

National Transportation Safety Board

Office of Research and Engineering

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ELECTRONIC DEVICES

Specialist's Factual Report

April 15, 2025

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A. ACCIDENT

Location: Hebron, North Dakota
Date: June 17, 2024
Time: 0710 central daylight time (CDT)
1210 coordinated universal time (UTC)
Airplane: Thrush Aircraft LLC S2G-G10, private operator, N529KC

B. ELECTRONIC DEVICES SPECIALIST

Specialist: Steven Smith
Mechanical Engineer (Recorder Specialist)
National Transportation Safety Board (NTSB)

C. DETAILS OF THE INVESTIGATION

A group was not convened. The NTSB Vehicle Recorder Division received the following electronic devices:

Recorder Manufacturer/Model: Appareo Stratus 3
Part Number: 153510-000113
Recorder Serial Number: 031691

Recorder Manufacturer/Model: Inero Solutions AgPilotX Lightbar
Part Number: Unknown
Recorder Serial Number: 1672

Recorder Manufacturer/Model: Inero Solutions AgPilotX Computer (Hub)
Part Number: ASSY-9007-001
Recorder Serial Number: Unknown

Recorder Manufacturer/Model: Flight Data Systems GT-50
Part Number: Unknown
Recorder Serial Number: Unknown

Recorder Manufacturer/Model: Shadin Avionics Miniflo-L™
Part Number: 912041T-D
Recorder Serial Number: 11095

1.0 Appareo Stratus 3 Description

The Appareo Stratus 3 device is a self-contained battery-powered unit that contains an internal AHRS, GPS/WAAS receiver, and ADS-B receiver in one compact

unit.^{1, 2, 3} The unit communicates wirelessly with compatible devices to display all the acquired information. In addition to communicating with compatible devices, the Stratus device records GPS position and AHRS information internally on a non-volatile flash memory chip (NVM).⁴

1.1 Appareo Stratus 3 Data Recovery

Upon arrival at the NTSB Vehicle Recorder Division, an external examination revealed the device was in good condition, as shown in figure 1. The device powered on normally and the data were extracted using laboratory tools.



Figure 1. Appareo Stratus 3 front (left) and back (right) as received by the NTSB Vehicle Recorder Laboratory.

¹ The Attitude Heading Reference System (AHRS) consists of a set of 3-axis gyroscope, accelerometers and heading reference sensors that enable the unit to compute pitch, roll, and yaw motions.

² The Wide Area Augmentation System (WAAS) is an air navigation aid to augment the Global Positioning System (GPS), by improving its accuracy, integrity, and availability.

³ Automatic Dependent Surveillance-Broadcast (ADS-B) is a surveillance technology deployed throughout the national airspace system. The ADS-B system is composed of aircraft avionics and a ground infrastructure. Onboard avionics determine the position of the aircraft by using the GPS and transmit its position along with additional information about the aircraft to ground stations for use by air traffic control (ATC) and other ADS-B services. This information is transmitted at a rate of approximately once per second. Operators equipped with ADS-B realize additional benefits from ADS-B broadcast services: Traffic Information Service - Broadcast (TIS-B) (traffic information) and Flight Information Service - Broadcast (FIS-B) (weather information).

⁴ Non-volatile memory is semiconductor memory that does not require external power for data retention.

1.2 Appareo Stratus 3 Recording Description

The recorded data included 6 sessions from April 13, 2019, through June 29, 2024, UTC. The session containing the accident event started on Monday June 17, 2024, at 11:41:57.0 UTC and ended at 12:09:52.4 UTC. The data were sampled at 5 Hertz (Hz). Accuracy of gyroscopic parameters such as pitch angle and bank angle are dependent on the orientation of the device in the aircraft and proper calibration of the device. The last recorded position does not align with the reported wreckage location. The last recorded position at 12:09:52.4 UTC, is approximately 40 feet from the reported wreckage location.

The Appareo Stratus 3 is an user-mounted device and is not necessarily fixed to the aircraft instrument panel in a rigid mounted position. As such, the device is subject to movement under extreme pitch and roll conditions. In such cases where the device is detached from its resting location, the device will continue to record. This means that in an extreme pitch, roll or acceleration scenario, the device may move out of correlation with the aircraft, and the device will continue to record data based on the orientation of the unit itself, which is not necessarily reflective of the aircraft pitch, roll or acceleration condition.

1.2.1 Appareo Stratus 3 Parameters Provided

Table 1 lists the Appareo Stratus 3 parameters verified and provided in this report.

Table 1. Appareo Stratus 3 data parameters provided.

Parameter Name (unit)	Parameter Description (unit)
Accel Lat (g)	Lateral Load Factor (gravitational acceleration)
Accel Long (g)	Longitudinal Load Factor (gravitational acceleration)
Accel Vert (g)	Vertical Load Factor (gravitational acceleration)
Alt MSL (ft)	Altitude Mean Sea Level (feet)
Date (mm/dd/yyyy)	Date (month/day/year)
Ground Track (deg)	Magnetic Ground Track (degrees)
Groundspeed (kts)	Groundspeed (knots)
Hdg True (deg)	True Heading (degrees)
Latitude (deg)	Latitude (degrees)
Longitude (deg)	Longitude (degrees)
Pitch (deg)	Pitch Attitude (degrees)
Roll (deg)	Roll Attitude (degrees)
Time (HH:MM:SS)	Time UTC (hours:minutes:seconds)
Vertical Speed (fpm)	Vertical Speed (feet per minute)

1.3 Appareo Stratus 3 Time Correlation

The Appareo Stratus 3 data was recorded in UTC. The accident flight data was offset from the recorded device time to CDT by subtracting 18,000 seconds. Therefore, for the remainder of this report, all times are referenced as CDT.

2.0 AgPilotX System Description

The Inero Solutions AgPilotX System is a guidance system for aerial applicators that consists of the AgPilotX Computer Hub, the AgPilotX Lightbar, and a device such as an iPad running the AgPilotX mobile application. The Lightbar provides guidance and has GPS/GNSS (Global Navigation Satellite System) onboard. Historical data are stored on a microSD card in the Lightbar.

2.1 AgPilotX System Data Recovery

Upon arrival at the NTSB Vehicle Recorder Division, an external examination revealed that two components of the system had sustained minor impact damage, as show in figure 2 (Inero Solutions AgPilotX Lightbar) and figure 3 (Inero Solutions AgPilotX Computer Hub). The NTSB Vehicle Recorder Division did not receive the associated third device, such as the iPad. The internal 8GB microSD card from the Inero Solutions AgPilotX Lightbar was in good condition and read out normally using laboratory tools. Its contents were examined and historical data associated with the accident flight were parsed out. The contents of the internal 8GB microSD card from the Inero Solutions AgPilotX Computer Hub were examined and no historical data were present.



Figure 2. Inero Solutions AgPilotX Lightbar as received by the NTSB Vehicle Recorder Laboratory.



Figure 3. Insero Solutions AgPilotX Computer Hub as received by the NTSB Vehicle Recorder Laboratory.

2.2 AgPilotX System Recording Description

The Insero Solutions Lightbar microSD card contained 338 recorded data sessions from March 17, 2022, through June 27, 2024, UTC. The session containing the accident event started on Monday June 17, 2024, at 11:46:26 UTC and ended at 12:09:18 UTC.

Data is typically recorded at 1 Hz; however, timestamps are only recorded once a minute or whenever there is a change in the Spray Switch Status parameter. Therefore, there are instances when multiple data points were recorded during a single second when the Spray Switch Status changed, and the system was in the process of resyncing time. Due to how the system resyncs the time, it is possible that there is up to 1 second of error in the timing.

2.2.1 AgPilotX System Parameters Provided

Table 2 lists the Insero Solutions AgPilotX Lightbar parameters verified and provided in this report. After a review of the log file settings, per the manufacturer's documentation, the operator had set the Spray Switch Status parameter to 'OFF,' and therefore this parameter was not recorded.

Table 2. Insero Solutions AgPilotX Lightbar parameters provided.

Parameter Name (unit)	Parameter Description (unit)
Area (ha)	Total Area (hectare)
GPA Meter1 (gpa)	Gallons/Acre, Meter 1 (gallons per acre)
GPA Meter2 (gpa)	Gallons/Acre, Meter 2 (gallons per acre)
GPM (gpm)	Gallons per minute [Selected Meter] (gallons per minute)
Date (yyyy/mm/dd)	Date (year/month/day)
Latitude (deg)	Latitude (degrees)

Parameter Name (unit)	Parameter Description (unit)
Longitude (deg)	Longitude (degrees)
Time (HH:MM:SS)	Time UTC (hours:minutes:seconds)
TotalLiters (L)	Total Volume (liters)

2.3 AgPilotX System Time Correlation

The Insero Solutions AgPilotX Lightbar data was recorded in UTC. CDT is lagging UTC by 5 hours, or 18,000 seconds. The accident flight data was offset from the recorded device time to CDT by subtracting 18,000 seconds. Therefore, for the remainder of this report, all times are referenced as CDT.

3.0 Flight Data Systems GT-50 Description

The Flight Data Systems GT-50 is a clock, timer, G-Meter, voltmeter and Outside Air Temperature (OAT) instrument enclosed in an aluminum case. The device is capable of storing maximum and minimum acceleration (g). The recorded maximum and minimum values are only reset when the user presses the reset button. The device records acceleration data at a sample rate of 4 Hz. The device does not store a time history of when the maximum and minimum values were obtained.

3.1 Flight Data Systems GT-50 Data Recovery

Upon arrival at the NTSB Vehicle Recorder Division, an external examination revealed the device was in good condition, as shown in figure 4. The device powered on normally, and the data were extracted using the manufacturers procedures.



Figure 4. Flight Data Systems GT-50 as received by the NTSB Vehicle Recorder Laboratory.

3.2 Flight Data Systems GT-50 Recording Description

The unit was powered on, and the following non-time-based data were extracted and provided in table 3.

Table 3. Flight Data Systems GT-50 data extracted.

Parameter Name	Value Extracted
Firmware Version	3.4
Maximum G	2.5 g
Minimum G	-0.2 g

4.0 Shadin Avionics Miniflo-L™ Description

The Miniflo-L™ is a digital fuel management system designed to provide fuel management information under real flight conditions using an electronic numerical display. The unit is connected to engine fuel flow transducer for fuel flow information. The unit can be connected to a Loran-C or GPS receiver serial port for navigation data, such as ground speed, distance, and estimated time enroute. The unit is also capable of transmitting fuel information to certain GPS receivers for additional calculations and display of fuel management data. The unit can display the following information to the crew:

- Specific Range⁵
- Fuel to Destination⁶
- Fuel Reserve⁵
- Endurance
- Fuel Flow
- Fuel Used
- Fuel Remaining

The unit contains limited NVM for data storage and records the fuel set state at the beginning of the flight (user selection of the amount of fuel onboard) and the amount of fuel used during the flight.

The unit does not interface with the aircraft fuel quantity indicating system.⁷ The unit requires the flight crew to enter the initial fuel on board the aircraft. All calculations and data provided by the unit are based on fuel flow and any provided navigational information.

⁵ The purpose of LeanFind mode is to find the first and last cylinder to peak with true peak detect and eliminate false peaks.

⁶ Real time calculation that requires an active Loran-C or GPS input.

⁷ The operating manual states in the preflight procedures section, "Miniflo-L™ is a fuel flow measuring system and NOT a quantity-sensing device. A visual inspection and positive determination of the usable fuel in the fuel tanks is a necessity. Therefore, it is imperative that the determined available usable fuel be manually entered into the system."

4.1 Shadin Avionics Miniflo-L™ Data Recovery

Upon arrival at the NTSB Vehicle Recorder Division, an external examination revealed the device was in good condition, as shown in figure 5. The unit was not connected to any fuel flow sensors or GPS/Loran devices during the data recovery process. Using procedures described in the Shadin Avionics Miniflo-L™ operating manual, data was recovered by applying power to the unit and cycling through the displayed values.⁸



Figure 5. Shadin Avionics Miniflo-L™ as received by the NTSB Vehicle Recorder Laboratory.

4.2 Shadin Avionics Miniflo-L™ Recording Description

Upon power up, the fuel flow indicator performed a self-test and reported a status of “-Good-” indicating a successful test. Fuel used and fuel remaining were displayed by moving the GAL. USED/GAL. REM. toggle switch to the appropriate USED and REM positions. The fuel used displayed a value of 3550 gallons, and the fuel remaining displayed a value of 0.0 gallons.⁹ The device’s fuel value may not represent the total fuel amount relevant to the accident flight as it relies on proper user input to reflect accurate fuel load values upon engine start. Diagnostic software test values were displayed by pressing the ENTER/TEST button. A success test was indicated by a “-Good-” appearing in the display window.

⁸ For further information on configuration settings refer to Shadin Avionics Miniflo-L™ operating manual for P/N: 91204XT-D, publication number OP91204E.

⁹ Fuel remaining is calculated by the unit by subtracting fuel used from the initial starting fuel entered by the crew.

This was followed by the K-factor setting of 23.3 and the units of measure set to gallons. Then "LoF" appeared indicating no Loran or GPS signal. Then the maximum usable fuel reported a value of 225 gallons. The last displayed value was the software version 60.01.83.

D. FIGURES AND TABULAR DATA

Figures 6 to 9 contain both Stratus 3 and AgPilotX Lightbar data recorded during the event on June 17, 2024. All the parameters listed in tables 1 and 2 are plotted except date and time.

Figures 6 and 7 are time history plots presenting Stratus 3 GPS and AHRS parameters and AgPilotX Lightbar parameters, for the entire flight and the final 3 minutes of the recording, respectively.

These figures are configured such that right turns are indicated by the trace moving toward the bottom of the page, left turns towards the top of the page, and nose up attitudes towards the top of the page.

The Stratus 3 and AgPilotX Lightbar indicated the following sequence of events:

- **06:41:57 CDT:** The Stratus 3 was powered on and began recording data.
- **06:46:19 CDT:** The aircraft began to taxi for runway 31 at Chase Airstrip in Hebron, North Dakota (6NA5).
- **06:46:26 CDT:** The AgPilotX Lightbar was powered on and began recording data.
- **06:46:48 CDT:** Groundspeed began to increase from 8 kts to 9 kts, and continually increased thereafter, consistent with takeoff roll.
- **06:49:02 CDT:** The aircraft was at an altitude of 2,870 ft MSL.
- **06:56:40 CDT:** The aircraft was approaching the field location for spraying.
- **06:58:01 CDT:** The AgPilotX GPA Meter2 and GPM parameters began to increase, consistent with the aircraft spraying. TotalLiters and Area increased during this period. The aircraft altitude and groundspeed fluctuated, as the aircraft dove while groundspeed increased.
- **06:59:08 CDT:** The AgPilotX GPA Meter2 and GPM parameters began to increase, consistent with the aircraft spraying for a second time. TotalLiters and Area increased during this period. The aircraft altitude and groundspeed fluctuated, as the aircraft dove while groundspeed increased.

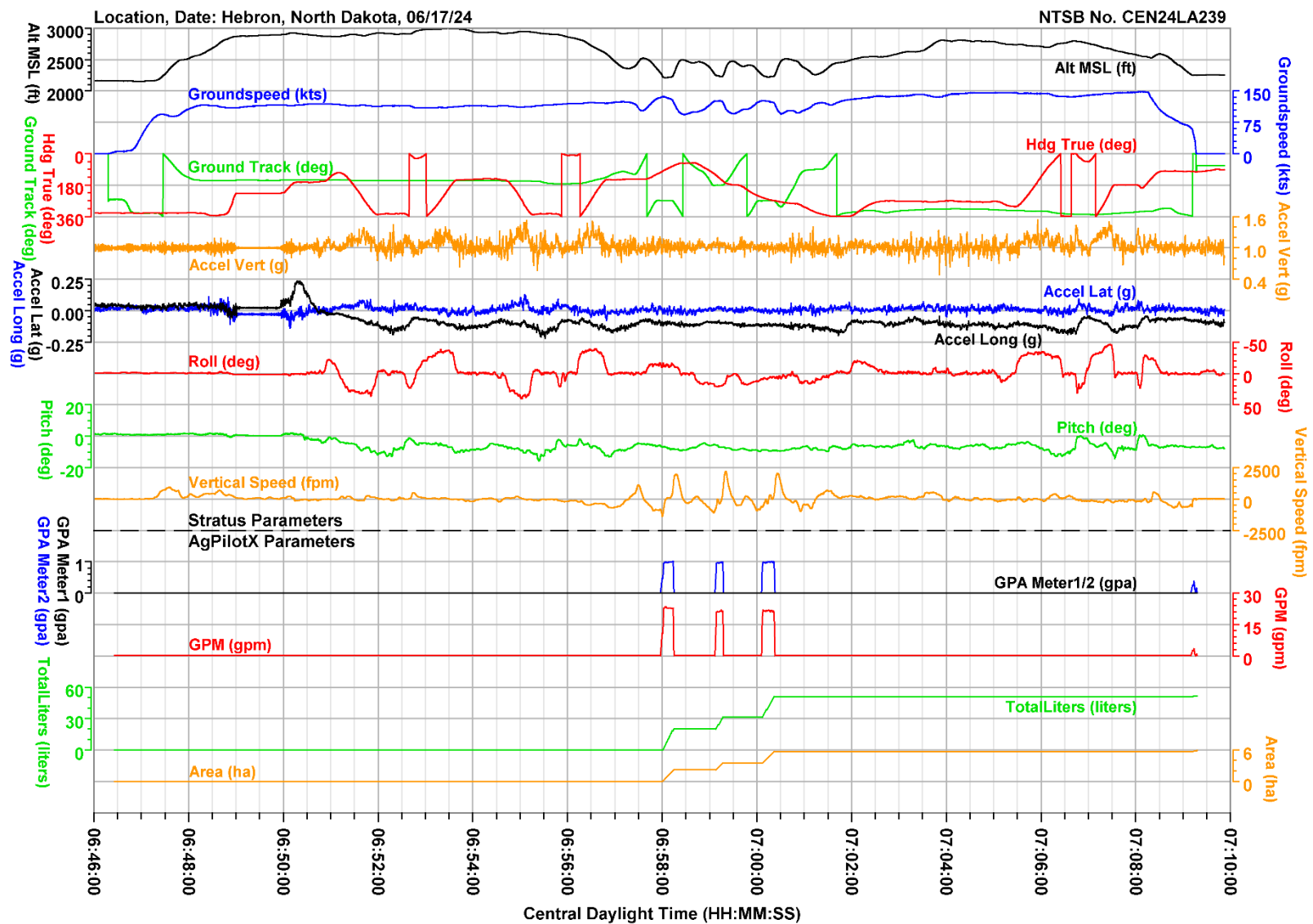
- **07:00:07 CDT:** The AgPilotX GPA Meter2 and GPM parameters began to increase, consistent with the aircraft spraying for a third time. TotalLiters and Area increased during this period. The aircraft altitude and groundspeed fluctuated, as the aircraft dove while groundspeed increased.
- **07:00:37 CDT:** The aircraft began a fourth dive from 2,511 ft MSL.
- **07:01:14 CDT:** The aircraft began to climb from 2,258 ft MSL.
- **07:01:40 CDT:** The aircraft exited the field location. The aircraft was flying in a northwesterly ground track.
- **07:08:16 CDT:** Altitude was 2,538 ft MSL and groundspeed was 147 kts. The aircraft was descending. Groundspeed began to reduce.
- **07:09:12 CDT:** The AgPilotX GPA Meter2 and GPM parameters began to increase, consistent with the aircraft spraying for a fourth time. TotalLiters and Area increased during this period.
- **07:09:17 CDT:** Altitude was 2,250 ft MSL and groundspeed was 0 kts.
- **07:09:18 CDT:** The AgPilotX Lightbar recorded the last data sample.
- **07:09:52.4 CDT:** The Stratus 3 recorded the last data sample.

Figures 8 and 9 are graphical overlays derived from the Stratus 3 data generated using Google Earth presenting the entire accident flight and the final minute and 52 seconds of the recording, respectively. Weather and lighting conditions in Google Earth are not necessarily the weather and lighting conditions present at the time of the recording.

The corresponding Stratus 3 tabular data used to create figures 6 to 9 are provided in electronic comma-separated value (CSV) format as attachment 1 to this report. The corresponding AgPilotX Lightbar data used to create figures 6 and 7 are provided in CSV format as attachment 2.

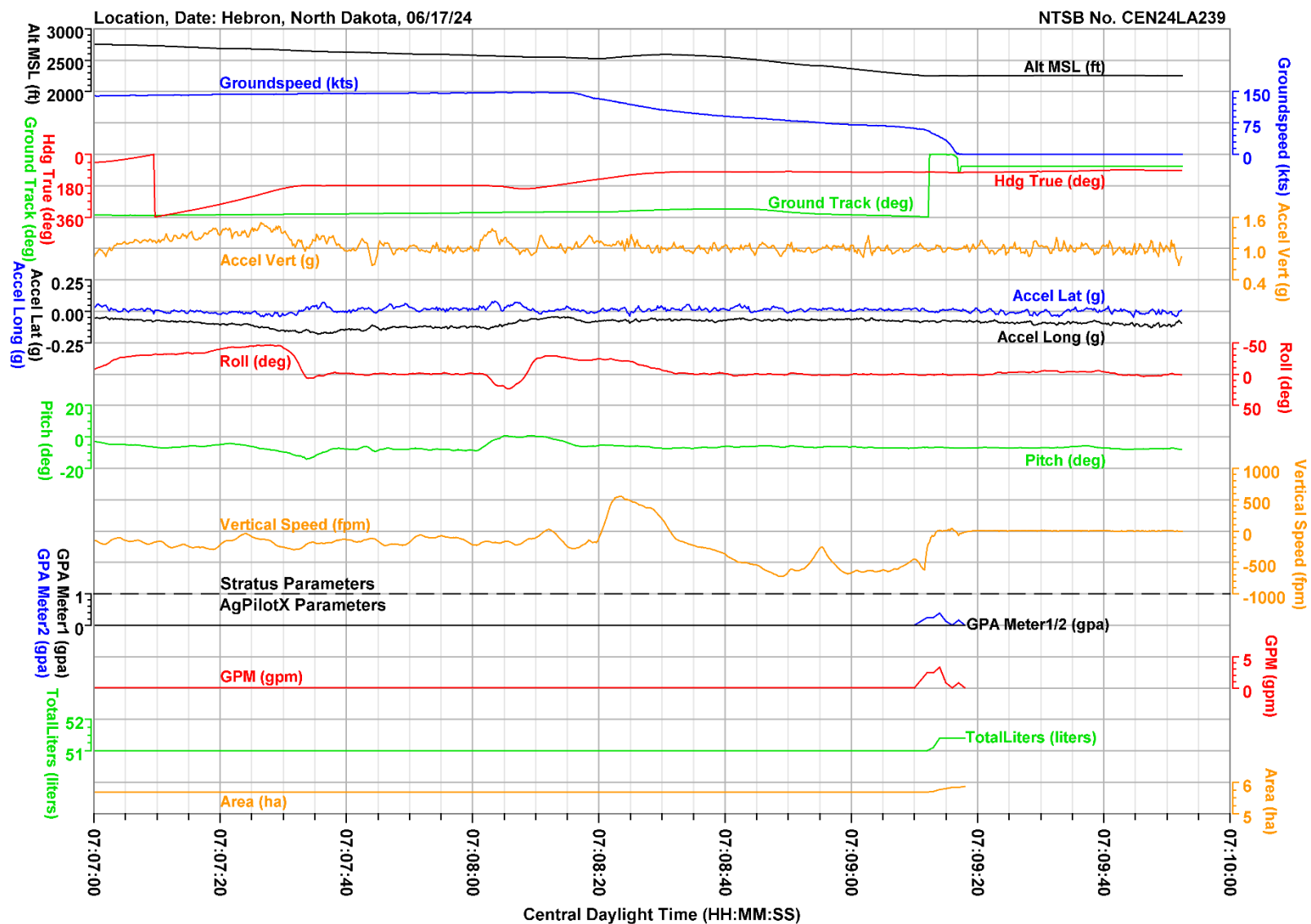
Submitted by:

Steven Smith
Mechanical Engineer (Recorder Specialist)



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Figure 6. Time history plot of the entire flight presenting both Appareo Stratus 3 and AgPilotX Lightbar parameters.



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Figure 7. Time history plot of the final 3-minutes of the recording presenting both Appareo Stratus 3 and AgPilotX Lightbar parameters.

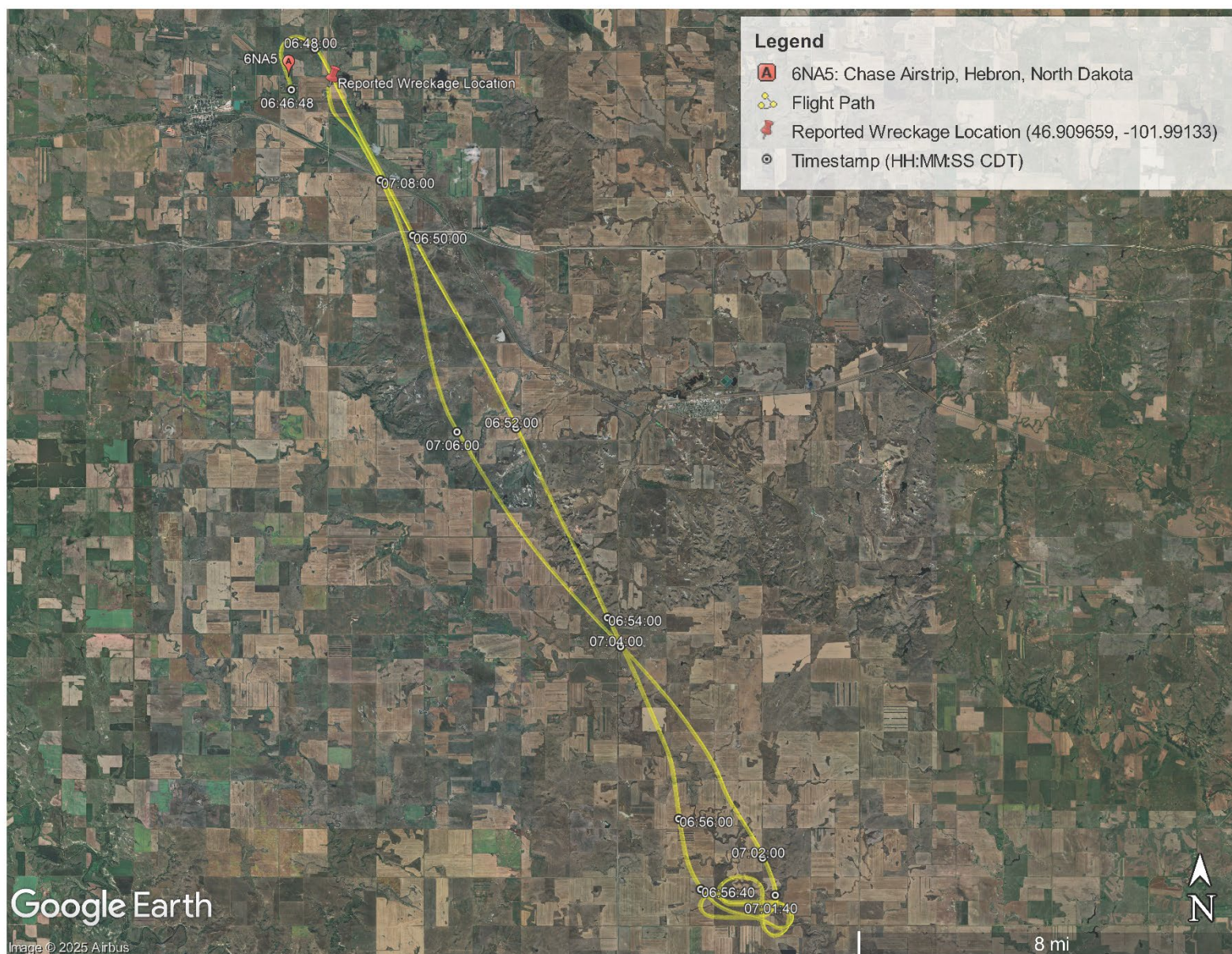


Figure 8. Google Earth overlay of the entire accident flight.



Figure 9. Google Earth overlay of the final minute and 52 seconds of the recording.