NATIONAL TRANSPORTATION SAFETY BOARD
Vehicle Recorder Division
Washington, D.C. 20594

August 7, 2015

Onboard Electronic Devices

Specialist's Factual Report
by George Haralampopoulos

1. EVENT

Location:	Reno, Nevada
Date:	September 08, 2014
Aircraft:	Backovich GP-5
Registration:	N501GP
Operator:	Private
NTSB Number:	WPR14FA369

On September 8, 2014, about 1516 pacific daylight time, an experimental amateur built Backovich GP-5 airplane, N501GP, was destroyed when it impacted terrain following an in-flight breakup while conducting a practice race at the Reno-Stead Airport (RTS) Reno, Nevada. The airplane was registered to Lancair Northwest LLC, Portland, Oregon, and operated by the pilot under the provisions of Title 14 *Code of Federal Regulations* Part 91. The commercial pilot, sole occupant of the airplane, was fatally injured. Visual meteorological conditions prevailed and no flight plan was filed for the air race flight. The local flight originated from RTS about 5 minutes prior to the accident.

2. DETAILS OF INVESTIGATION

The National Transportation Safety Board (NTSB) Vehicle Recorder Division received the following devices:

Device 1:	Advanced Flight Systems AF-4500s EEp
Device 1 Serial Number:	N/A
Device 2:	Cosworth Pectel SQ6 Engine Control Unit
Device 2 Serial Number:	219

2.1. Advanced Flight Systems AF-4500 Device Description

The Advanced Flight Systems Inc. AF-4500 and AF-3400 series are multifunction, liquid crystal displays (LCD) capable of displaying aircraft attitude, altitude, heading, navigation, moving map, engine information, and airway and approach databases, depending on options and installation. The units can record dynamic flight information on internal flash non-volatile memory[1] at a pilot selectable interval.

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

The time in the units is set by the operator and maintained by an internal lithium-ion battery between power cycles. Displayed and recorded times are from the internal clock on each unit. However, when power is applied and the unit is connected to a GPS, the internal clock will automatically be set to GPS time. Thereafter the clock will advance based on the internal microprocessor. When connected to another Advanced Flight Systems Inc. device, discrete data parameters are shared and recorded (except time).

2.1.1. Advanced Flight Systems AF-4500 Display Data Recovery

Upon arrival at the Vehicle Recorder Division, an exterior examination revealed the unit had sustained significant impact damage as shown in figure 1. The memory board containing the unit's non-volatile memory had sustained impact damage and the memory chip was partially detached from its circuit board (figure 2). The memory chip was re-soldered and placed into a surrogate unit.

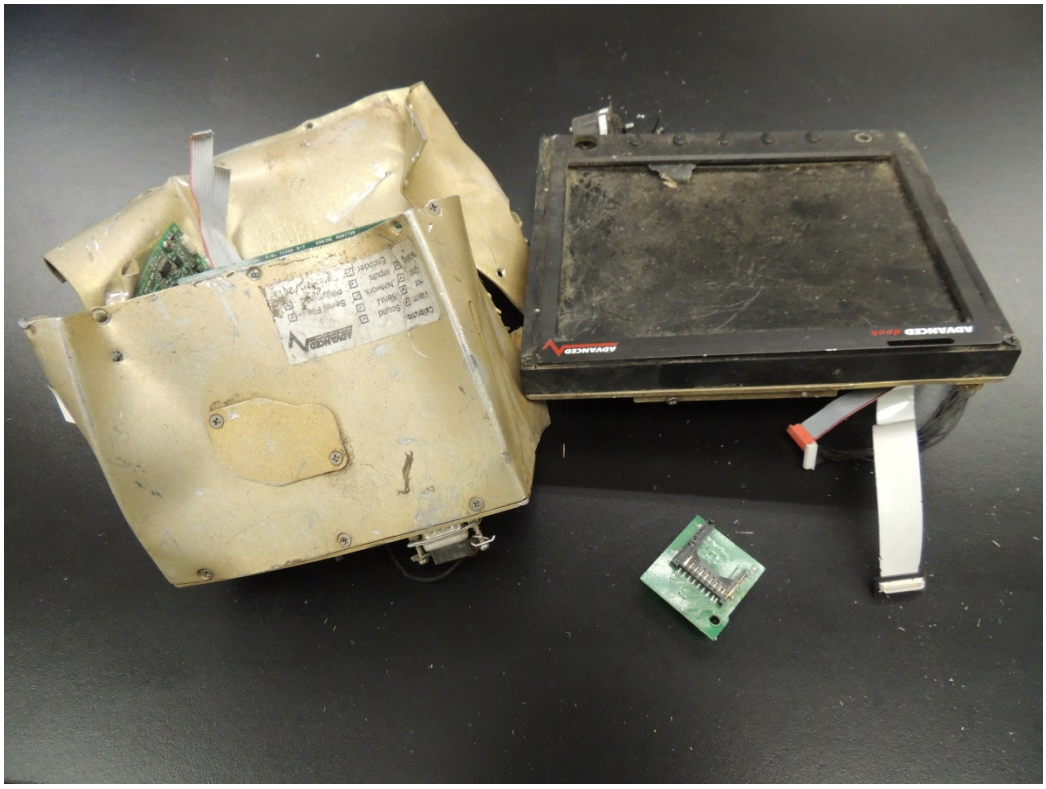

Figure 1. AF-4500 as received

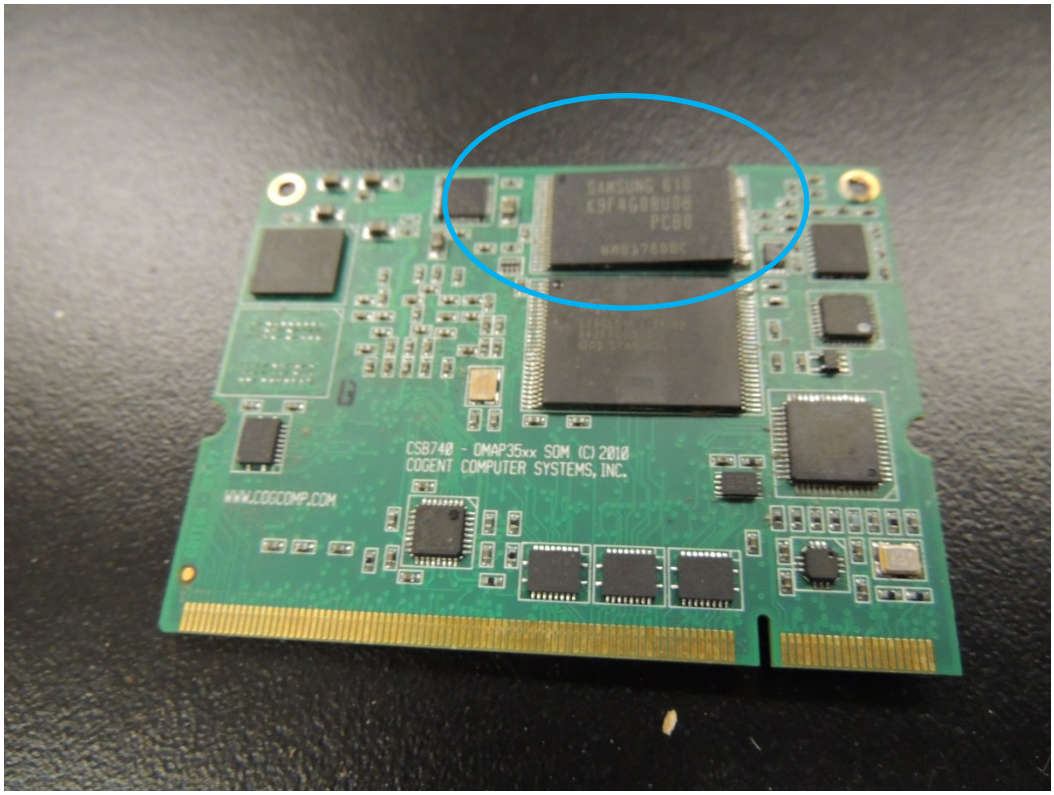

Figure 2. Removed AF-4500 Memory Board with partially detached chip highlighted

2.1.2. Advanced Flight Systems AF-4500s Display Data Description

The data extracted was from April 6, 2014 through September 8, 2014 and was sampled at 5 samples a second.

The event flight was identified by the device's recorded data and time from 22:03:35 to 22:17:55 UTC on September 8, 2014.

The flight prior to the event was identified from 18:28:50 to 18:59:50 UTC on September 8, 2014.

2.2. Pectel SQ6 Engine Control Unit Device Description

The SQ6 Engine Control Unit (ECU) is an engine management system whose primary function is ensuring engine performance and is commonly found in motorsport applications. The device is highly customizable and contains 8 digital inputs and 10 analog inputs. The device contains a data logging function that records a user defined sample rate. Data is recorded on volatile[2] memory and is backed up by an internal battery. The recorded parameters are user defined based on the installation of the device.

The device has a rev limiter function to protect against engine over speed conditions. The rev limiter function is made up off a soft limit and a hard limit. The rev limiting function is ultimately user configurable; generally the soft limit is used to define how the hard limit is

[2] Volatile memory requires constant power to retain data, if the connection from the battery to the circuit board gets severed, the data is lost.

reached. Based on the settings the soft limit will remove fuel, spark, or retard ignition timing to a particular cylinder and then gradually retard all cylinders as it approaches the hard limit. The hard limit cuts both fuel and spark to all cylinders.

2.2.1. Pectel SQ6 Engine Control Unit Data Recovery

Upon arrival at the Vehicle Recorder Laboratory, an exterior examination revealed the unit had sustained major impact damage. The battery containing the unit's memory was severed from the main circuit board; therefore, no data could be extracted (figure 3).

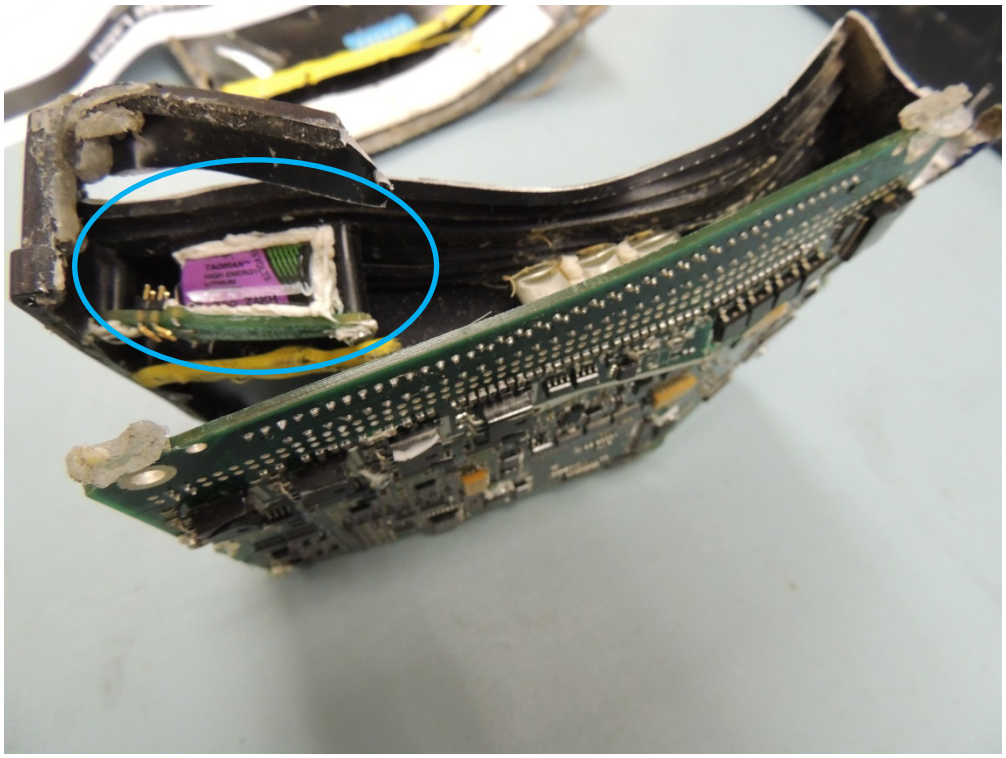

Figure 3. SQ6 ECU as received with detached battery highlighted.

However, the NTSB Vehicle Recorder Laboratory had received a download of the SQ6 ECU from the previous flight. The SQ6 ECU was downloaded by the pilot's race team prior to the event flight, during which the aircraft had experienced an over-speed condition. The SQ6 ECU data contained in this report pertains to the received file.

2.2.2. Pectel SQ6 Engine Control Unit Data File Description

The data received was 25 minutes in length recorded during the prior flight on September 8, 2014. The data was recorded at 20 samples per second.

Based on the device's configuration file, the soft and hard rev limits were configured such that the soft rev limit started at 6150 rpm, with a torque reduction level of 15%[3] using fuel cuts. The hard limit was set at 6300 rpm, with full fuel and spark being cut. A 'Rev Cut Spike Window' parameter was set to 150 rpm allowing brief spikes of engine rpm to 6450 rpm.

[3] 15 cuts in each 100 firing events

2.3. Data Source and Timing

The AF-4500 records time in Coordinated Universal Time (UTC). Correlation of the data to the event local time, PDT, was established by using the recorded time and then subtracting 7 hours to offset UTC to PDT.

The SQ6 ECU records time in elapsed seconds from the start of each event (EES). Correlation between the SQ6 ECU and AF-4500 was established by plotting Engine Rotations Per Minute (RPM) from both data sources and overlaying the plots to find a common point. The engine startup was selected due to the engine RPM's dynamic range during this time. The resulting equation between the SQ6 ECU and the AF-4500 was found to be:

PDT = EES + 66894 seconds

Therefore, for the rest of this report, all times are referenced as PDT.

3. PLOTS AND CORRESPONDING TABULAR DATA

The following plots contain data from the event and prior flight on September 8, 2014. The event flight data from the AF-4500 appeared to end inflight. According to the display manufacturer, a loss of signal from the engine, GPS, and air data system concurrently will stop the data from writing inflight.

Figure 4 is an overview of the event flight from 15:10:00 to the last recorded data point at 15:17:55 PDT. The aircraft took off at approximately 15:16:05 PDT. The last recorded RPM was 5679 at an indicated airspeed of 280 knots.

Figure 5 is an overview of the prior flight from 11:45:00 to 11:57:00 PDT. The aircraft took off at approximately 11:47:00 PDT. A dashed area denotes the occurrence of the ECU rev limiter function. This area is expanded in figure 6.

During the prior flight, the aircraft's indicated airspeed steadily increased to its maximum recorded value of 271 knots at 11:49:49 PDT. At this time, the ECU engine speed reached a recorded value of 6129 rpm, when the ECU engine speed began oscillating at a rate of 6 Hz.

Concurrently, the spark plug ignition angle began oscillating consistent with the soft rev limit function. About a half second later, the engine speed reached its max recorded value of 6206 rpm, at which time the injection time dropped to zero. The aircraft recorded a pitch up at 11:49:50 PDT, when the ECU recorded engine speed oscillations began to dampen. As the aircraft began to climb, a second rev limiter application occurred at 11:49:51 lasting a half second.

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 corresponding tabular data from the event flight and prior

flight are provided in electronic (*.csv[4]) format as Attachment 1 and 2, respectively to this report.

[4] Comma Separated Value format.

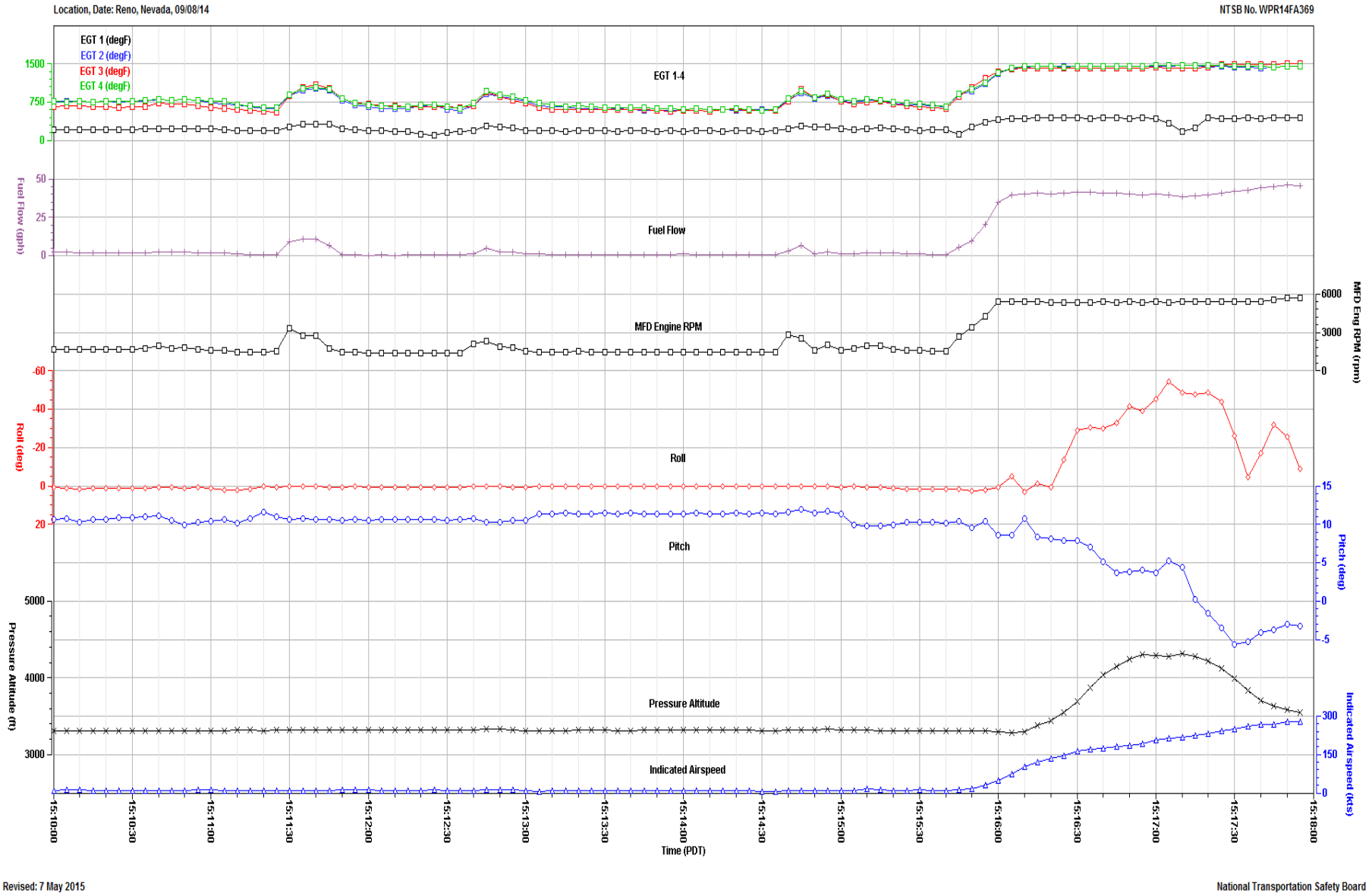

Figure 4. Plot of aircraft parameters during event flight.

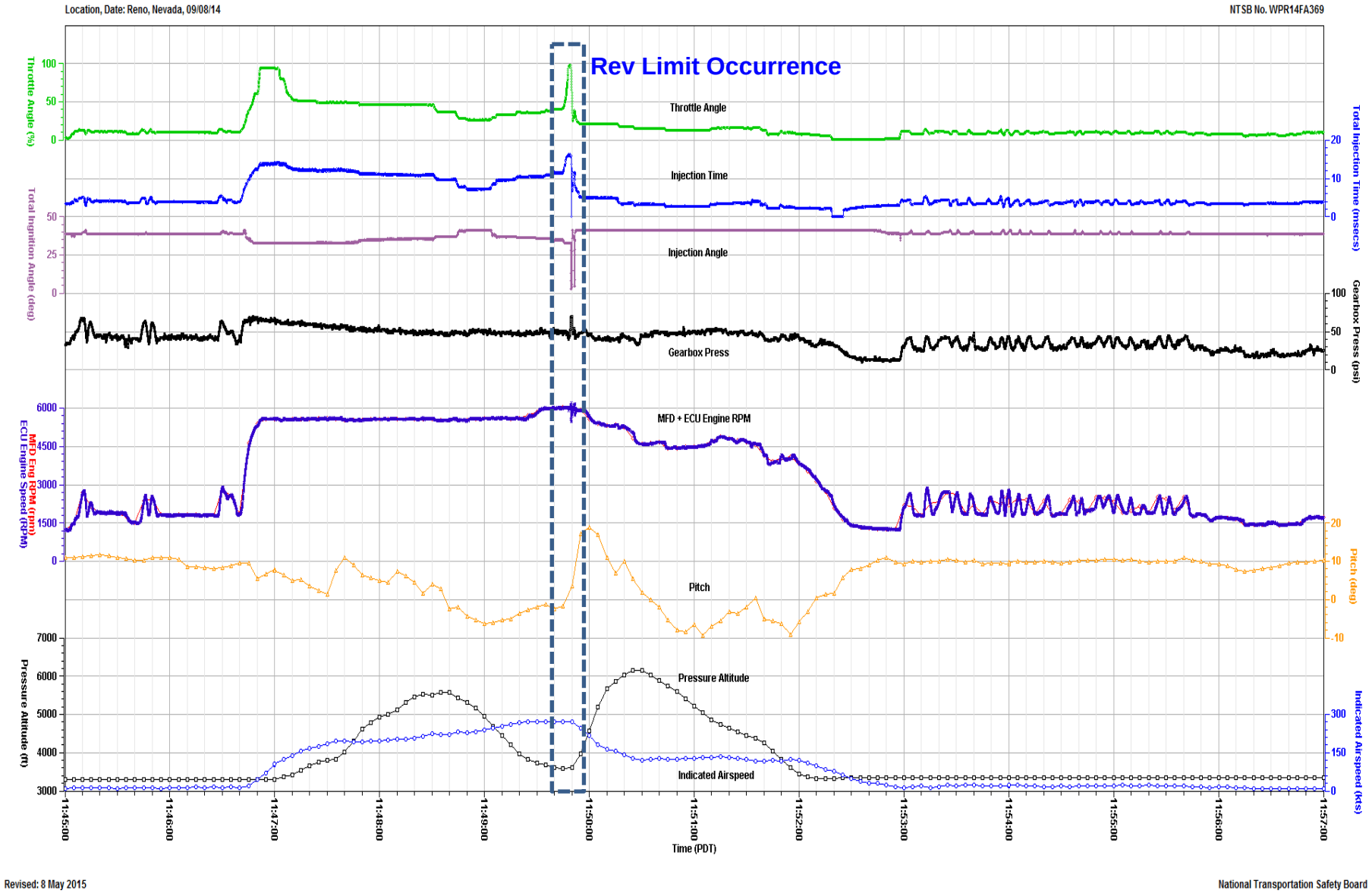

Figure 5. Plot of aircraft parameters during prior flight.

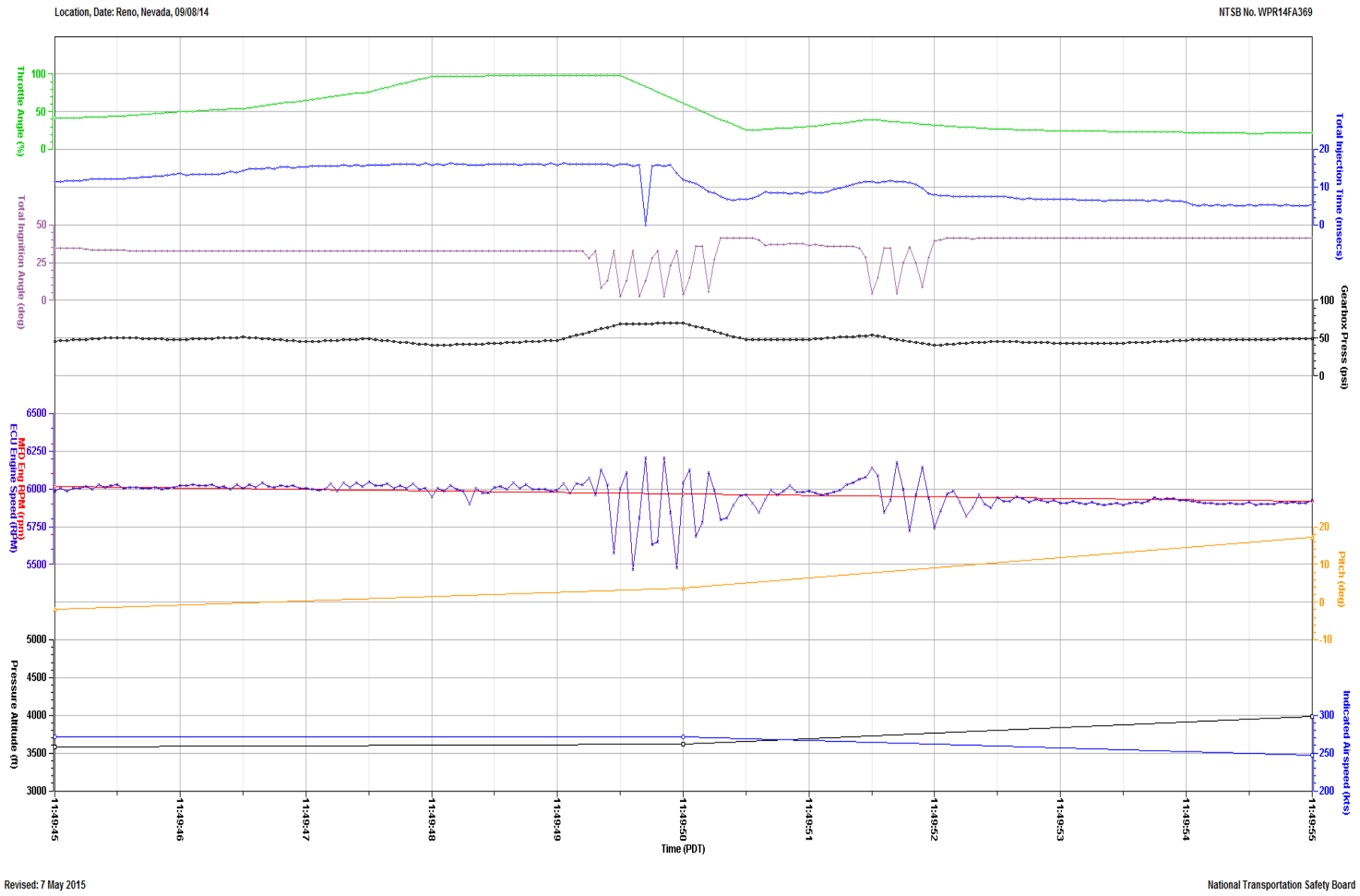

Figure 6. Plot of prior flight highlighting rev limiter.

APPENDIX A

This appendix describes the parameters provided and verified in this report. Table A-1 lists the parameters from the AF-4500, table A-2 lists the parameters from the SQ6 ECU, Table A-3 describes the unit abbreviations used in this report.

Table A-1. Verified and provided AF-4500 parameters.

Parameter Name	Parameter Description
1. Pressure Altitude (ft)	Pressure Altitude
2. Indicated Airspeed (kts)	Indicated Airspeed
3. MFD Eng RPM (rpm)	AF-4500 Engine Rotations per Minute
4. Pitch (deg)	Pitch
5. Roll (deg)	Roll Angle
6. Heading [a] (deg)	Heading
7. Fuel Flow (gph)	Engine Fuel Flow
8. EGT 1 (degF)	Exhaust Gas Temperature Cylinder 1
9. EGT 2 (degF)	Exhaust Gas Temperature Cylinder 2
10. EGT 3 (degF)	Exhaust Gas Temperature Cylinder 3
11. EGT 4 (degF)	Exhaust Gas Temperature Cylinder 4
12. Latitude [a] (deg)	GPS Latitude
13. Longitude [a] (deg)	GPS Longitude
14. Oil Press [a] (psi)	Oil Pressure
15. Oil Temp [a] (degF)	Oil Temperature

NOTE: [a] Not Plotted

Table A-2. Verified and provided SQ6 ECU parameters.

Parameter Name	Parameter Description
1. Total Injection Time (msecs)	Total Fuel Injection time
2. Throttle Angle (%)	Throttle Angle
3. Total Ignition Angle (deg)	Spark Plug Ignition Angle
4. Gearbox Press (psi)	Engine – Propeller Gear Box Pressure
5. ECU Engine Speed (rpm)	Shaft Engine Speed

Table A-3. Unit abbreviations.

Units Abbreviation	Description
deg	degrees
degF	degree Fahrenheit
kts	Knots
msecs	milliseconds
%	percentage
psi	pounds per square inch
gph	gallons per hour
ft	feet
RPM	revolutions per minute