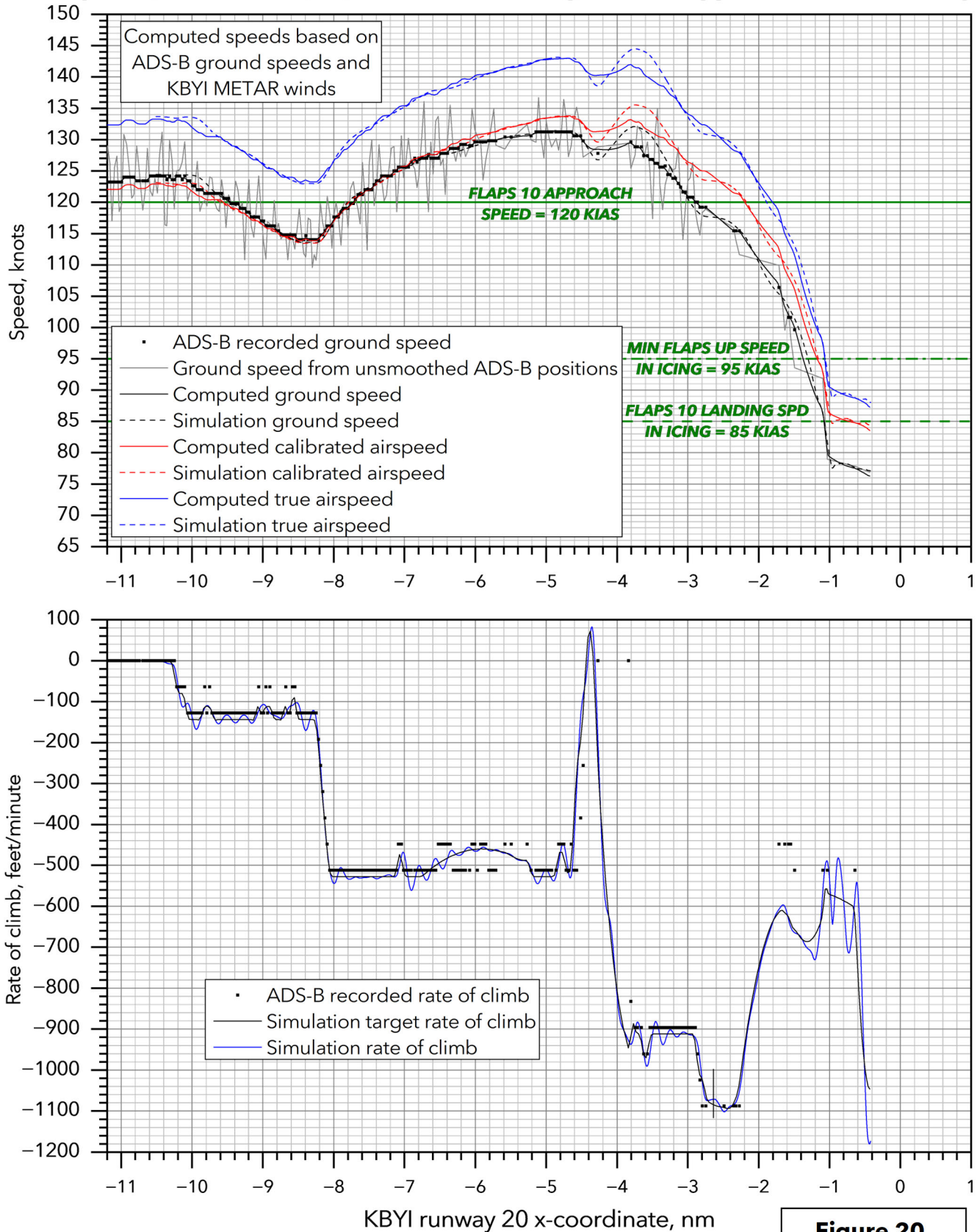


Figure 20.

WPR22FA151: Cessna 208B, N928JP, Heyburn, ID, 04/13/2022

Pitch & power vs. time during accident approach to KBYI runway 20

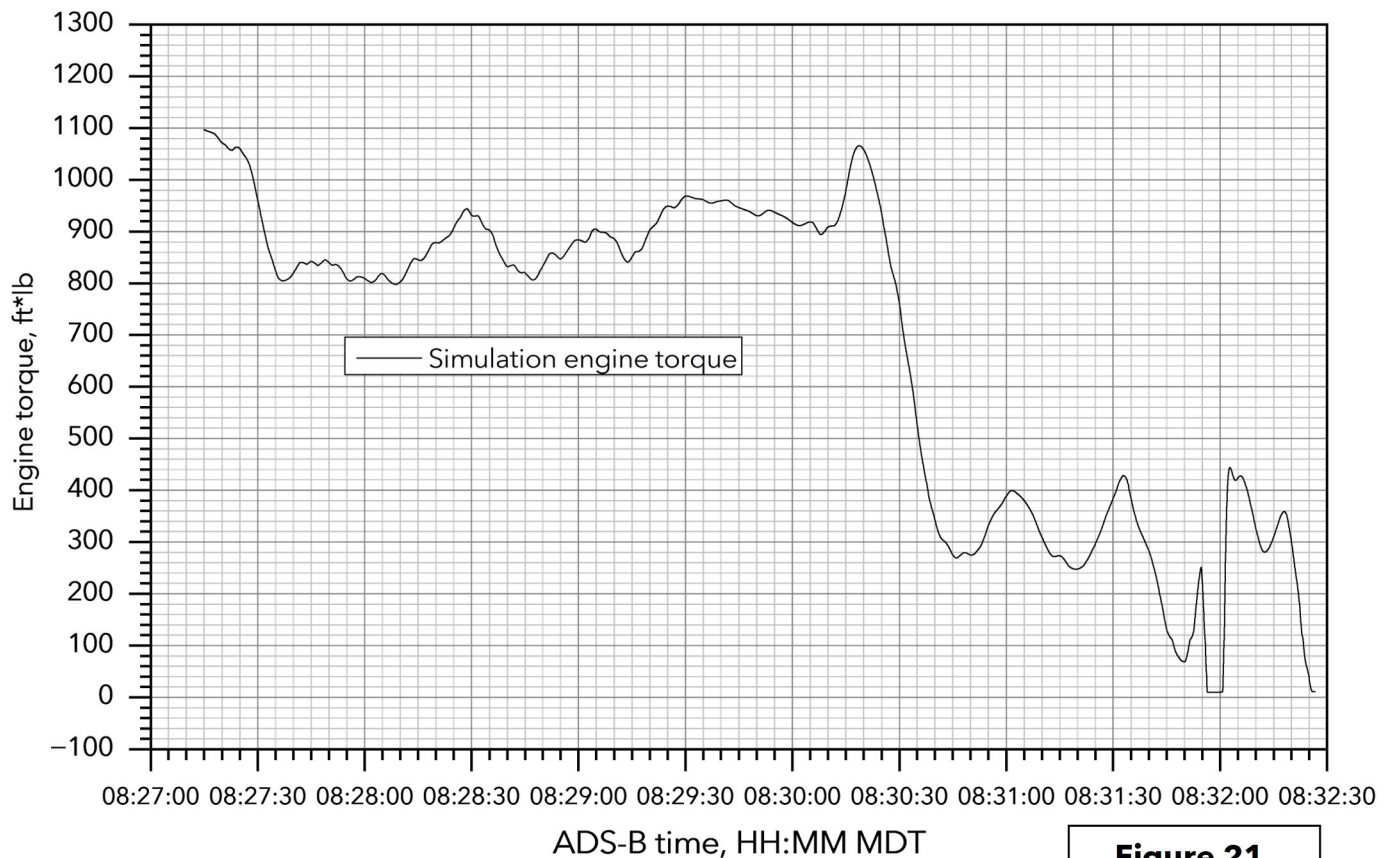
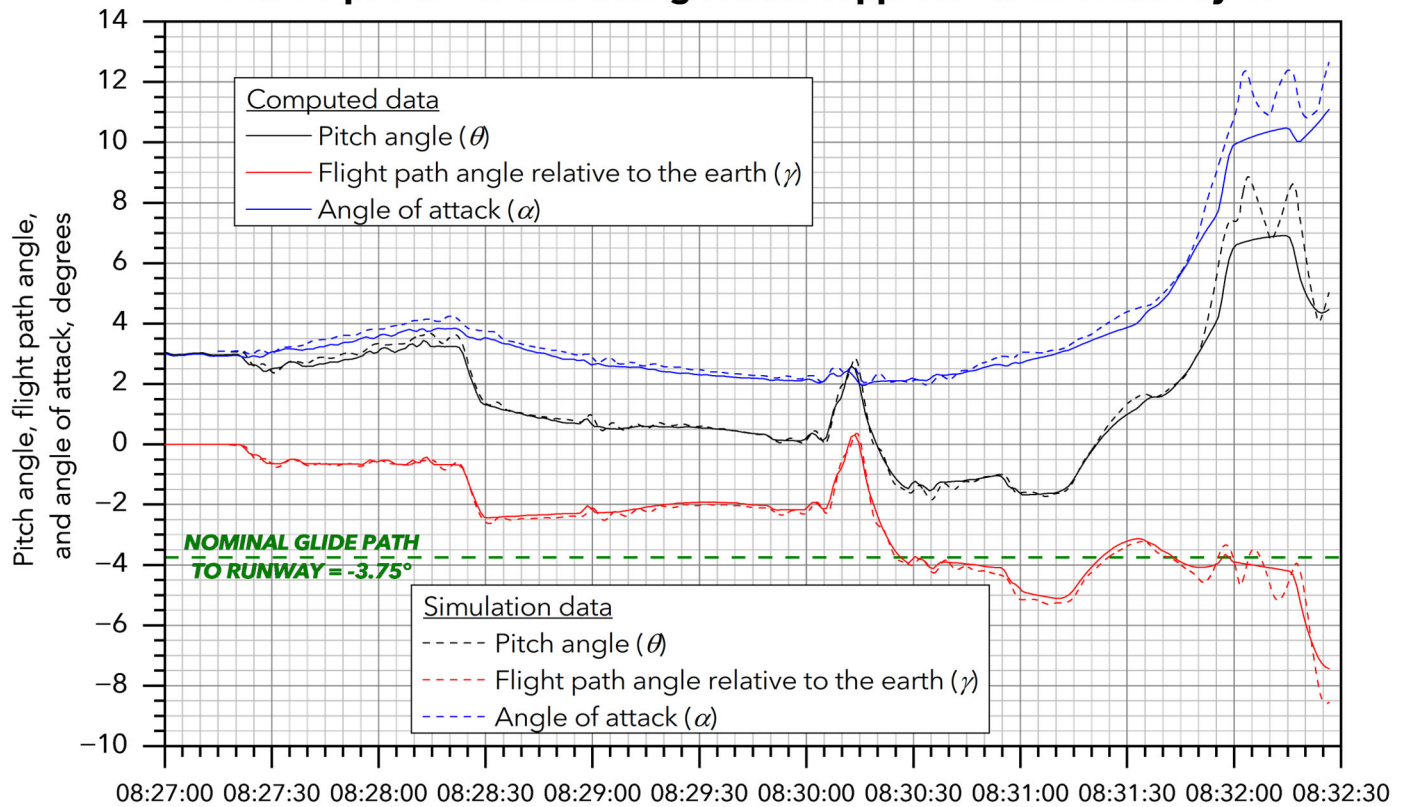


Figure 21.

WPR22FA151: Cessna 208B, N928JP, Heyburn, ID, 04/13/2022

Pitch & power vs. distance during accident approach to KBYI runway 20

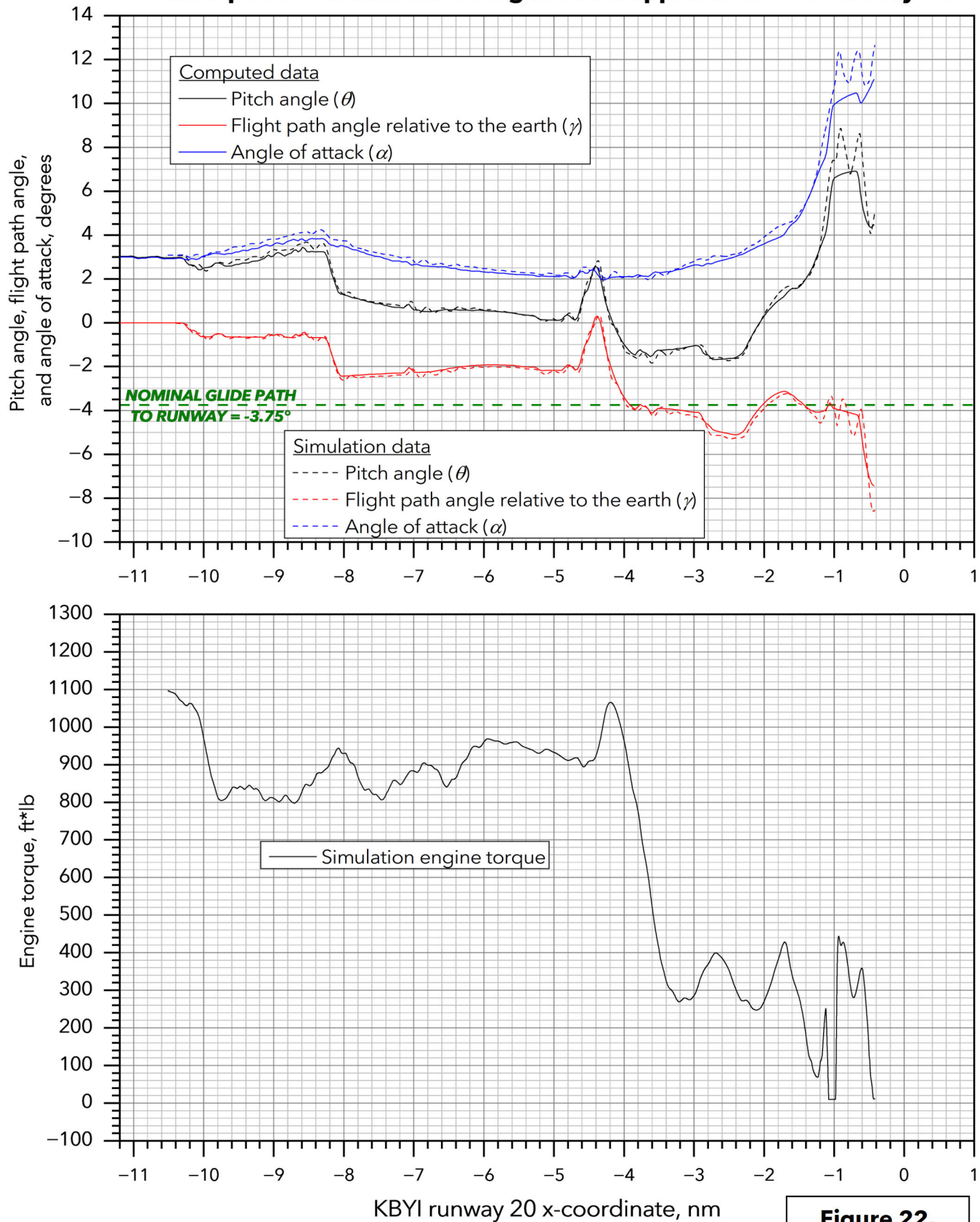


Figure 22.

WPR22FA151: Cessna 208B, N928JP, Heyburn, ID, 04/13/2022

Runway x coordinate vs. time during approaches to KBYI runway 20

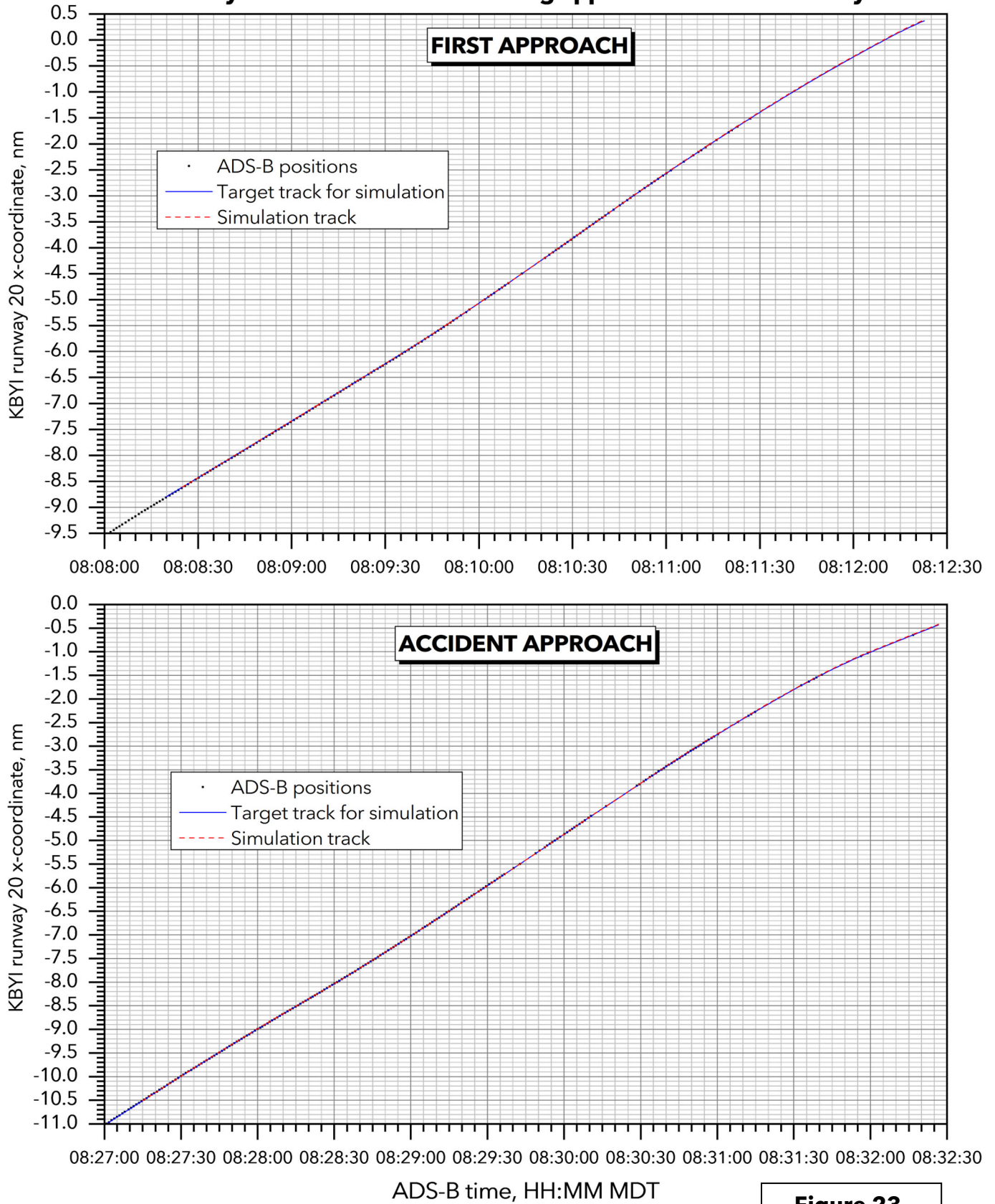


Figure 23.

WPR22FA151: Cessna 208B, N928JP, Heyburn, ID, 04/13/2022

Speeds, rate of climb, & γ vs. runway x coordinate during approaches to KBYI runway 20

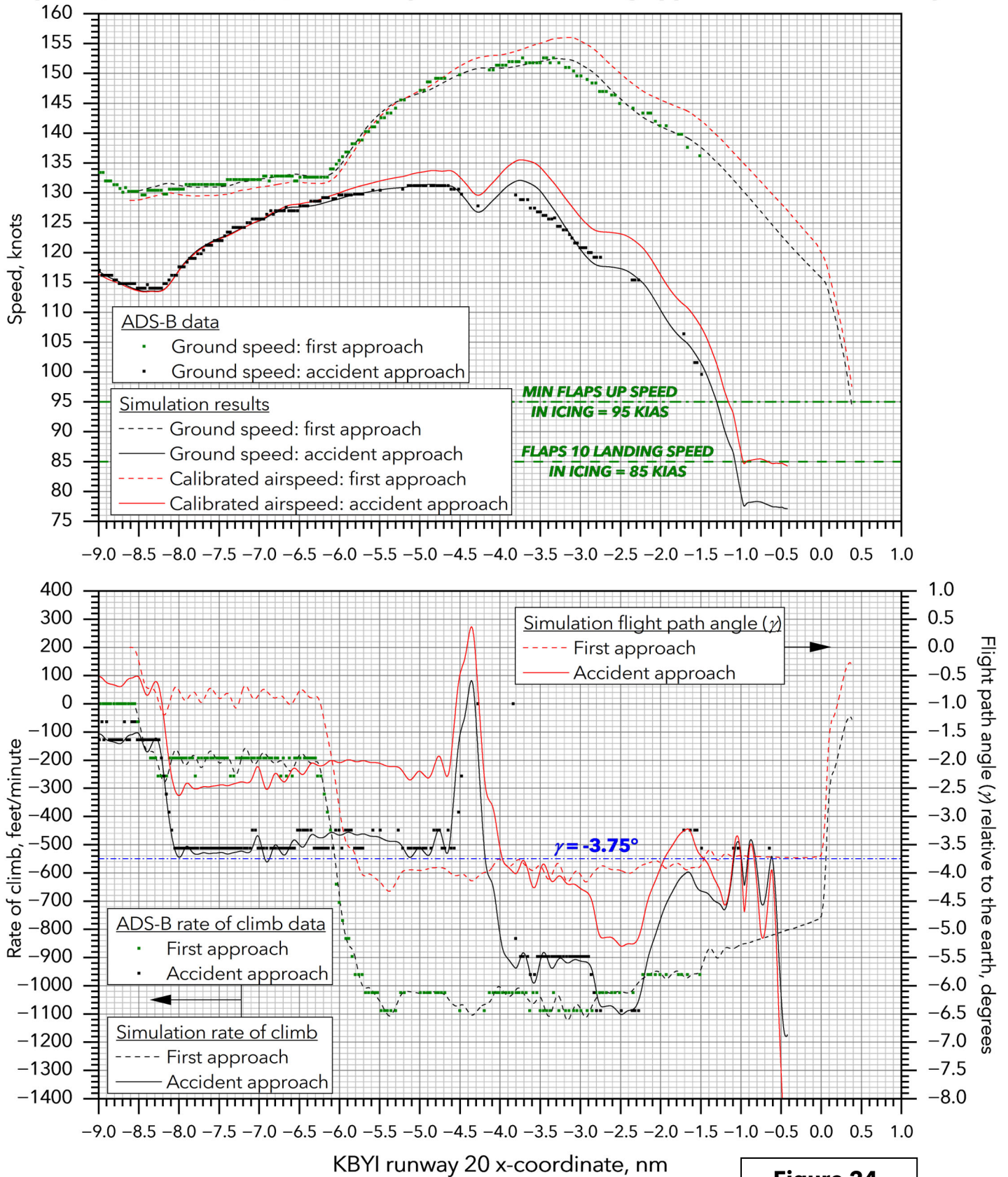


Figure 24.

WPR22FA151: Cessna 208B, N928JP, Heyburn, ID, 04/13/2022

Speeds & C_L vs. runway x coordinate during approaches to KBYI runway 20

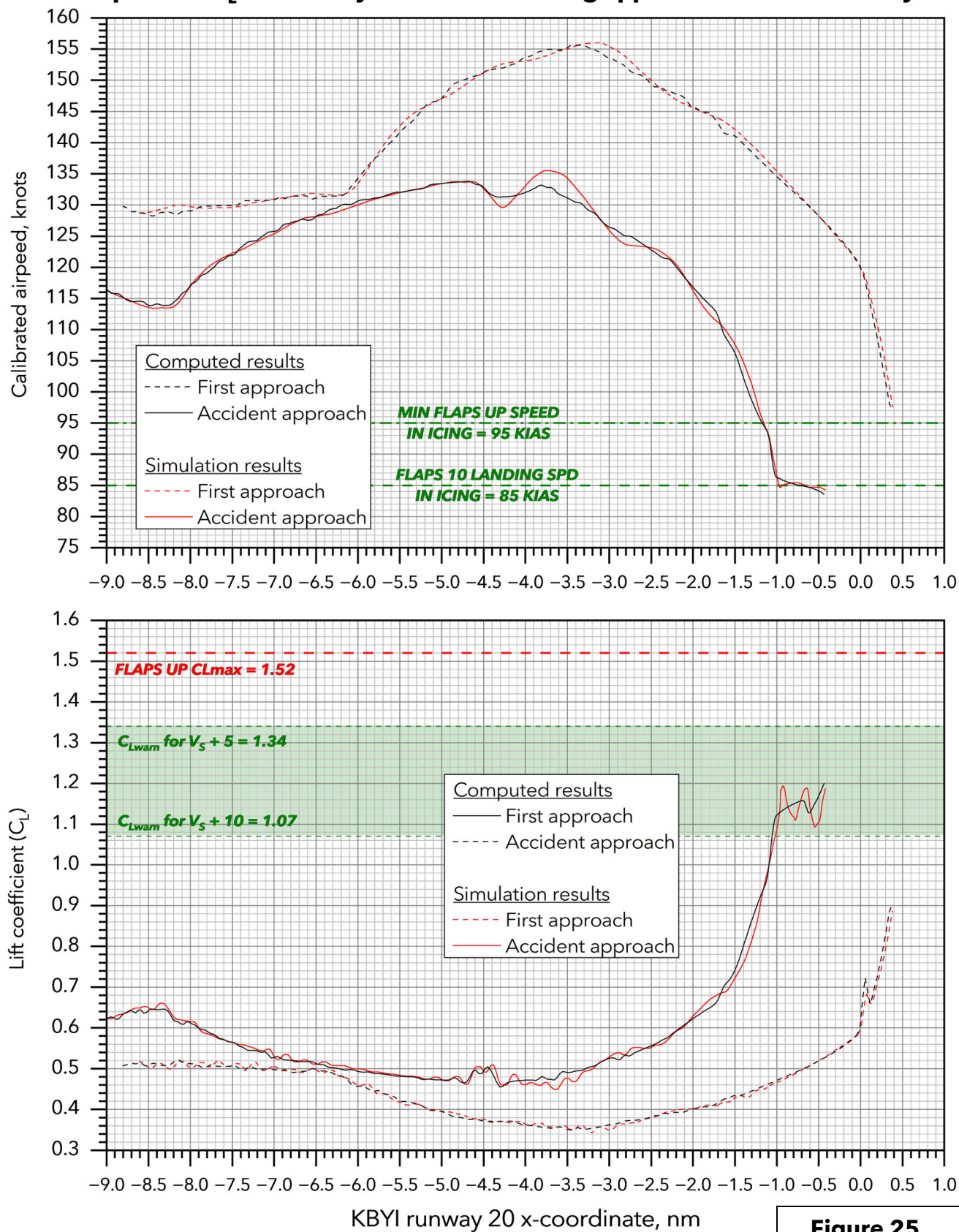


Figure 25.

WPR22FA151: Cessna 208B, N928JP, Heyburn, ID, 04/13/2022

Altitude comparisons: ADS-B data from known flights vs. ADAS data from unknown flights

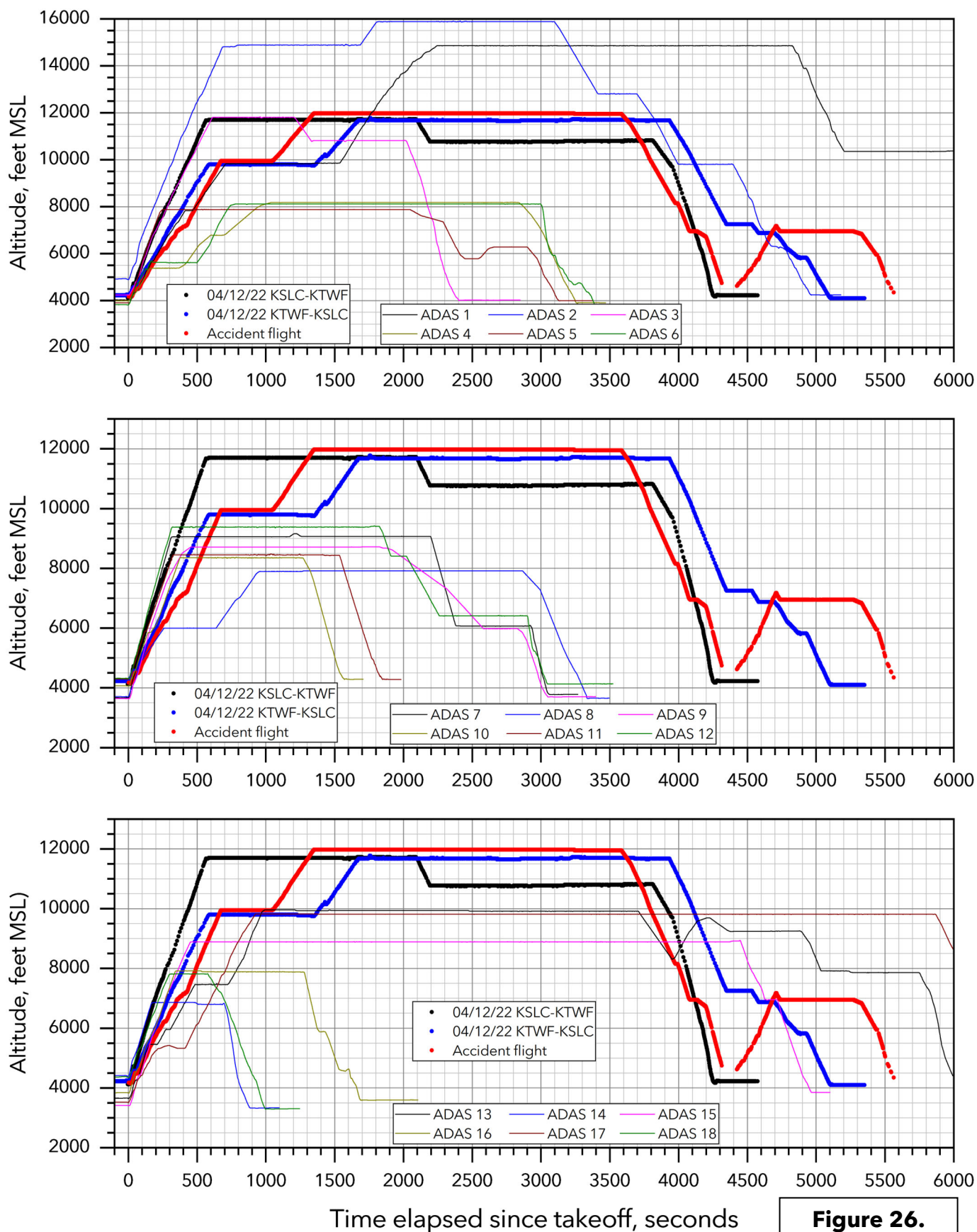


Figure 26.

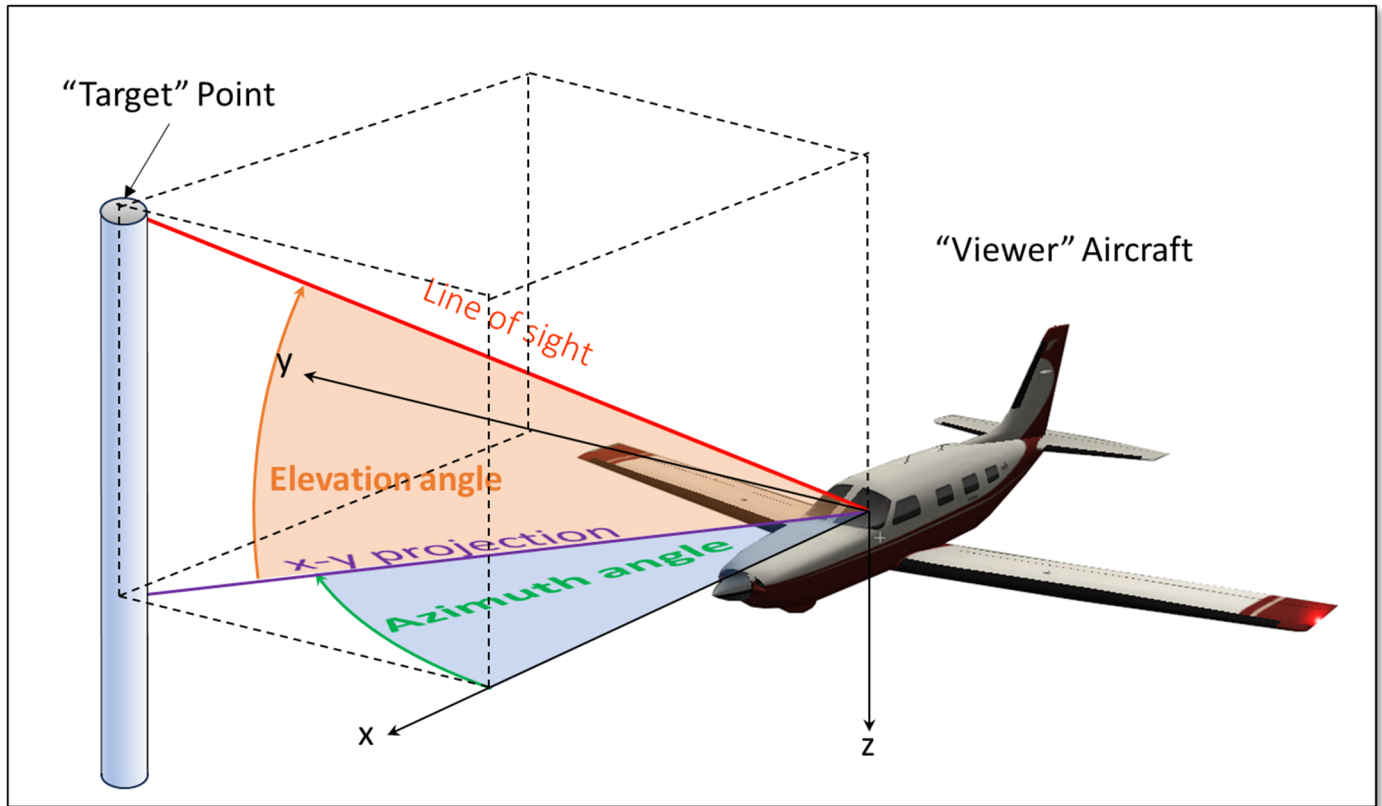


Figure 27. Azimuth and elevation angles from “viewer” airplane to “target” point.

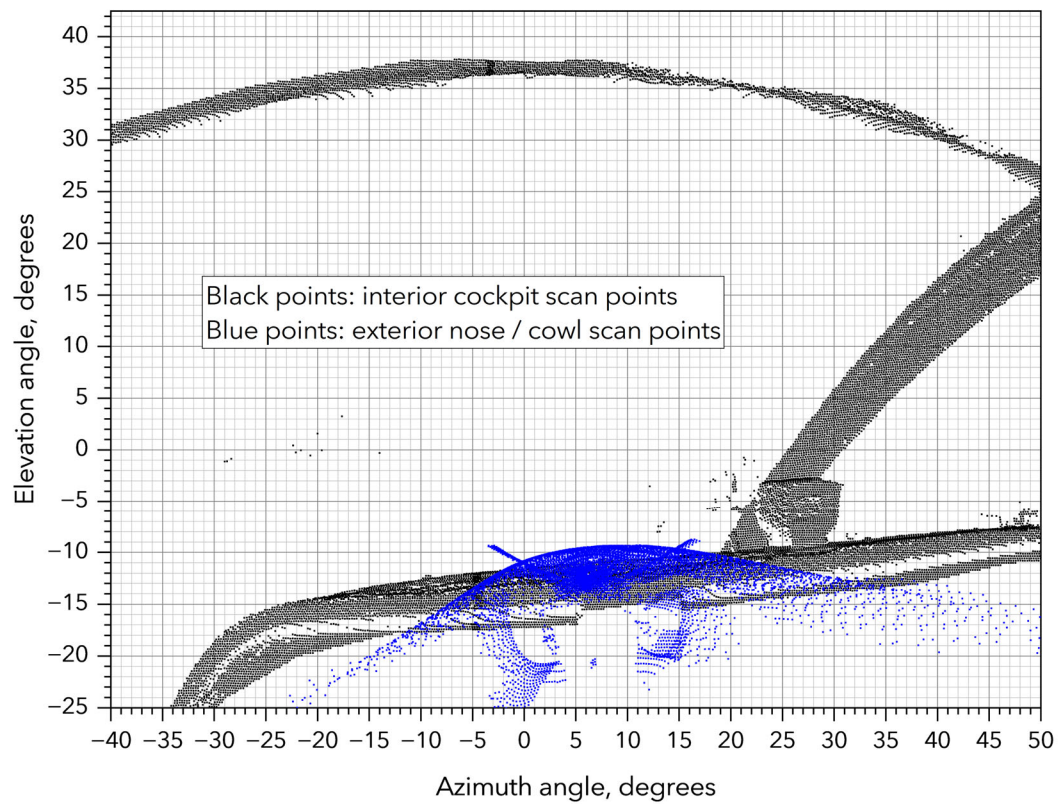


Figure 28a. Azimuth and elevation angles from scan of exemplar C208B.



Figure 28b. Instrument panel “mask” for FSX constructed from C208B laser scan data. Black color denotes transparency (windshield); gray color denotes structure (cockpit / cowl).

WPR22FA151: Cessna 208B, N928JP, Heyburn, ID, 04/13/2022

Azimuth & elevation visibility angles from cockpit to stack (accident approach)

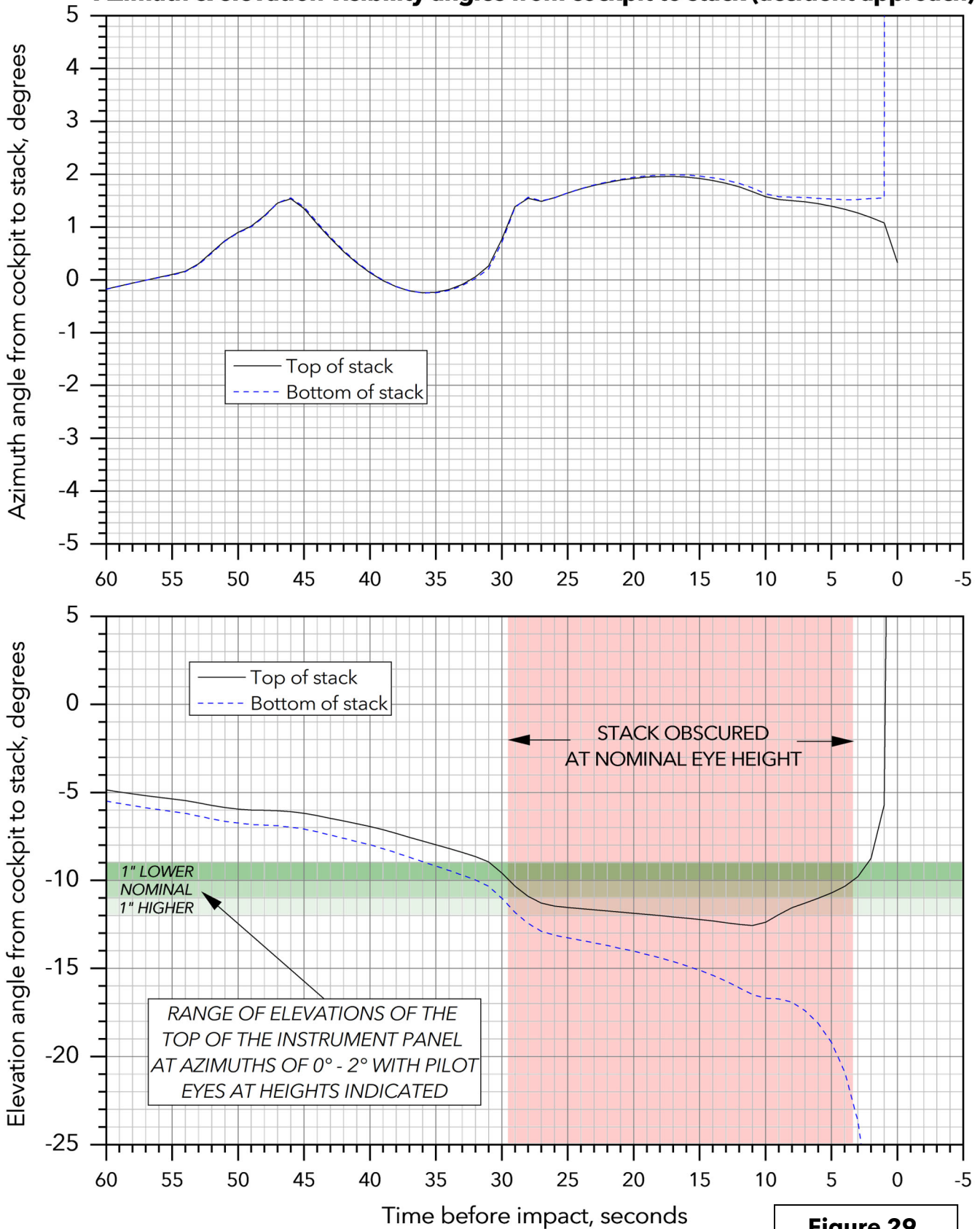


Figure 29.

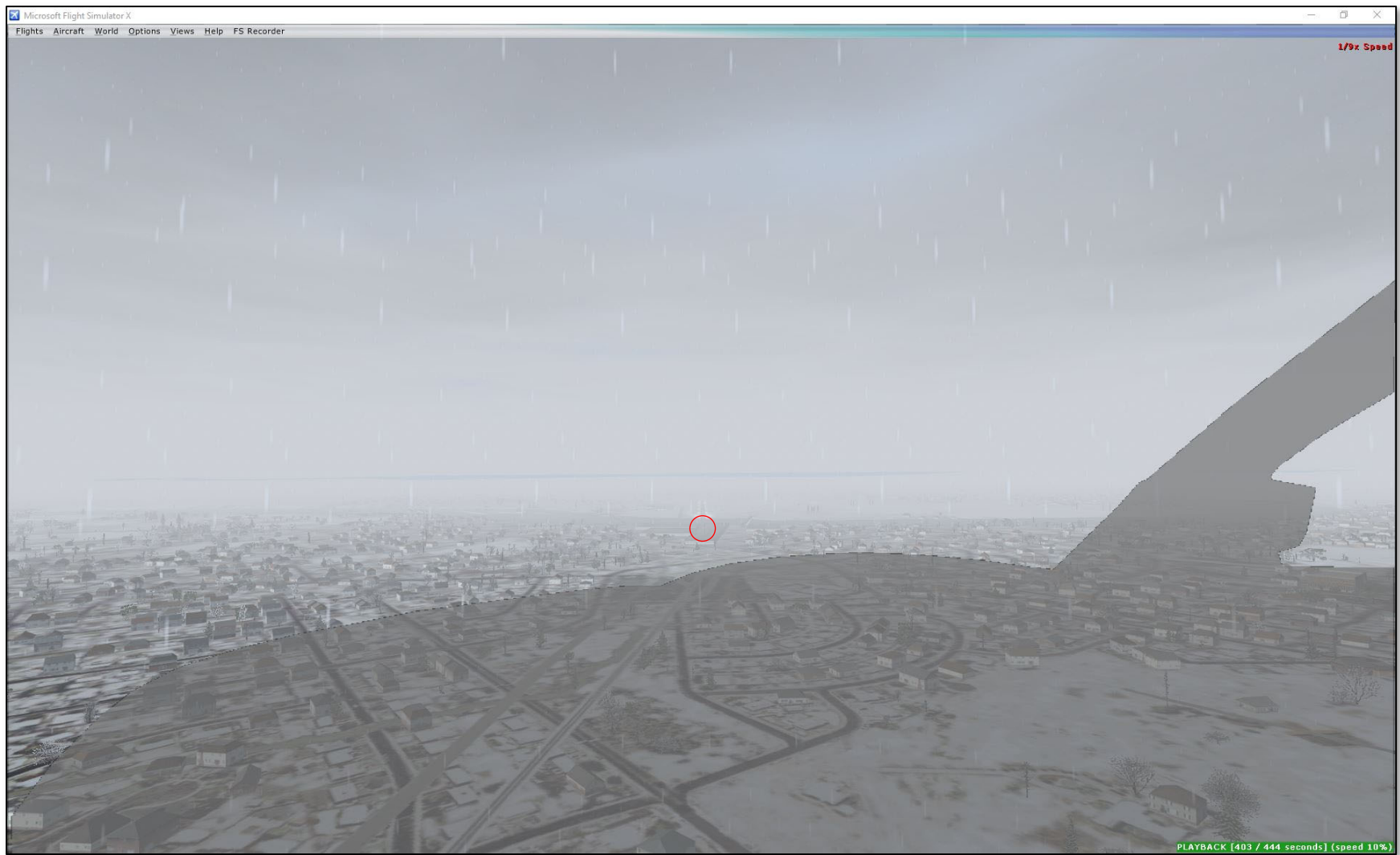


Figure 30a. FSX cockpit view at 08:31:46.6 (40 seconds before impact). The red circle locates the exhaust stack.



Figure 30b. FSX cockpit view at 08:31:51.6 (35 seconds before impact). The red circle locates the exhaust stack.

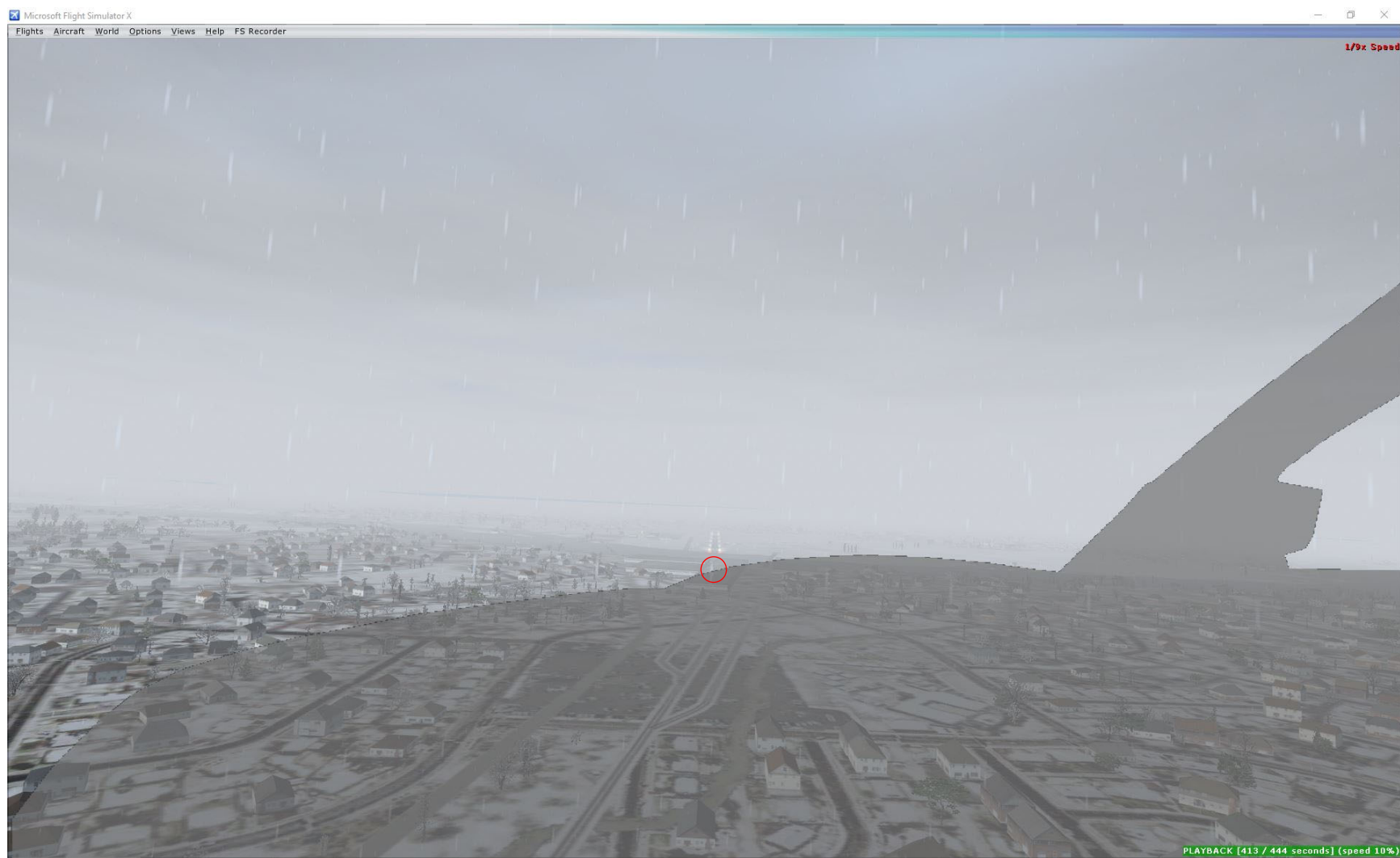


Figure 30c. FSX cockpit view at 08:31:56.6 (30 seconds before impact). The red circle locates the exhaust stack.



Figure 30d. FSX cockpit view at 08:32:01.6 (25 seconds before impact). The red circle locates the exhaust stack.

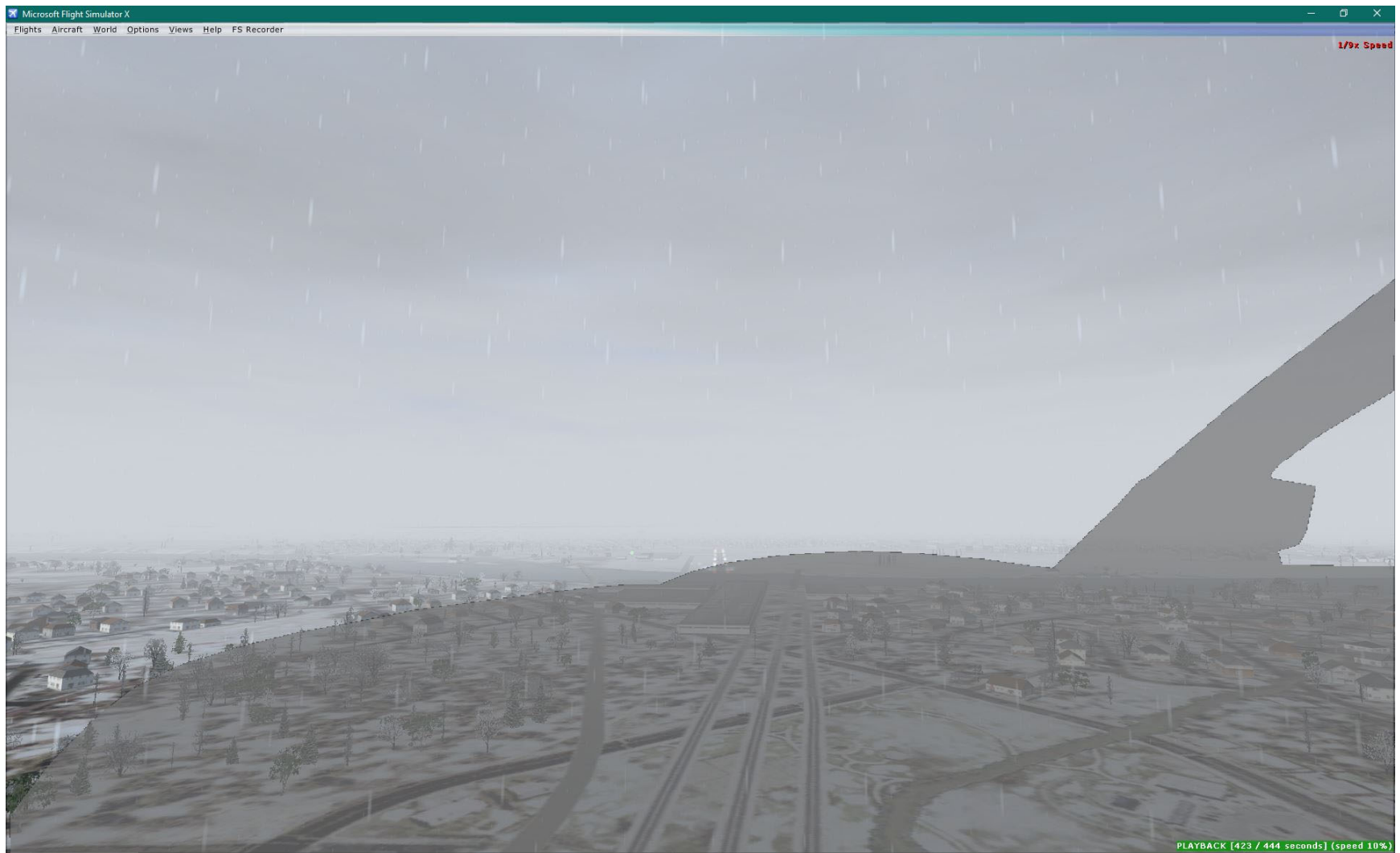


Figure 30e. FSX cockpit view at 08:32:06.6 (20 seconds before impact).

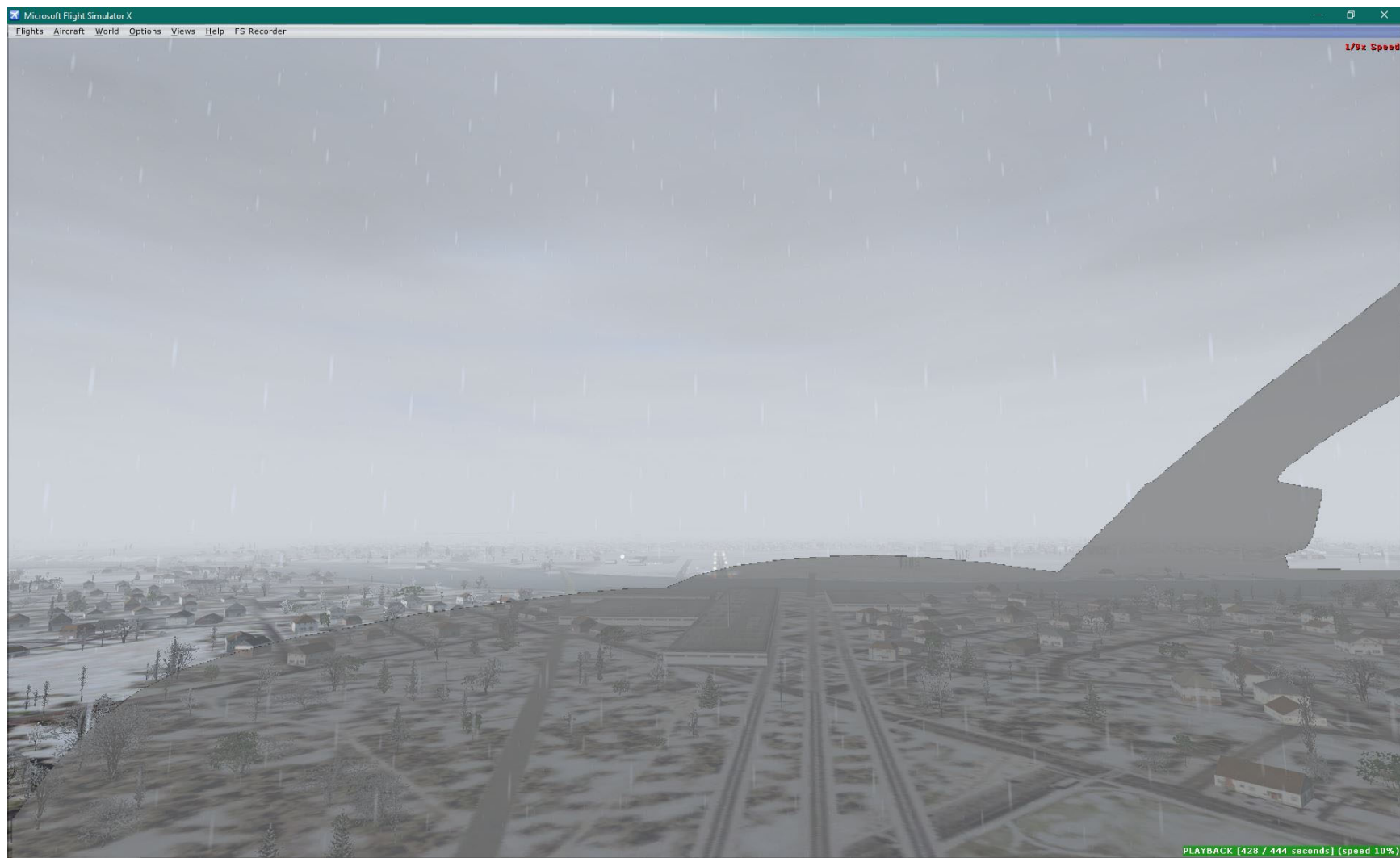


Figure 30f. FSX cockpit view at 08:32:11.6 (15 seconds before impact).

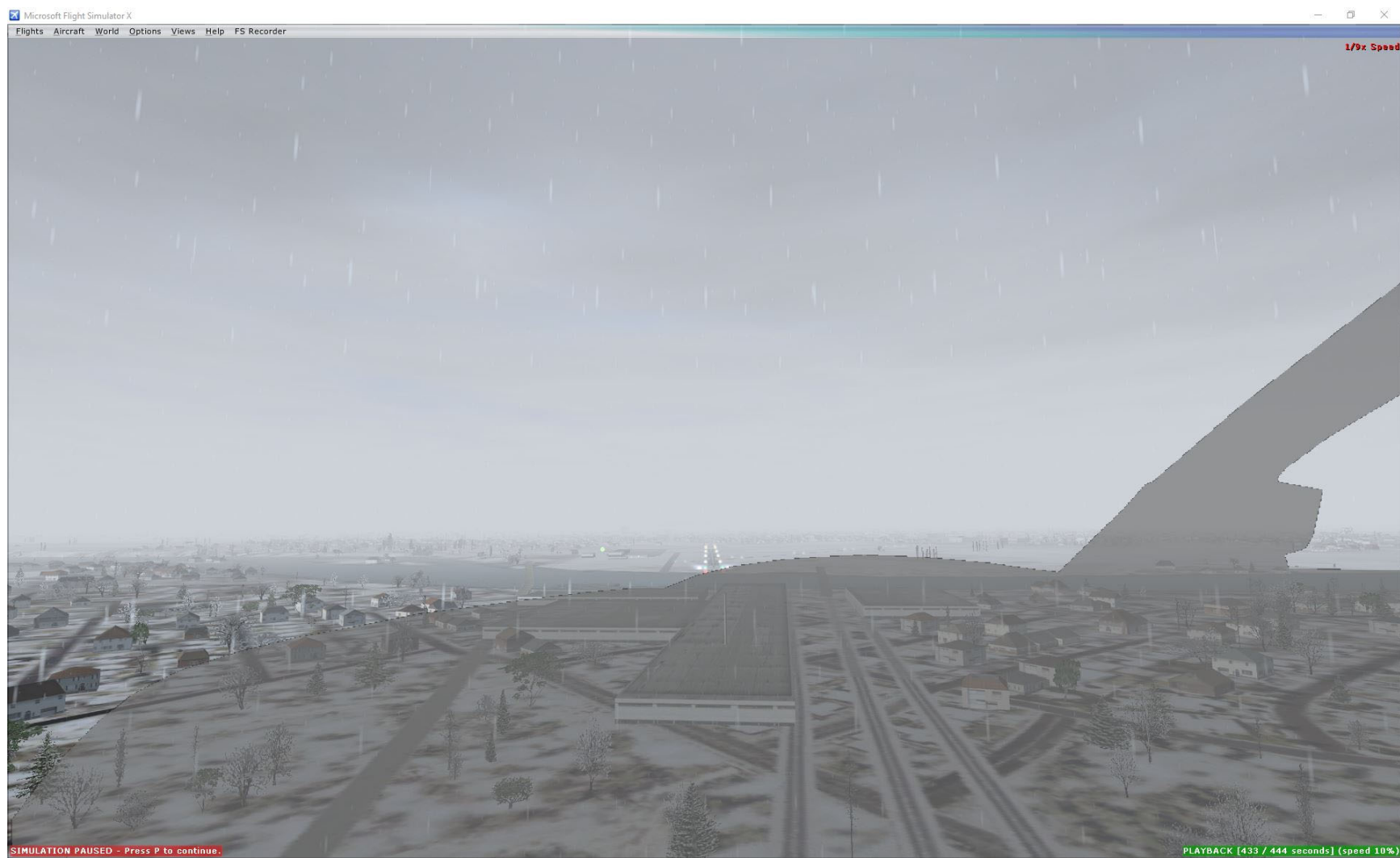


Figure 30g. FSX cockpit view at 08:32:16.6 (10 seconds before impact).



Figure 30h. FSX cockpit view at 08:32:21.6 (5 seconds before impact).



Figure 30i. FSX cockpit view at 08:32:24.6 (2 seconds before impact).