August 1, 2017

Aircraft Performance Simulation Study

I. ACCIDENT

NTSB Number:	CEN15FA190
Location:	Bloomington, Illinois
Date:	Flight departed on April 6, 2015; accident occurred on April 7, 2015
Time:	0006 central daylight time (CDT) 0506 coordinated universal time (UTC)
Airplane:	N789UP, Cessna 414A modified in accordance with available STC's for engines, spoilers, winglets, and vortex generators

II. VEHICLE PERFORMANCE SPECIALIST

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1.0 INTRODUCTION

On April 7, 2015, about 0006 central daylight time, a Cessna model 414A twin-engine airplane, N789UP, was substantially damaged when it collided with terrain following a loss of control during an instrument approach to Central Illinois Regional Airport (BMI), Bloomington, Illinois. The airline transport pilot and six passengers were fatally injured. The airplane was owned by and registered to Make It Happen Aviation, LLC, and was operated by the pilot under the provisions of 14 Code of Federal Regulations Part 91 while on an instrument flight rules (IFR) flight plan. Night instrument meteorological conditions prevailed for the cross-country flight that departed Indianapolis International Airport (IND), Indianapolis, Indiana, at 2307 central daylight time.

2.0 METHOD

The objectives of the aircraft performance simulation study were to 1) determine if recorded glideslope and localizer deviation data could be used together with recorded airplane position data (latitude-longitude) to reconstruct the airplane altitude and course during two periods when the accident airplane was flying below radar coverage and 2) calculate the engine horsepower required to match the recorded altitude, latitude, and longitude time history data that document the accident airplane flightpath. The maximum power available from each engine was taken to be 325 horsepower. The engine horsepower required to match the airplane flightpath during the event upset is expected to fall into one of three categories: little or no engine power required, engine power required less than 325 HP (one engine maximum horsepower available), or engine power required greater than 325 HP but less than 650 HP (two engine maximum horsepower available).

2.1 Air Traffic Control (ATC) Radar Data

The available ATC radar data are documented in the Air Traffic Control Specialist's Report which is located in the NTSB public docket for this accident. The simulation study used radar data from the Champaign, Illinois ASR-11 radar (CMI radar, located about 44 miles southeast of BMI) because according to the ATC Specialist's Report, "The Champaign radar data contained additional flight track data from the accident aircraft after the first loss of Peoria radar coverage, as well as, after the last recorded Peoria radar target."

2.2 Sandel SN3500 Electronic Navigation Data

A factual description of 23 time history parameters that were recovered from the N789UP Sandel SN3500 electronic navigation indicator and validated by the NTSB Office of Research and Engineering is provided in the Specialist's Factual Report of Multiple Electronic Devices, located on the NTSB public docket for this accident. Parameters pertinent to this study include latitude, longitude, ground speed, glideslope deviation, localizer deviation, magnetic heading, ground track, and the set of corresponding validity status parameters. The Sandel SN3500 device does not record altitude data.

2.3 Airplane Weight and Balance

This simulation study used the calculated weight and balance results documented in the Weight and Balance Study for this accident, located on the NTSB public docket for this investigation.

2.4 Atmospheric and Wind Data

Weather and wind data used to support simulation study calculations for the accident flight approach to BMI are documented in the NTSB Meteorology Weather Study (available on the NTSB public docket for this accident). The specific model sounding data for winds aloft near BMI that bounded the timeframe of the N789UP approach to BMI are available in Attachment 5 of the NTSB Weight and Balance Study.

2.5 Simplified Aerodynamic Model

A simplified aerodynamic model was constructed to support simulation scenarios for this study based on data documented in the N789UP Airplane Flight Manual (AFM), Supplement FM1023, Revision B for the Cessna Model 414A, dated October 18, 2005. The accident airplane aerodynamic and engine features reflect the baseline Cessna 414A and the four (4) Supplemental Type Certificate (STC) modifications listed below that added RAM Series IV engines at 325 hp each, vortex generators, winglets, and spoilers.

STC SA4546SW – RAM Series III/IV Engines
STC SA8125SW – RAM Vortex Generators
STC SA4943SW – RAM Aircraft Limited Partnership Winglets
STC SA4913NM – Spoilers Inc. Spoiler System SP4000

The simulation model total lift coefficient was derived from FAA-approved stall speeds published in the N789UP AFM, Supplement FM1023, Revision B, as a function of flap and weight. The simplified aerodynamic model assumes that lift and drag coefficient values are consistent with attached flow over nominal airfoils, as opposed to also including specific lift, drag, and pitching moment increments intended to more accurately model approach to stall, stall, and/or stall recovery effects.

Given that the simplified simulation model underestimates the aerodynamic drag during flight at high angles of attack and/or high sideslip angles, including the approach to stall, stall, and/or stall recovery regimes, the simulation is expected to yield a conservative estimate for the engine power required to match the airplane flightpath. That is, the actual airplane drag was probably greater during periods of approach to stall, stall, and/or stall recovery, so the actual engine power required must have been similar to or greater than the engine horsepower results calculated using the simplified aerodynamic model in this study.

2.6 N789UP Flap and Landing Gear Configuration

The accident airplane flap and gear configurations as a function of time during the approach and event excursion were not recorded. However, based on guidance in the Flight Safety International Cessna 300/400 Training Manual, the simulation airplane was configured at flaps 15 with gear deployed as it was descending below 2,500 feet and transitioned to flaps up, gear stowed during the event excursion. Aerodynamic lift and drag increments were estimated for flaps 15 and a drag increment was estimated for landing gear deployed.

Cessna Model 300/400 airspeed, throttle, propeller, flap, and landing gear configuration procedures for normal and single engine approach, missed approach, and go-around scenarios were reviewed to determine the probable N789UP flap and gear configuration. For a typical ILS approach, the airplane is recommended to slow to between 120 – 140 KIAS prior to the initial approach fix (IAF), begin to slow to 120 KIAS and deploy flaps 15 abeam the final approach fix (FAF), and check landing gear down and maintain 120 KIAS at the glideslope intercept. Flaps 30 and 45 are only recommended once the airport is in sight and landing is "assured."

Based on the recorded airplane altitude, position, and weather at the time of arrival, there is no documented evidence that the pilot had the airport in sight prior to the event excursion. Therefore, all simulation scenarios were conducted at flaps 15, gear deployed with a transition to flaps up (clean wing), gear stowed during the climb following the first period when N789UP was flying below radar coverage. The airplane wreckage evidence indicated that both the flaps and the landing gear were stowed when the airplane impacted the ground.

2.7 Propeller Horsepower Absorbed

The Hartzell Propeller, Inc. Propeller Teardown Report (available on the NTSB public docket for this accident) indicated that “power on the engines at time of impact could have been as high as maximum rated depending on aircraft speed and RPM” and that “A definitive power setting could not be determined. Neither propeller was in the feathered position. Blade damage was consistent with rotation at impact …”

Hartzell Propeller, Inc. provided the estimated propeller horsepower absorbed as a function of speed and engine RPM (see Figure 1). At 2,700 RPM, for true airspeeds below 120 KTAS, each propeller could absorb up to 325 horsepower.

2.8 Reconstruction of Airplane Altitude and Instrument Landing System (ILS) Guidance Deviation

Available Sandel SN3500 and Air Traffic Control (ATC) radar data for five N789UP approaches were aligned, plotted, and used with known ILS geometry to calculate the expected airplane altitude, glideslope deviation, and localizer deviation parameters during the respective approach.

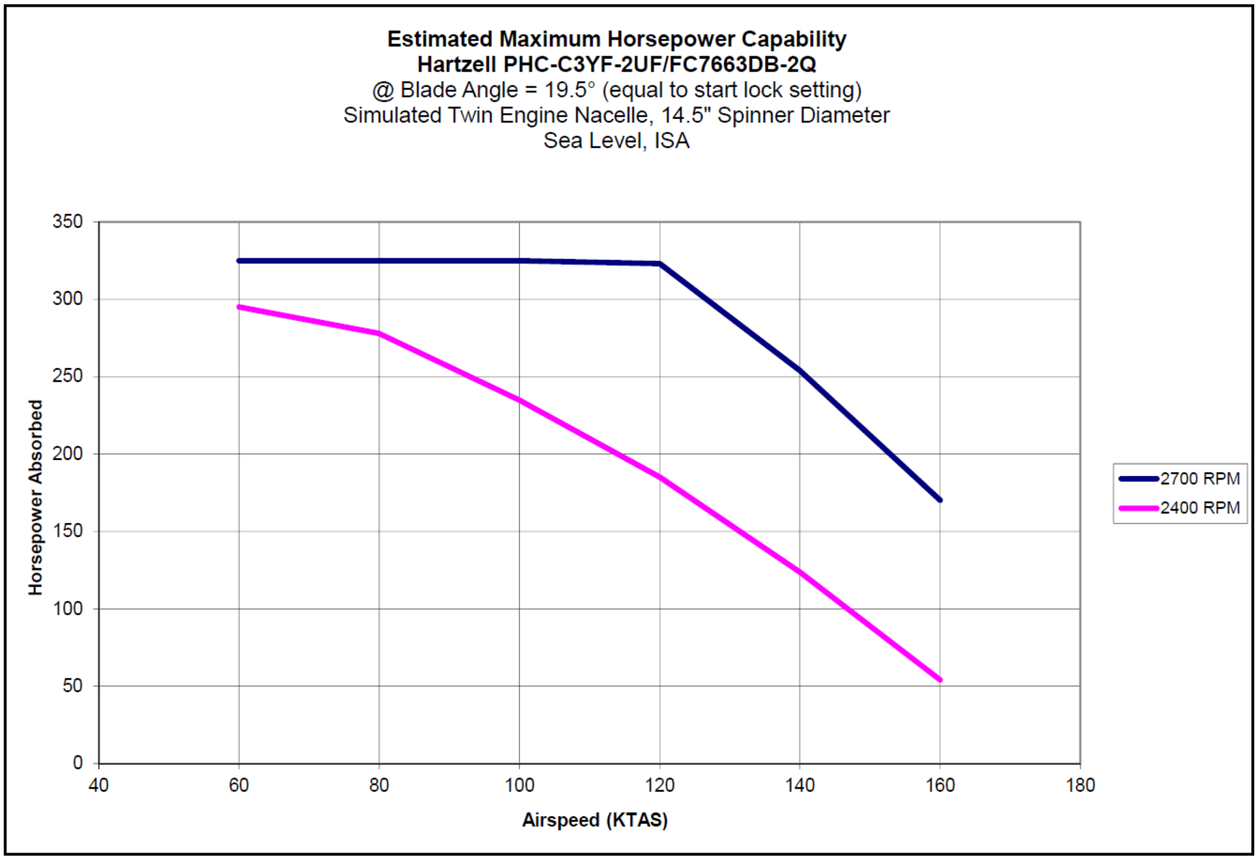


Figure 1: Estimated maximum horsepower capability, excerpted from Hartzell Propeller, Inc. Propeller Teardown Report for convenient reference.

Two methods were used to reconstruct the airplane position. Method 1 used recorded latitude, longitude, and altitude data to calculate the expected glideslope and localizer deviation time history. Method 2 used recorded glideslope and localizer deviation data to calculate the expected airplane altitude and course as a function of time.

2.9 Estimated Engine Horsepower Required During Accident Approach and Excursion

The simplified aerodynamic model was constructed to estimate the engine horsepower required to match the recorded altitude, latitude, and longitude time history data during the accident airplane instrument approach and subsequent event upset. The calculated engine horsepower required to match the airplane flightpath is expected to fall into one of three categories: little or no engine power required, engine power required less than one engine maximum horsepower available, or engine power required less than two engine maximum horsepower available.

The calculated horsepower required values must be scaled by the applicable propeller and shaft efficiency factors to calculate the minimum engine horsepower available. The combined propeller and shaft efficiency factor for this study was estimated to be about 0.80.

The available winds aloft data during the accident approach and course lateral excursion event were obtained from model sounding data at three (3) hour intervals and interpolated to the time of the accident. A comparison of BMI surface wind direction information available in high-resolution ASOS data (recorded every five minutes) indicated a surface wind direction shift that was not reflected in the model sounding data due to the sparser model sample rate (every 180 minutes as opposed to every 5 minutes). Separate simulation results were therefore calculated using the winds aloft data from the interpolated sounding model as well as winds aloft data that incorporated a hypothetical -40° shift in wind direction (based on the observation of the BMI surface wind direction shift at the time of the accident).

Simulation scenarios include the two aforementioned winds aloft models and two engine throttle strategies with engine power settings that range from 25 percent of twin engine power (equivalent to 50 percent of one engine power) to 100 percent of twin engine power. The first throttle strategy allows time-varying throttle changes during the instrument approach and subsequent event upset, as required to best match the recorded airplane position and ground speed data. The second (or alternate) throttle strategy maintains constant engine power to estimate the average equivalent engine energy input required to reach the accident site and to mimic a potential "set and forget" engine power input.

The simulation model uses estimated parameters as an input or simulation validation reference and produces calculated parameters as an output. An estimated parameter may refer to:

1. An initial parameter time history (such as that for pitch attitude, roll angle, or true heading) derived from simplified mathematical models and/or engineering assumptions that describe the three-dimensional flight path of a vehicle
2. An initial parameter time history derived by curve fitting recorded data (such as altitude) and supplementing these data with engineering judgment to bridge data gaps (such as the altitude gaps created when N789UP flew below radar coverage)
3. A representative value derived from limited information and/or reasonable engineering assumptions (such as stall speed, maximum lift coefficient, landing gear drag coefficient increment, or rate of climb)

Estimated values of pitch, roll, heading, and altitude are used in this simulation study to define nominal values for the simulation "math pilot" to target as it attempts to match (or reconstruct) the magnitude, rate, and/or trend of the recorded CMI radar altitude, Sandel SN3500 position, and Sandel SN3500 ground speed data that define the airplane trajectory. The "math pilot" in this simulation varies elevator to track pitch attitude and altitude, aileron to track roll attitude, rudder to track heading, and engine throttle/power to track position and ground speed during the reconstruction of the N789UP instrument approach and event excursion.

3.0 RESULTS

The results of the simulation study are presented in this section.

3.1 Reconstruction of Airplane Altitude and Instrument Landing System (ILS) Guidance Deviation

Available Sandel SN3500 and Air Traffic Control (ATC) radar data for five N789UP approaches were aligned, plotted, and used with known ILS geometry to calculate the expected airplane altitude, glideslope deviation, and localizer deviation parameters during the respective approach. The five N789UP approaches that were evaluated are summarized in Table 1 and the results are plotted in Attachment 1. The accident flight data are presented on page A1.10.

The recorded localizer deviation was able to be reconstructed for each approach and each approach had at least one localizer deviation validity parameter recorded to be valid during the approach. The recorded glideslope deviation parameter was able to be reconstructed for the first three approaches but not for the last two approaches. At least one recorded glideslope deviation validity parameter was recorded to be valid during each of the first three approaches whereas no glideslope deviation validity parameters were recorded to be valid during the accident approach or the preceding approach.

Table 1: Summary of N789UP Approaches, Recorded ILS guidance, and ILS Guidance Reconstruction Results

Date	Airport	Runway	Sandel SN3500 Log Number	Page	Glideslope Parameters Valid, #	Localizer Parameters Valid, #	Able to Reconstruct Recorded Deviation?	
							Glideslope	Localizer
04-01-2015	BMI	20	1	A1.2	Yes, 3 of 3	Yes, 2 of 2	Yes	Yes
04-02-2015	MDW	31R	4	A1.4	Yes, 3 of 3	Yes, 2 of 2	Yes	Yes
04-03-2015	BMI [1]	29	6	A1.6	Yes, 2 of 3	Yes, 1 of 2	Yes	Yes
04-06-2015	IND	23L	8	A1.8	No, 0 of 3	Yes, 2 of 2	No	Yes
04-06-2015 04-07-2015	BMI	20	0	A1.10	No, 0 of 3	Yes, 2 of 2	No	Yes

3.1.1 Example Reconstruction of Altitude, Glideslope Deviation, and Localizer Deviation

An exemplar reconstruction of N789UP parameters for the successful landing at BMI runway 20 on April 1, 2015 is illustrated in Figure 2. Longitude, latitude, altitude, ground speed, glideslope deviation, and localizer deviation parameters are plotted as a function of elapsed time in seconds, ordered top to bottom in the first column for the first four parameters and then top to bottom in the second column. For longitude and latitude, Sandel SN3500 and ATC radar data are presented together with an indication of the position of the outer marker (green line) and the inner marker (blue line).

The available altitude data are generally denoted as “ATC exelis" data.[2] The Sandel SN3500 unit does not record altitude so the corresponding parameter was assigned a zero value. The next four derived altitude parameters correspond to the expected glideslope centerline (wide green line) and the reconstructed altitude based on the recorded Sandel SN3500 glideslope deviation values (GSDev) that correspond to the GS1, NAV1, and NAV2 parameters, respectively.

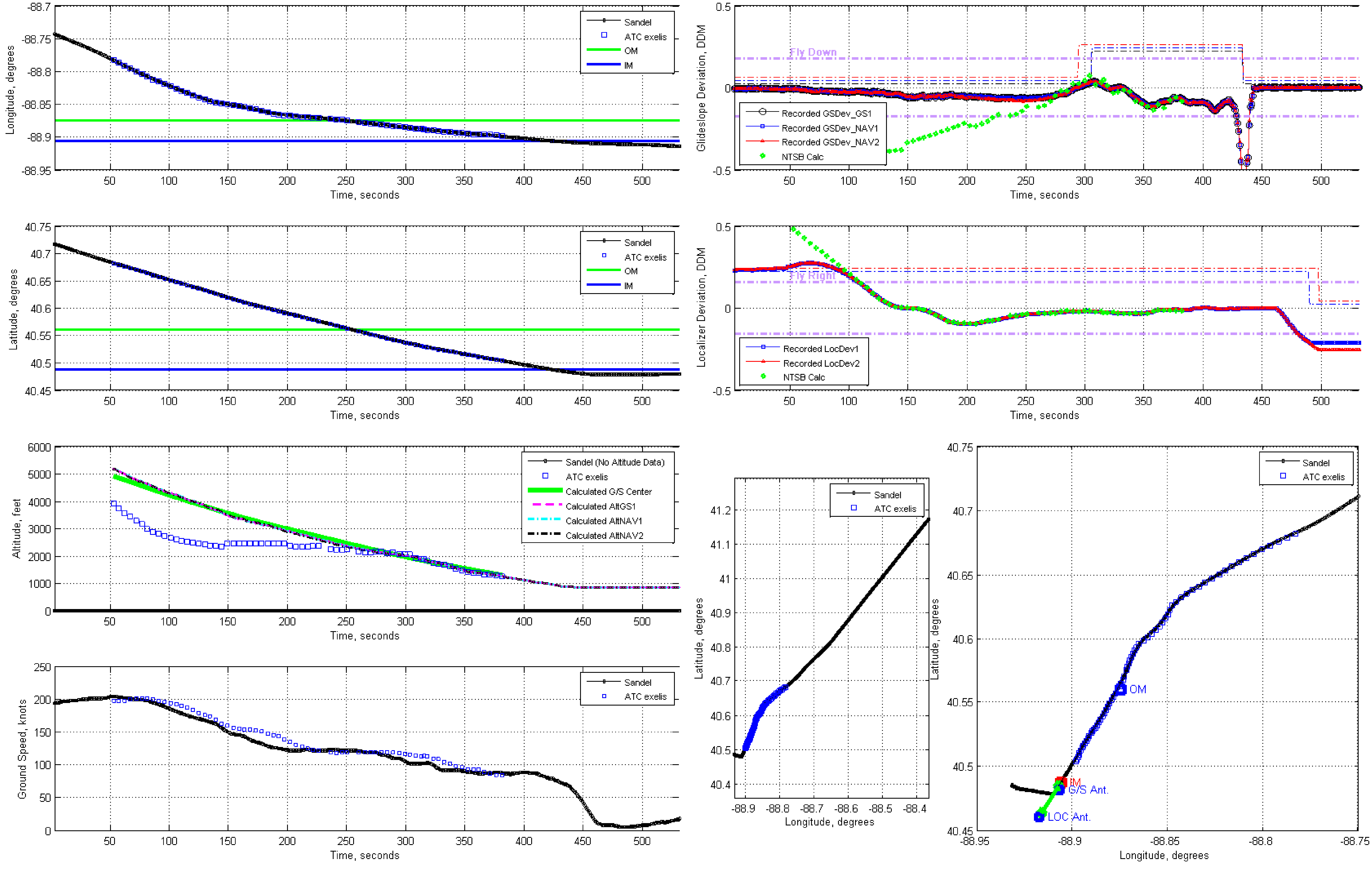
The ground speed plot compares the Sandel SN3500 data recorded at one sample per second to the ground speed derived from the ATC radar data. Note that the ATC derived ground speed data generally appear to lag the Sandel SN3500 values during ground speed transients.

The Sandel SN3500 unit recorded three glideslope deviation (GSDev) parameters (GS1, NAV1, and NAV2) and two localizer deviation (LocDev) parameters (1 and 2). Each recorded glideslope deviation and localizer deviation parameter has a corresponding validity parameter (see the color-matching, dash-dot lines) that documents whether or not the recorded deviation parameter state was classified as valid or invalid. The NTSB reconstruction of the expected glideslope and localizer deviation parameters based on the Sandel SN3500 latitude and longitude data, the ATC radar data for altitude, and the runway ILS geometry is depicted by the respective green circular symbols. The glideslope and localizer deviation plots also include indications of the full scale “Fly Down” and “Fly Right” limits.

[1] According to the Sandel SN3500 data, only the NAV1 channel was in the ILS mode during this approach. As such, it would be expected that the NAV2 channel would not have a valid localizer and/or glideslope parameter indication.
[2] The best available radar data for the accident flight were recorded by the CMI ASR-11 radar. For the purposes of this study, due to the lack of availability of raw FAA radar data for the flight segments prior to the accident flight, ATC radar track data were sourced from the Harris OpsVue "Exelis" application. The Exelis track data are a reproduction of the original FAA ATC radar track data. The use of Exelis data in this study may be subsequently referred to as ATC radar data.

Figure 2: Exemplar Reconstruction of Airplane Altitude, Glideslope Deviation, and Localizer Deviation Parameters

BMI RWY 20 04-01-15 log 1



The two lower right-hand charts in Figure 2 present a planform view of the respective Sandel SN3500 flight leg with ATC radar data overlaid. Available radar track data are shown on the left-hand planform view plot with a close up view that includes all ATC track data on the right. Available runway approach threshold, runway departure threshold, glideslope antenna, localizer antenna, outer marker, and inner marker position data are identified.

3.1.2 Discussion

Sandel SN3500 latitude, longitude, glideslope deviation, and localizer deviation data were used to estimate the expected airplane altitude and course. Separately, Sandel SN3500 latitude and longitude and ATC radar data were used to estimate expected glideslope and localizer deviation parameters. The results in Attachment 1 include the following calculated data and annotations:

1. Calculated altitude derived from the Sandel SN3500 recorded latitude, longitude, and glideslope deviation parameters, shown in the altitude plot (first column, third plot region from the top on pages A1.2, A1.4, A1.6, A1.8, and A1.10). The calculated G/S center parameter represents the expected position of the center of the glideslope beam. A zoomed-in view that compares calculated altitude parameters to available ATC radar data for each approach is provided on pages A1.3, A1.5, A1.7, A1.9, and A1.11, respectively.

2. Calculated glideslope and localizer deviation parameters. “Fly Down” and “Fly Right” notes for the respective glideslope and localizer deviation plots (first and second plot regions in the second column on pages A1.2, A1.4, A1.6, A1.8, and A1.10) along with dash-dot lines that denote the expected instrument full scale deflection.

Calculated glideslope and localizer deviation results (in DDM units) were added to the plots for each of the five approaches, shown with green circular symbols in the top two plot regions in the second column on each page (see pages A1.2, A1.4, A1.6, A1.8, and A1.10). In addition, the offset dash-dot lines in these two plot regions indicate when the respective Sandel SN3500 glideslope or localizer parameter was recorded to be valid (value of about +0.2 on the vertical scale) or invalid (value less than +0.05 on the vertical scale). Note that for the MDW landing, the recorded ILS deviation data were assumed to correspond to the ILS equipment on runway 31C (which was adjacent to the landing runway, 31R).

The calculated glideslope deviation data (green circular symbols) appear to line up reasonably well for some subset of the approach if/when the Sandel SN3500 glideslope data are recorded to be valid during the approach (see pages A1.2, A1.4, and A1.6). During these time periods, the green symbols match the Sandel SN3500 black/blue/red data or at least follow the trend (subject to potentially poor quality altitude/position data). These results indicate that the glideslope deviation data for the flight to IND preceding the accident flight as well as the accident flight, which were both tagged invalid, were most likely invalid. Note the magnitude of the difference between the green symbols and the recorded data even before the event upset or the short final segment (page A1.10).

The calculated localizer deviation data (green circular symbols) generally line up with some subset of each approach when the Sandel SN3500 localizer data are recorded to be valid. During these time periods, the green symbols match the Sandel blue/red data. However, it appears that portions of the Sandel SN3500 localizer data may include filtering, saturation (maximum scale deflection), clipping, or similar artifacts.

The calculated results indicate that attempts to extract altitude data from the Sandel glideslope deviation data must be limited to periods when the Sandel validity parameters of interest were in fact recorded to be valid. According to the Sandel SN3500 Study Report available in the public docket for this accident,

> *The Sandel SN3500 was damaged in the accident, but all basic functions were likely operative during the accident flight. The glideslope from Channel 1 and 2 were never valid on the accident flight and the Sandel SN3500 reported the invalid condition on the Sandel SN3500 display.*

3.2 Reconstruction of Engine Horsepower Required to Match the Recorded Airplane Flightpath

The various accident approach simulation scenarios evaluated two wind models and two engine throttle strategies. Summary data for each scenario are plotted as a function of time in seconds (see exemplar Figures 3–4) and as a function of distance in nautical miles (see exemplar Figures 5–6). A representative profile view of the accident approach is shown in Figure 7 as a function of distance in nautical miles and altitude in feet.

3.2.1 Inadequate and Adequate Engine Power Examples

The exemplar engine power plots in Figures 3–4 compare recorded and calculated parameters as a function of time. The parameters are ordered top to bottom and then left to right as follows: altitude in feet, speed in knots (calibrated airspeed, ground speed, other), nondimensional lift coefficient, angle in degrees (pitch attitude or angle of attack), roll angle in degrees, true heading in degrees, rate of climb in feet per minute, and engine horsepower (available and required). The altitude parameters include calculated altitude, recorded CMI radar altitude, estimated altitude, and for reference, the non-precision localizer approach minimum descent altitude (MDA), the ILS runway 20 decision altitude, the runway 20 touchdown zone elevation, and the accident site elevation.

The speed parameters plotted are calculated calibrated airspeed, calculated ground speed, recorded ground speed (from the Sandel SN3500 device), estimated speed for minimum control in the air, estimated stall speed at flaps 45, estimated stall speed for flaps up and gear stowed, and estimated stall speed for flaps 45, gear down. The lift coefficient data include calculated non-dimensional lift coefficient, calculated non-dimensional lift coefficient scaled by normal load factor, the estimated maximum lift coefficient for flaps up, and the estimated maximum lift coefficient for flaps 45.

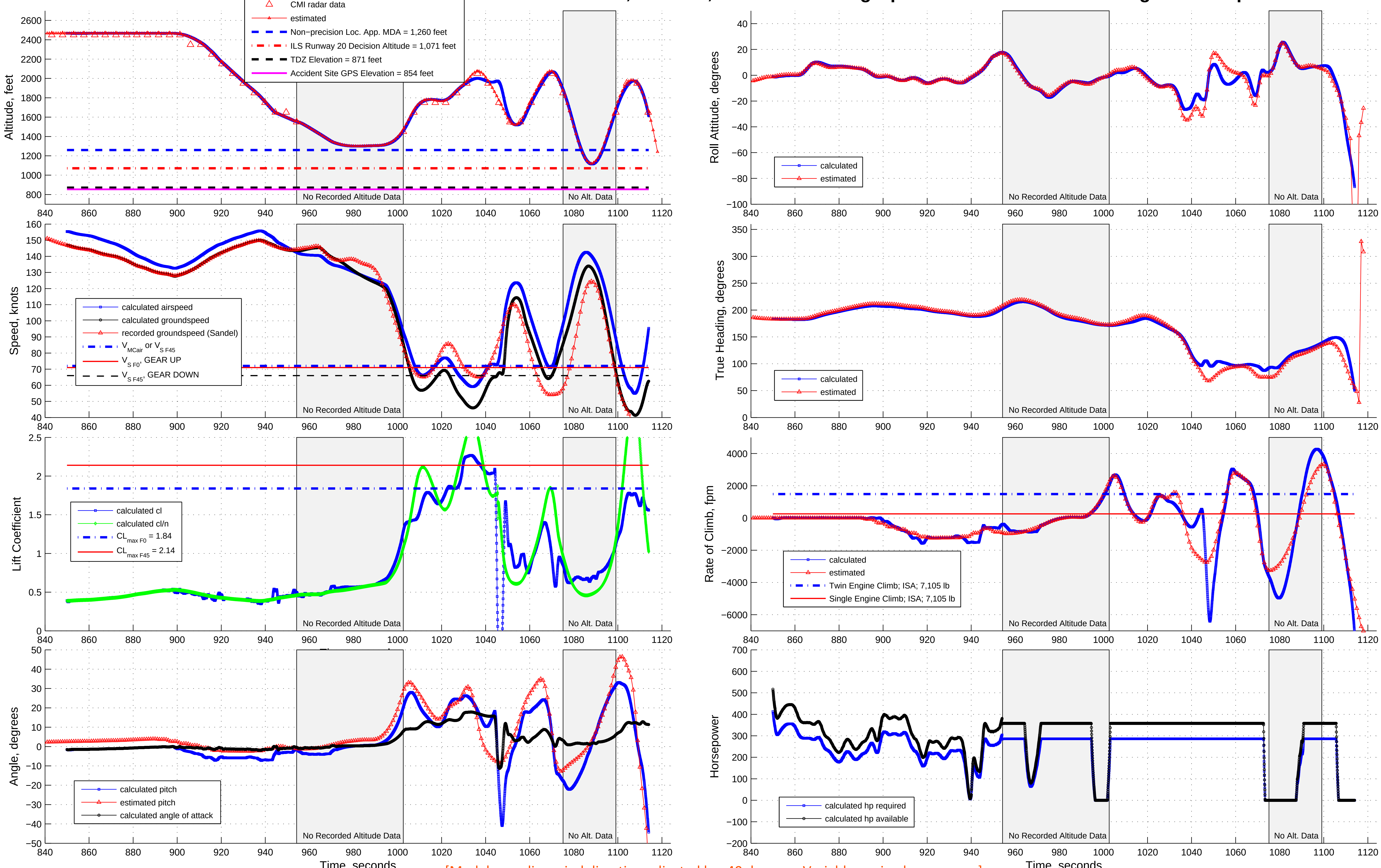
The plotted attitude parameters include calculated pitch attitude, estimated pitch attitude, calculated angle of attack, calculated roll angle, estimated roll angle, calculated true heading, and estimated true heading. The rate of climb data are the calculated rate of climb, estimated rate of climb, and the published single and twin engine climb capabilities at a weight of 7,105 pounds for a standard day atmosphere condition.[3] Finally, the horsepower data include the total calculated engine horsepower required and the corresponding horsepower available.

A comparison of the simulation data in Figures 3 and 4 (by electronically paging forward or backward, as necessary) illustrates the substantial aircraft performance differences due to engine power setting. Inadequate engine power is indicated in Figure 3 by the airplane's inability to adequately match the recorded ATC radar altitude (blue line/symbols should consistently match the red line/symbols) and recorded Sandel SN3500 ground speed data (black line/symbols should consistently match the red

[3] These Cessna 414A single and twin engine climb performance data were published on the RAM Aircraft, LP website at http://www.ramaircraft.com/Aircraft-Engine-Upgrade-Packages/Performance/414A-Series-IV-Performance/SM042C4-414A-Series-IV-Performance.htm. See page A6.2 of the Weight and Balance Study, which is available on the NTSB public docket for this accident investigation.

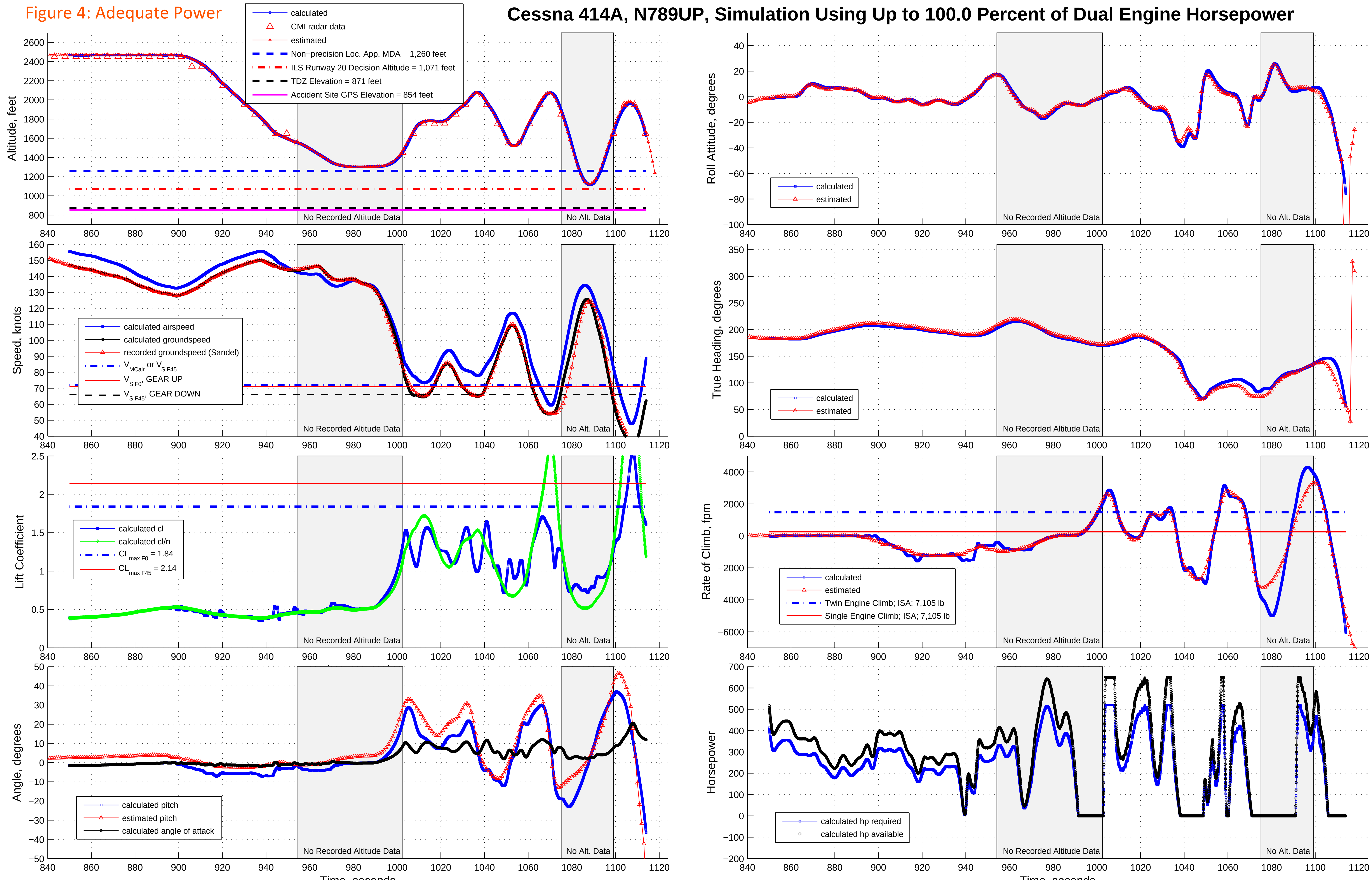
Figure 3: Inadequate Power

Cessna 414A, N789UP, Simulation Using Up to 55.0 Percent of Dual Engine Horsepower



[Model sounding wind direction adjusted by -40 degrees; Variable engine horsepower]

Figure 4: Adequate Power



[Model sounding wind direction adjusted by -40 degrees; Variable engine horsepower]

line/symbols) throughout the simulated accident approach. In contrast, with the adequate engine power shown in Figure 4, the simulation airplane can generally match the magnitude and/or trend of both the recorded altitude and ground speed data while avoiding the aerodynamic inconsistency noted in Figure 3 between times 1000 and 1040 (when calculated lift coefficient values substantially exceed the expected maximum lift coefficient values during a 40 second period when N789UP was recorded to be climbing).

3.2.2 Unacceptable and Acceptable Ground Track Examples

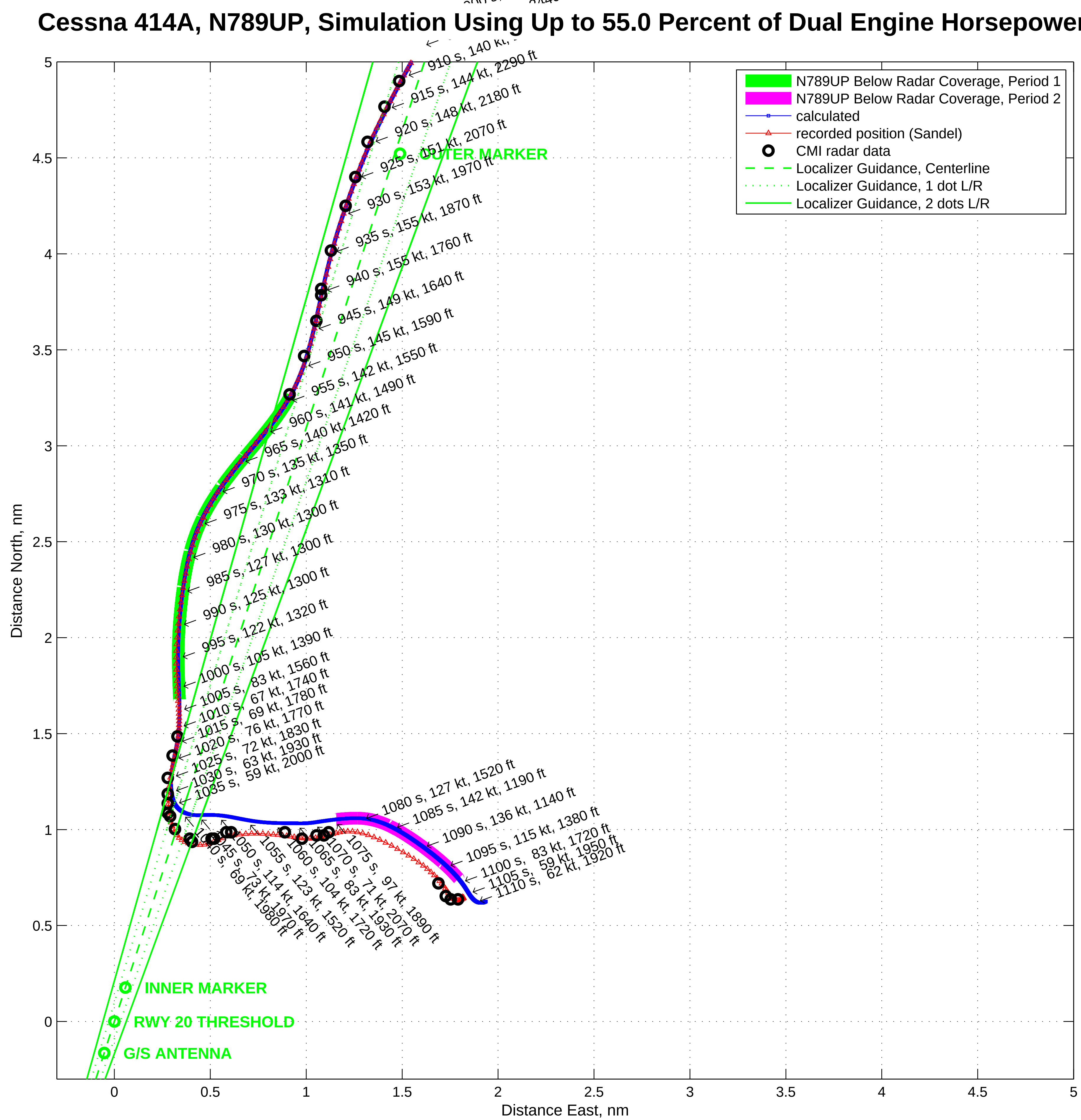
The exemplar ground track plots in Figures 5 and 6 show the N789UP distance north of the runway 20 approach threshold in nautical miles versus the distance east of the runway 20 approach threshold in nautical miles. The recorded parameters include the Sandel SN3500 and the CMI radar-based position data. The simulation calculated ground track data are shown in blue. The documented positions of the outer marker, inner marker, runway 20 approach threshold, and the glideslope antenna are noted. The calculated position of the localizer beam centerline, the localizer beam position at ±1 dot, and the localizer beam position at ±2 dots are depicted. Green/magenta ribbons along the ground track identify two regions when N789UP was flying below radar coverage. The calculated ground track is additionally annotated with time in seconds, calculated calibrated airspeed in knots, and calculated altitude in feet at a frequency of every five seconds to provide a detailed airplane altitude, airspeed, and position context during the approach.

A comparison of the simulation data in Figures 5 and 6 (by electronically paging forward or backward, as applicable) illustrates the substantial performance effects of engine power setting. An unacceptable ground track match is depicted in Figure 5, identified by the airplane's inability to adequately match the Sandel SN3500-based ground track (red line with triangular symbols). In contrast, at the increased engine power level shown in Figure 6, the simulation airplane is able to reasonably match the recorded airplane ground track until a ground speed offset develops (likely related to the simplified aerodynamic model limitations in the approach to stall, stall, and stall recovery regimes) during the last 30 seconds of the simulation.

The data in Figure 6 indicate that N789UP did not successfully track the localizer centerline but rather flew one to two (or more) dots to the right of it between the outer marker (about 4.8 nm prior to the runway 20 approach threshold), the estimated altitude level off (about 2.5 nm prior to the runway 20 approach threshold), and the initial altitude increase (about 2 nm prior to the runway 20 approach threshold). It appears that N789UP transitioned from right to left through the localizer guidance width, executing nearly a 90 degree turn to the east, about 1 nm prior to the runway 20 approach threshold and remained to the east during the balance of the event excursion. Based on the calculated angle of attack and lift coefficient data, the N789UP initial course deviation to the east does not appear to be associated with an aerodynamic wing stall.

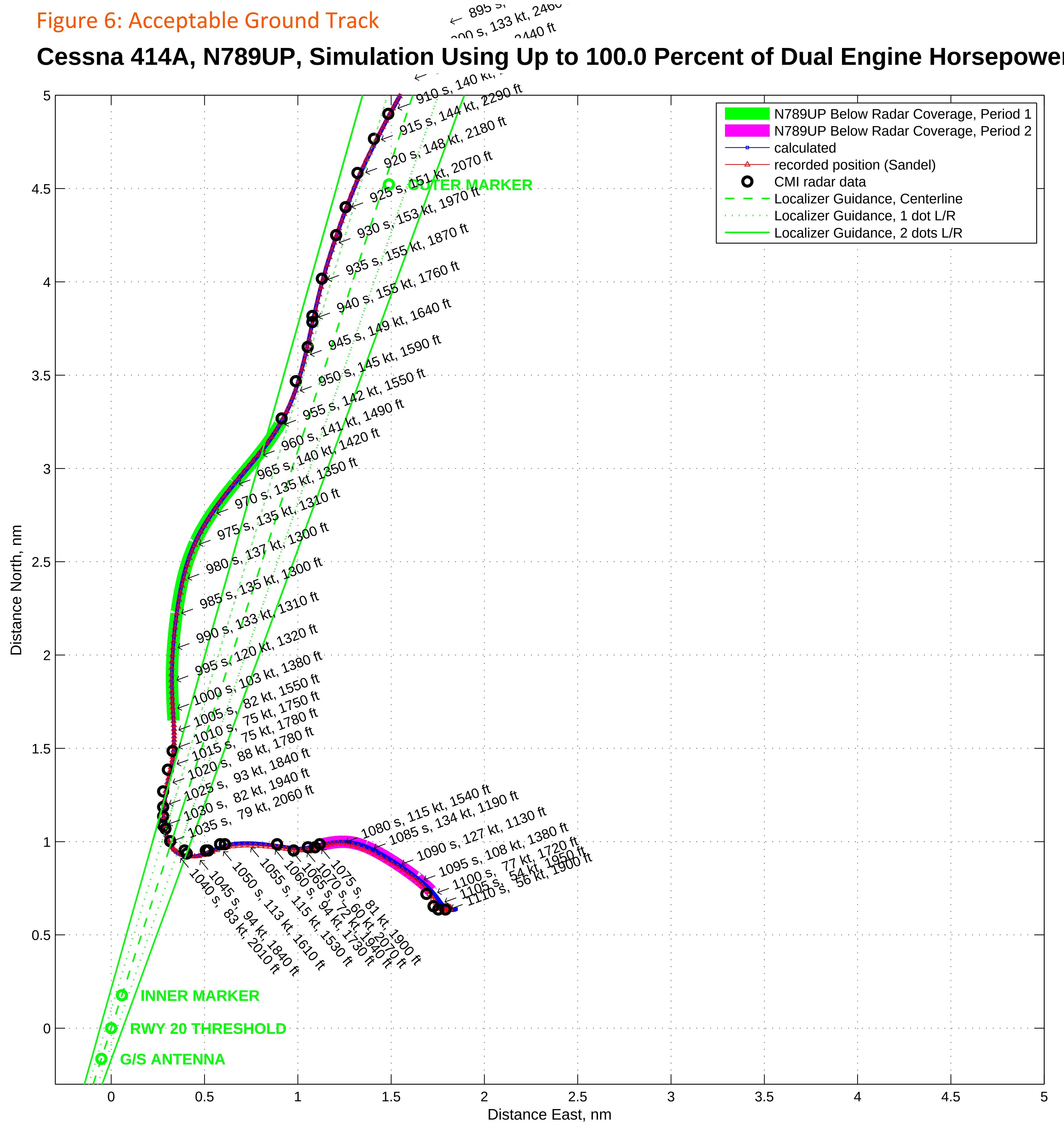
The airplane was flying about 150 KCAS at an altitude of about 2,100 feet at the outer marker and slowed to 80 knots airspeed or less three times between the first two periods when the airplane dropped below ATC radar coverage. The calculated data for angle of attack and lift coefficient corrected for normal load factor suggest that the airplane likely experienced an aerodynamic wing stall when it was about 1 nm north and 1 nm east of the runway 20 approach threshold. Another aerodynamic wing stall may have occurred shortly before the airplane final descent to the accident wreckage site (following the second period when N789UP dropped below radar coverage).

Figure 5: Unacceptable Ground Track



[Model sounding wind direction adjusted by -40 degrees; Variable engine horsepower]

Figure 6: Acceptable Ground Track



[Model sounding wind direction adjusted by -40 degrees; Variable engine horsepower]

3.2.3 Approach Profile View Example

A profile view of the accident approach is shown in Figure 7. Altitude in feet is plotted as a function of distance in nautical miles along the runway 20 centerline relative to the runway 20 approach threshold. The recorded and calculated parameters plotted include the CMI radar data, the estimated altitude, and the calculated altitude. The positions of the outer marker, inner marker, runway 20 approach threshold, glideslope antenna, runway 20 departure threshold, and localizer antenna are identified. The glideslope beam centerline, glideslope beam position at ±1 dot, and glideslope beam position at ±2 dots are depicted together with green/magenta ribbons along the descent profile that denote two regions when N789UP was flying below radar coverage. The non-precision localizer approach minimum descent altitude (MDA) and the ILS runway 20 decision altitude are shown for reference.

The recorded and calculated data in Figure 7 indicate that N789UP did not successfully intercept the glideslope centerline but rather flew one to two (or more) dots below the target glideslope between the outer marker (about 4.8 nm prior to the runway 20 approach threshold), the estimated altitude level off (about 2.5 nm prior to the runway 20 approach threshold), and the initial altitude increase (about 2 nm prior to the runway 20 approach threshold). After ascending through the glideslope guidance (about 1.7 nm prior to the runway 20 approach threshold), N789UP operated above the calculated glideslope guidance during the event excursion except for the second and third periods when it dropped below ATC radar coverage.

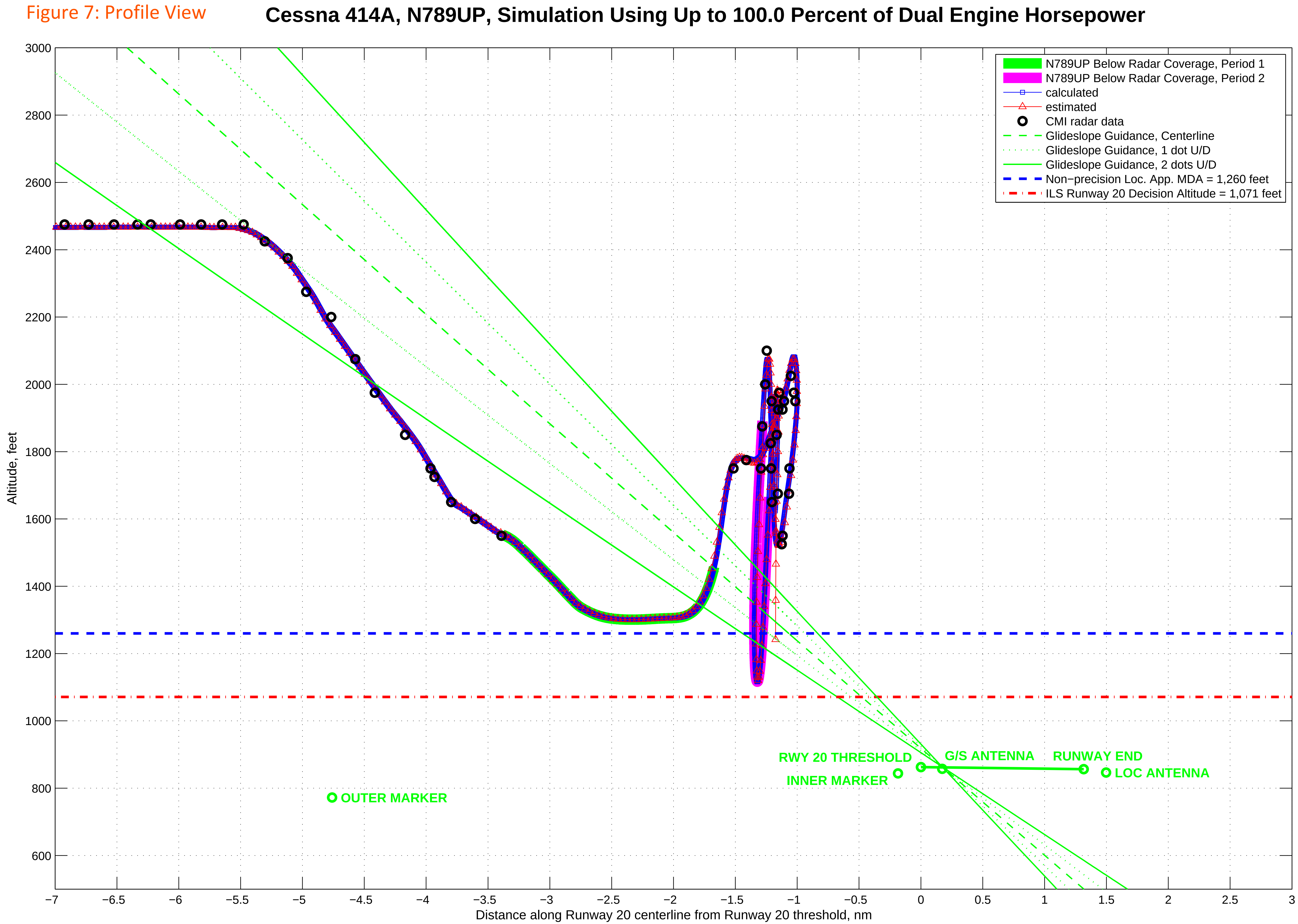
3.2.4 Estimated Engine Horsepower Required and Available

A summary of the estimated engine horsepower required to match the recorded accident airplane altitude, latitude, and longitude time history data is presented in Table 2 with supporting plots provided in Attachments 2–9. The grey rectangles and green/magenta ribbons in the respective attachments identify time periods when N789UP was flying below radar coverage. In these regions the altitude was estimated to enable the simulation to better match the recorded ground speed and to perform a continuous calculation throughout the event. Simulation results in the time periods denoted by a grey rectangle or green/magenta ribbon may be optionally reviewed qualitatively but should not be scrutinized quantitatively.

The simulation study results clearly indicate that 75 to 90 percent of time-varying dual engine power is required to achieve an acceptable and simultaneous parameter match (meaning reasonable and complementary parameter magnitudes, rates, and trends) to the recorded altitude, latitude-longitude position, and recorded ground speed data. The quality of the simulation match can be measured by comparing calculated altitude and ground speed results to the corresponding recorded targets, along with comparing the calculated ground track against the actual ground track. This knowledge allows readers to page through the simulation results presented in the attachments and independently evaluate the quality of the match.

On average, about 50 percent of continuous, as opposed to time-varying, dual engine power (equivalent to one engine operating at full power) was required to provide sufficient energy for the airplane to arrive in the general vicinity of the accident site at the proper time. However, the constant-throttle simulations did not yield an acceptable correlation with known ground speeds as recorded by the Sandel SN3500 device or derived from the ATC radar data. The winds aloft model used did not significantly affect conclusions regarding the minimum calculated engine power required during the accident excursion event.

Figure 7: Profile View



[Model sounding wind direction adjusted by -40 degrees; Variable engine horsepower]

Table 2: Calculated Minimum Percent of Twin Engine Horsepower Required to Match N789UP Accident Flight

Scenario	Winds Aloft Source	Engine Power	Minimum Percent of Twin Engine Horsepower Required for Acceptable Match to the Following Recorded Parameters			Attachment	Page	Parameters Matched or Calculated
			Altitude	North-East Position	Ground Speed			
1	Model Sounding (for both wind magnitude and direction)	Variable Throttle (to match ground speed)	57	N/A	75–90	2	A2.1	Altitude, ground speed, calculated engine power
2			N/A	72	N/A	3	A3.1	Position east and north of runway 20 threshold
3		Constant Throttle	52	N/A	no match	4	A4.1	Altitude, ground speed, calculated engine power
4			N/A	50	N/A	5	A5.1	Position east and north of runway 20 threshold
5	Model Sounding (for wind magnitude; wind direction shifted by -40°)	Variable Throttle (to match ground speed)	60	N/A	75–90	6	A6.1	Altitude, ground speed, calculated engine power
6			N/A	75	N/A	7	A7.1	Position east and north of runway 20 threshold
7		Constant Throttle	50	N/A	no match	8	A8.1	Altitude, ground speed, calculated engine power
8			N/A	50	N/A	9	A9.1	Position east and north of runway 20 threshold

4.0 CONCLUSION

The results of the simulation study indicate that it is possible to reconstruct the airplane altitude from recorded glideslope deviation parameters when applicable airplane glideslope valid signal status parameters indicate a valid state. Similarly, it is possible to reconstruct the airplane course from recorded localizer deviation parameters when applicable localizer valid signal status parameters indicate a valid state. However, when the respective glideslope(/localizer) valid signal status parameters indicate an invalid state, it is not possible to reconstruct the airplane altitude(/course), as applicable, based solely on airplane-recorded instrument landing system time history data and knowledge of the applicable ground-based instrument landing system configuration.

During the accident flight approach and altitude/course excursion event, the applicable airplane-recorded glideslope parameters indicated an invalid state, so it was not possible to reconstruct the airplane altitude using Method 2 during two periods when the airplane was flying at altitudes below the available CMI ASR-11 radar coverage.

The simulation of the accident flight approach and altitude/course excursion event indicated that the minimum engine power available must have exceeded the maximum horsepower generated with one engine operating. Engine power available must have exceeded the maximum horsepower available from one engine operating for significant time durations during the accident excursion event in order to simultaneously match the recorded airplane altitude, airplane position east and north of the runway 20 approach threshold, and the airplane ground speed as a function of time. For this accident event, the ability to reconstruct the recorded airplane altitude profile (where available) represented a relaxed constraint compared to the constraint imposed by the high resolution airplane ground track data documented by the Sandel SN3500 unit, which defined the airplane position and ground speed with high confidence.

The available winds aloft data during the accident approach and course lateral excursion event were obtained from model sounding data at three (3) hour intervals and interpolated to the time of the accident. A comparison of BMI surface wind direction information available in high-resolution ASOS data (recorded every five minutes) indicated a surface wind direction shift that was not reflected in the model sounding data due to the sparser model sample rate (every 180 minutes as opposed to every 5 minutes). Separate simulation results were therefore presented using the winds aloft data from the interpolated sounding model as well as winds aloft data that incorporated a hypothetical -40° shift in wind direction (based on the observation of the BMI surface wind direction shift at the time of the accident). The winds aloft model used did not affect the conclusion regarding the minimum calculated engine power available during the accident excursion event.

Simulation scenarios included the two winds aloft models and two engine throttle strategies with engine power settings that ranged from 25 percent of twin engine power (equivalent to 50 percent of one engine power) to 100 percent of twin engine power. The first throttle strategy allowed time-varying throttle changes during the event upset, as required to best match the recorded airplane position and ground speed data. The second throttle strategy maintained constant engine power to estimate the average equivalent engine energy input and to mimic a potential “set and forget” engine power input.

The simulation study results clearly indicate that 75 to 90 percent of time-varying dual engine power is required to achieve an acceptable and simultaneous parameter match (meaning reasonable and complementary parameter magnitudes, rates, and trends) to the recorded altitude, latitude-longitude position, and recorded ground speed data. On average, about 50 percent of continuous, as opposed to time-varying, dual engine power (equivalent to one engine operating at full power) was required to provide sufficient energy for the airplane to arrive in the general vicinity of the accident site at the proper time. However, the constant-throttle simulations did not yield a reasonable correlation with known ground speeds as recorded by the Sandel SN3500 device or derived from the ATC radar data.

Given that the simplified simulation model underestimates the aerodynamic drag during flight at high angles of attack and/or high sideslip angles, including the approach to stall, stall, and/or stall recovery regimes, the simulation model yields a conservative estimate of the engine power required to match the airplane flightpath. That is, the actual airplane drag was probably greater during periods of approach to stall, stall, and/or stall recovery, so the actual engine power required must have been similar to or greater than the engine horsepower results calculated using the simplified aerodynamic model in this study.