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

July 30, 2015

Multiple Electronic Devices

Specialist's Factual Report
by Bill Tuccio, Ph.D.

1. EVENT

Location:	Challis, Idaho
Date:	April 10, 2015
Aircraft:	Cessna T210M
Registration:	N732YQ
Operator:	Private
NTSB Number:	WPR15FA143

On April 10, 2015 about 1315 mountain daylight time, a Cessna Centurion T210M, N732YQ, collided with trees shortly after departing from Upper Loon Creek USFS Airport (U72) located in the Salmon-Challis National Forest near Challis, Idaho. The pilot, who was the registered owner, was operating the airplane under the provisions of 14 *Code of Federal Regulations* Part 91. The private pilot and three passengers sustained fatal injuries; the airplane sustained substantial damage. The personal cross-country flight was originating from Upper Loon Creek with a planned destination of Driggs-Reed Memorial Airport (DIJ), Driggs, Idaho. Visual meteorological conditions prevailed and no flight plan had been filed.

2. DETAILS OF INVESTIGATION

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

Devices With Unrecoverable Information

Device 1: Unknown Camera
Device 1 Serial Number: Unknown

Device 2: Canon Camera (Model Unknown)
Device 2 Serial Number: Unknown

Devices With Recoverable Information

Device 3: Garmin GPSMAP 496
Device 3 Serial Number: 19723483

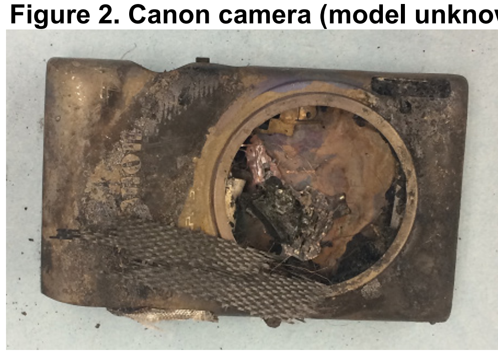
Device 4: J.P. Instruments (JPI) EDM-700
Device 4 Serial Number: Unknown

2.1. Devices With Unrecoverable Information

Figures 1 and 2 show two cameras received with extensive fire damage. Due to the fire damage, no information could be recovered.

Figure 1. Camera (make and model unknown).

Figure 2. Canon camera (model unknown).



2.2. Devices With Recoverable Information

2.2.1. Garmin GPSMAP 496 Device Description

The Garmin GPSMAP 496 is a battery-powered portable 12-channel GPS receiver with a 256-color TFT LCD display screen. The unit includes a built-in Jeppesen database and is capable of receiving XM satellite radio for flight information including NEXRAD radar, lightning, METARs, TAFs, and TFRs. The unit stores date, route-of-flight, and flight-time information for up to 50 flights. A flight record is triggered when groundspeed exceeds 30 knots and altitude exceeds 500 feet, and ends when groundspeed drops below 30 knots for 10 minutes or more. A detailed tracklog – including latitude, longitude, date, time, and GPS altitude information for an unspecified number of points – is stored within the unit whenever the receiver has a lock on the GPS navigation signal. Position is updated within the tracklog as a function of time or distance moved, depending on how the unit has been configured. Once the current tracklog memory becomes full, new information either overwrites the oldest information or the recording stops, depending on how the unit is configured. The current tracklog can be saved to long-term memory and 15 saved tracklogs can be maintained in addition to the current tracklog. Tracklog storage may be activated or de-activated at user discretion. All recorded data are stored in non-volatile memory[1]. The unit contains hardware and software permitting the download of recorded waypoint, route, and tracklog information to a PC via a built-in serial port using the NMEA 0183 version 2.0 protocol. The unit can also communicate with external devices such as a computer using a built in USB port. An internal button-battery is used to back-up power to the internal memory and real-time clock during those periods when main power is removed.

2.2.1.1. Garmin GPSMAP 496 Data Recovery

Upon arrival at the Vehicle Recorder Division, an exterior examination revealed the unit had sustained heat and impact damage, as shown in figure 3. An internal inspection revealed the non-volatile memory was intact, as shown in figure 4.

The non-volatile memory chip was removed from the printed circuit board (PCB) using a hot air re-work station. Figure 5 shows a close-up view of the 6x8 ball grid array (BGA) on the back of the chip during removal from the PCB (hot air re-work station in foreground). The BGA was reworked and a raw-data binary readout of the chip was obtained using a Xeltek SP-3000u EEPROM programmer. Recorded tracklog data was identified and converted to engineering units using an in-house software program.

Figure 3. Garmin GPS 496 as received.

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

Figure 4. Non-volatile memory (highlighted in red).

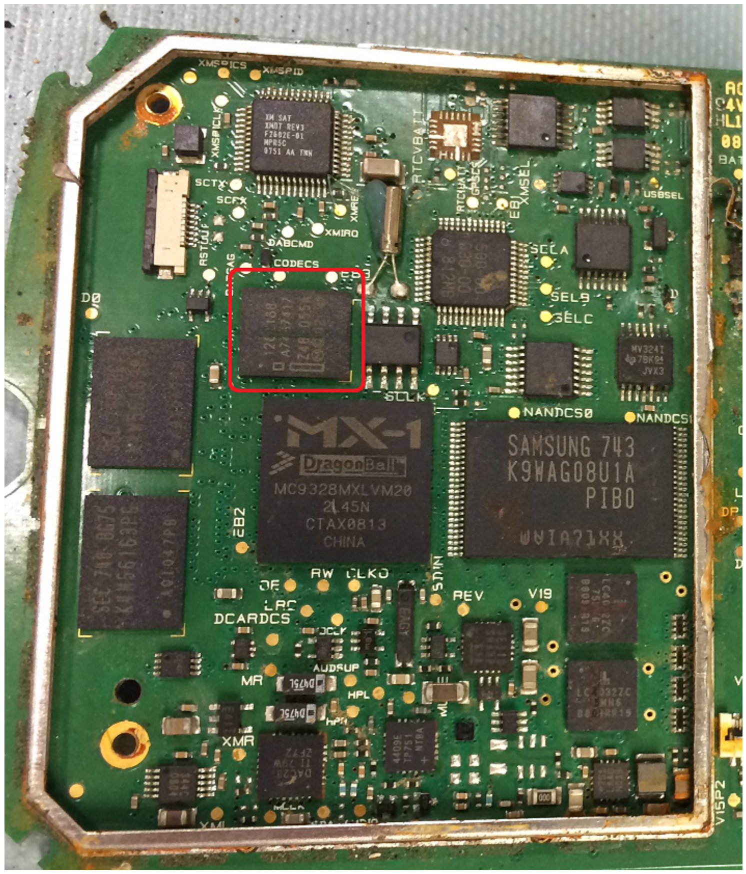
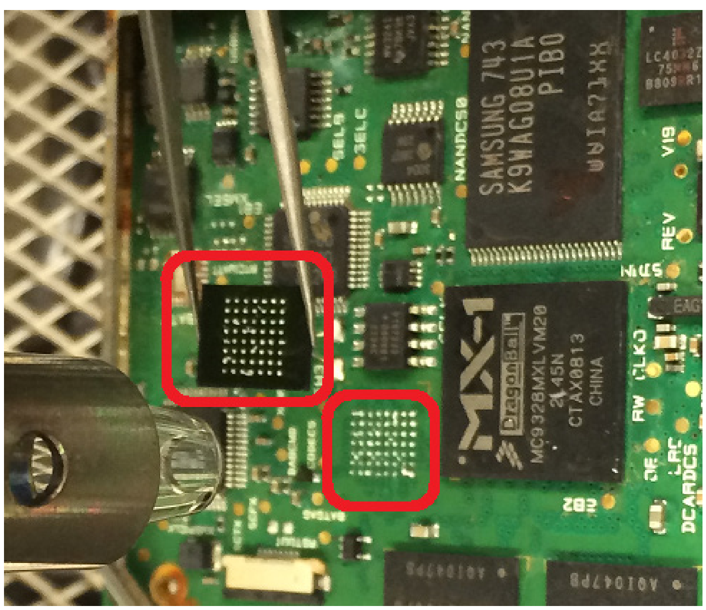


Figure 5. Non-volatile memory chip removed from PCB.



2.2.1.2. Garmin GPSMAP 496 Data Description

The data extracted included 50 sessions (15,818 total data points) from June 17, 2014[2], through April 10, 2015. The accident flight was the last session; the recording started at 1823:03 UTC and ended at 1825:02 UTC on April 10, 2015 (13 total data points).

The following flights were examined for this report:

- accident flight on April 10, 2015;
- flight prior to the accident flight (from DIJ to U72) on April 10, 2015; and
- nine prior runway 4 takeoffs from U72 between June 22, 2014 and September 25, 2014.

2.2.1.3. Garmin GPSMAP 496 Parameters Provided

Table 1 describes data parameters provided by the GPS device. Date, Time, Latitude, Longitude, and GPS Altitude are recorded by the device. Groundspeed and Track are derived from the recorded parameters.

Table 1: GPS Data Parameters

Parameter Name	Parameter Description
Date	Date for recorded data point (MM/DD/YYYY)
Time	Time for recorded data point (HH:MM:SS)
Latitude	Recorded Latitude (degrees)
Longitude	Recorded Longitude (degrees)
GPS Alt	Recorded GPS Altitude (feet, MSL[3])
Groundspeed	Average groundspeed between current and previous data point (knots)
Track	Average true course between current and previous data point (degrees)

2.2.1.4. Garmin GPSMAP 496 Overlays and Tabular Data

Figures 6 through 11 were generated using data extracted from the Garmin GPSMAP 496 and overlaid using Google Earth. The weather and lighting conditions depicted in Google Earth are not necessarily representative of the weather and lighting conditions experienced by the accident flight.

Figures 6 through 8 show all recorded data for the accident flight. The recording began at 1823:03 UTC and ended at 1825:02 UTC. The aircraft maneuvered into position for takeoff from 1823:03 UTC through 1824:09 UTC. The takeoff roll began sometime between 1824:09 UTC and 1824:32 UTC, when the recorded altitude on the ground was about 5,550 feet. The aircraft reached a maximum recorded altitude of 5,567 feet.

Figure 9 shows the prior flight from DIJ to U72 on April 10, 2015. The recording started at 1420:27 UTC and ended at 1547:37 UTC (about 1 hour 27 minutes); the portion from

[2] All dates and times are referenced to Coordinated Universal Time (UTC).
[3] MSL means altitude above mean sea level

takeoff to touchdown occurred between approximately 1426:42 UTC and 1545:46 UTC (approximately 1 hour 19 minutes).

A comparison was made between the accident takeoff and nine prior U72 takeoffs from the same runway direction. Two recorded points from the accident flight were used as the basis of comparison to the other nine flights: 1824:56 UTC and 1825:00 UTC; these two points are shown in figure 10, along with an annotation showing the method used to measure the lateral, perpendicular distance between the nine prior average flight paths and the two accident points. Figure 11 shows a composite view of the nine prior takeoff paths compared to the accident path. All distance measurements were performed in Google Earth.

Table 2 shows distances measured in Google Earth for the nine prior flights[4]. Positive displacements in table 2 are to the right of the associated accident point and negative numbers are to the left (relative to a northeast flight path). Relative to the 1824:56 UTC accident flight point, all nine prior flights were on a flight path to the right of this accident flight point with the farthest being 111 feet right of this accident flight point. Relative to the 1825:00 UTC accident flight point, five flights were to the right of this accident flight point, with the farthest being 126 feet right of this accident flight point. Using data from all the prior takeoffs, the average course was 56 feet right of the 1824:56 UTC accident flight point and 21 feet right of the 1825:00 UTC accident flight point.

Table 2. Lateral displacements relative to accident flight.

		Displacement Relative to Accident Points	
Leg	**Flight Date**	**Compared to accident point at 1824:56 feet**	**Compared to accident point at 1825:00 feet**
3	6/22/2014	42	54
6	7/11/2014	71	33
8	7/15/2014	67	55
11	7/25/2014	19	-22
16	8/17/2014	34	-39
19	9/6/2014	111	118
21	9/9/2014	110	126
23	9/10/2014	26	-63
27	9/25/2014	28	-72
49 (acc)	4/10/2015	0	0

Table 3 shows average computed ground speeds[5] for the nine prior flights compared to the accident flight. Due to the limited sample rate of data points, the points used for comparison are not adjacent to the accident flight points at 1824:56 and 1825:00 UTC.

[4] These values do not consider dilution of precision (DOP) or other confounding factors. See Langley, R. B. (1999). "Dilution of Precision," *GPS World*, May 1999, pp. 52-59.

[5] Lack of atmospheric conditions (e.g., density altitude, winds) for flights did not permit a conversion of ground speed to calibrated airspeed.

See figure 11 for the relative position of each of the nine prior flights and the accident flight.

Table 3. Ground speed comparisons relative to accident flight.

	Time of Recorded Point Used for Comparison		Ground Speed	
Leg	**Accident at 1824:56 (UTC)**	**Accident at 1825:00 (UTC)**	**Accident at 1824:56 (kts)**	**Accident at 1825:00 (kts)**
3	1426:44	1426:50	69	69
6	1437:54	1438:00	75	77
8	1652:08	1652:15	73	73
11	1449:39	1449:45	80	81
16	1519:38*	1519:14*	68	68
19	1731:01	1731:08	75	79
21	1357:52*	1357:58	73	76
23	1656:23*	1656:30*	70	73
27	1859:56*	1900:03	74	79
49 (acc)	1824:56	1825:00	73	77

Note: * means the magnitude of the distance along the flight path relative to the two accident points was greater than that shown for the points in Leg 19.

Table 4 shows recorded GPS altitudes[4] for the nine prior flights compared to the accident flight. The points used for comparison in table 4 are the same points used in table 3, with the same sample rate limitations; see figure 11 for the relative position of each of the nine prior flights and the accident flight.

Table 4. GPS altitude comparisons relative to accident flight.

	Time of Recorded Point Used for Comparison		GPS Altitude (ft)	
Leg	**Accident at 1824:56 (UTC)**	**Accident at 1825:00 (UTC)**	**Accident at 1824:56 (ft)**	**Accident at 1825:00 (ft)**
3	1426:44	1426:50	5,649	5,740
6	1437:54	1438:00	5,589	5,655
8	1652:08	1652:15	5,597	5,657
11	1449:39	1449:45	5,614	5,723
16	1519:38*	1519:14*	5,617	5,676
19	1731:01	1731:08	5,603	5,690
21	1357:52*	1357:58	5,613	5,693
23	1656:23*	1656:30*	5,572	5,651
27	1859:56*	1900:03	5,540	5,589
49 (acc)	1824:56	1825:00	5,548	5,567

Note: * means the magnitude of the distance along the flight path relative to the two accident points was greater than that shown for the points in Leg 19.

Tabular data used to generate figures 6 through 11 are included as attachment 1 in electronic comma-delimited (.CSV) format.

Figure 6. Entire accident flight recording.

Figure 7. Start of accident flight recording.

Figure 8. End of accident flight recording.

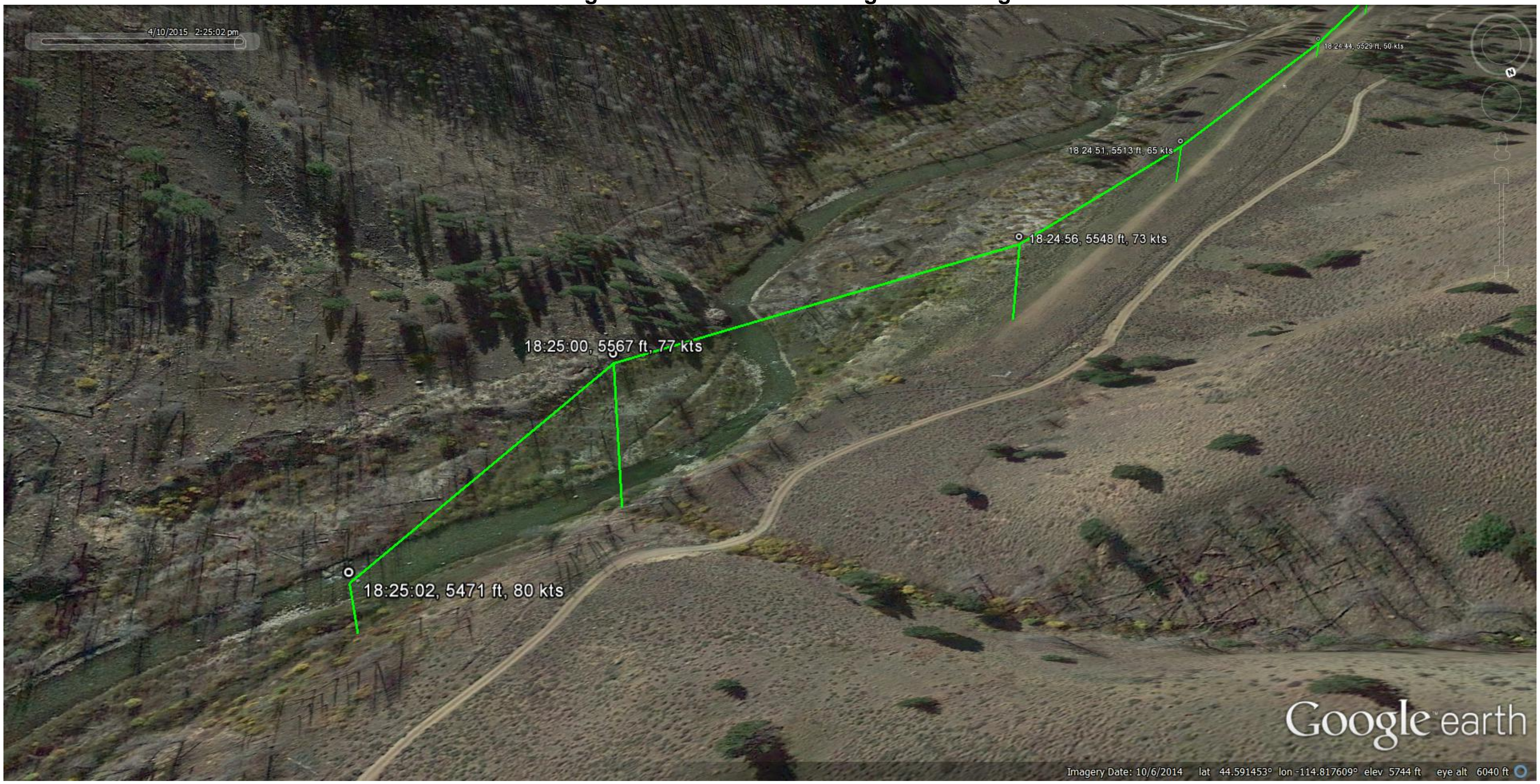


Figure 9. Flight prior to accident flight (DIJ to U72).

Figure 10. Method used to measure distance relative to accident flight.

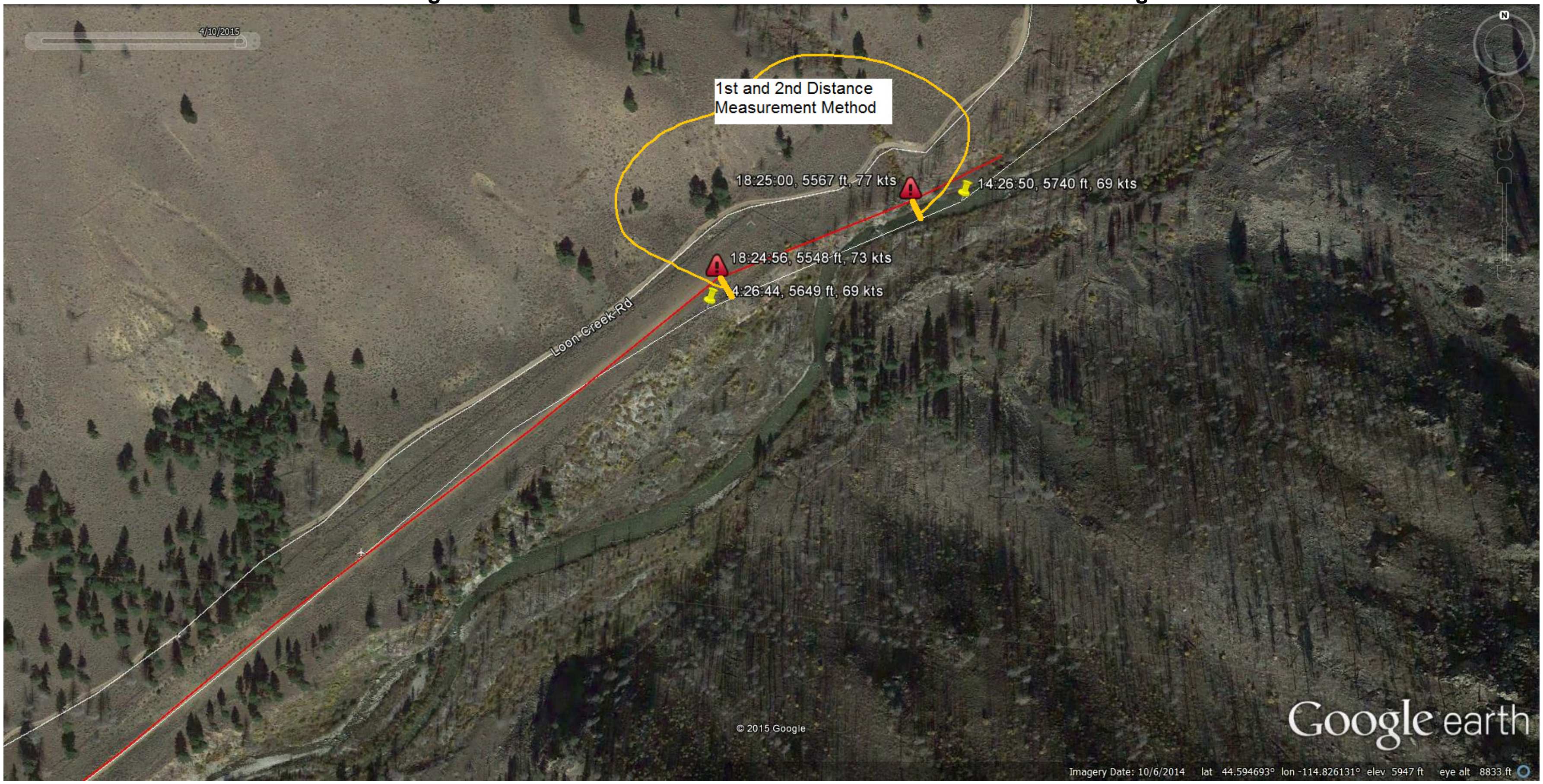


Figure 11. Comparison of nine prior U72 runway 4 takeoffs.

2.2.2. JPI EDM-700 Device Description

The JPI EDM-700 is a panel mounted instrument enabling the operator to monitor and record up to 24 parameters related to engine operations. Depending on the installation, engine parameters monitored can include: exhaust gas temperature (EGT), cylinder head temperature (CHT), oil pressure and temperature, manifold pressure, outside air temperature, turbine inlet temperature (TIT), engine revolutions per minute, compressor discharge temperature, fuel flow, carburetor temperature, and battery voltage.

The unit can also calculate, in real-time, horsepower, fuel used, shock cooling rate, and EGT differentials between the highest and lowest cylinder temperatures. The calculations are also based on the aircraft installation.

The unit contains non-volatile memory for data storage of the parameters recorded and calculated. The rate at which the data is stored is selectable by the operator from 2 to 500 seconds per sample. The memory can store up to 20 hours of data at a 6 second sample rate. The data can then be downloaded by the operator using the JPI software.

2.2.2.1. JPI EDM-700 Data Recovery

Upon arrival at the Vehicle Recorder Laboratory, an exterior examination revealed the unit had sustained significant heat and minor structural damage, as shown in figure 12. An internal inspection revealed that non-volatile memory chips containing recorded information were intact, as shown in figures 13 and 14[6].

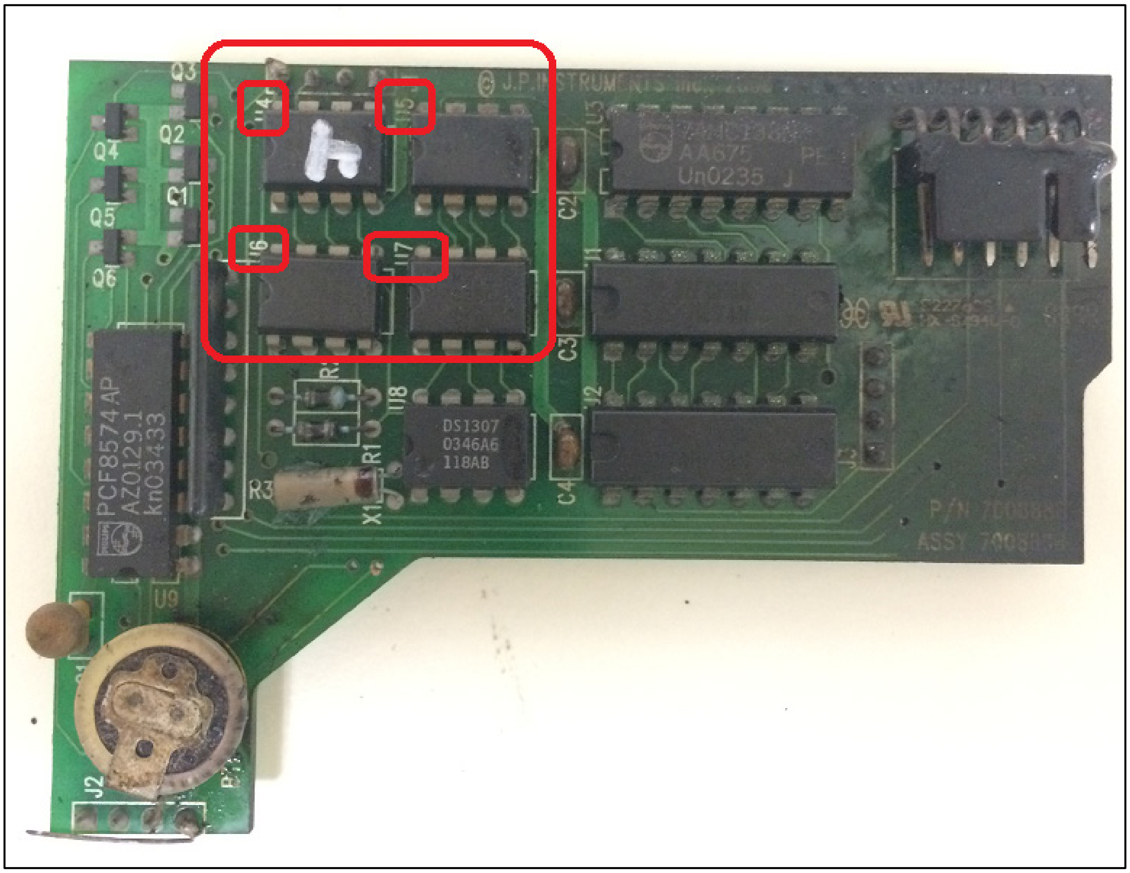
The non-volatile memory chips were removed from the printed circuit board (PCB) using a hot air re-work station. A raw-data binary readout of the chips was obtained using a Xeltek SP-3000u EEPROM programmer. Recorded data was identified and converted to engineering units using an in-house software program.

[6] Recorded data is contained on the chips located at PCB locations U4,U5,U6,U7. Optional configuration information is contained on the chip located at U19. The U19 chip was destroyed in this accident.

Figure 12. JPI EDM-700 as received.

Figure 13. JPI EDM-700 internal inspection.

Figure 14. JPI EDM-700 non-volatile memory chips.



2.2.2.2. JPI EDM-700 Data Description

The data extracted included 22 sessions from September 25, 2014 through April 10, 2015, JPI Recorded Time[7]. The accident flight was the last session, recorded starting at April 10, 2015, at 2117:10 JPI Recorded Time and ending on April 14, 2015, at 1848:56 JPI Recorded Time. The end time of the last session was invalid and was likely due to a combination of: (a) the accident circumstances, (b) the JPI recording logic, and (c) the chip-level recovery and decode process. The last two sessions on the device—containing the prior flight from DIJ to U72 and the accident flight—are discussed in this report.

The data was recorded once every 12 seconds. All JPI EDM-700 times in this report are reported as relative time from the start of each recording session.

2.2.2.3. JPI EDM-700 Parameters Provided

The engineering units conversions used for the data contained in this report are based on documentation from the manufacturer of the EDM-700, JPI.

[7] The JPI uses an internal clock, manually set by the user.

Table 5: JPI EDM-700 Data Parameters

Parameter Name	Parameter Description
1. BAT (Volts)	Bus Voltage
2. Eng1 CHT-1 (degF)	Cylinder Head Temperature Cylinder 1
3. Eng1 CHT-2 (degF)	Cylinder Head Temperature Cylinder 2
4. Eng1 CHT-3 (degF)	Cylinder Head Temperature Cylinder 3
5. Eng1 CHT-4 (degF)	Cylinder Head Temperature Cylinder 4
6. Eng1 CHT-5 (degF)	Cylinder Head Temperature Cylinder 5
7. Eng1 CHT-6 (degF)	Cylinder Head Temperature Cylinder 6
8. Eng1 EGT-1 (degF)	Exhaust Gas Temperature Cylinder 1
9. Eng1 EGT-2 (degF)	Exhaust Gas Temperature Cylinder 2
10. Eng1 EGT-3 (degF)	Exhaust Gas Temperature Cylinder 3
11. Eng1 EGT-4 (degF)	Exhaust Gas Temperature Cylinder 4
12. Eng1 EGT-5 (degF)	Exhaust Gas Temperature Cylinder 5
13. Eng1 EGT-6 (degF)	Exhaust Gas Temperature Cylinder 6
14. Eng1 Fuel Flow (pph)	Fuel Flow[8]
15. Eng1 Fuel Used (lbs)	Fuel Used
16. Eng1 MAP (inHg)	Manifold Pressure
17. Eng1 RPM (rpm)	Propeller RPM
18. Eng1 TIT-1 (degF)	Turbine Inlet Temperature
19. Time (hh:mm:ss)	Relative Time of Data Sample

Note: degF is degrees Fahrenheit; pph is pounds per hour; lbs is pounds; inHg is inches of Mercury; rpm is revolutions per minute.

2.2.2.4. JPI EDM-700 Plots and Tabular Data

Figure 15 shows the engine data recorded for the accident flight takeoff from U72[9]. By 0000:24 elapsed time, the CHT values began to increase. Between 0001:36 and 0001:48 elapsed time, the EGT values, RPM, and fuel flow all began to increase. After 0002:12 elapsed time, all values contain no variation, consistent with invalid data.

Figure 16 shows the entire prior flight from DIJ[10] to U72. The recording was 1 hour and 27 minutes in length, consistent with the Garmin GPSMAP 496 recording on April 10, 2015. This plot highlights the fuel flow values during a steady-state part of the flight. The fuel flow was about 100 pph for 45 minutes; during this period the fuel used increased 76 lbs from 32 to 108 lbs, supporting the fuel flow parameter was measuring fuel flow (as opposed to a different physical measurement, such as fuel pressure).[11]

Figure 17 shows the prior flight takeoff from DIJ. By 0006:12 elapsed time, the CHT values began to increase. Between 0006:36 and 0007:00 elapsed time, the EGT values,

[8] The EDM-700 allows fuel-related units to be configured for gallons or pounds; this device was configured for pounds.
[9] The U72 airport elevation is 5,500 feet.
[10] The DIJ airport elevation is 6,231 feet.
[11] While the fuel flow parameter was measuring fuel flow, the accuracy of fuel flow measurement is dependent upon proper installation and continued airworthiness of the fuel flow sensor. See JPI Pilot's Guide EDM-700/EDM-800/EDM-711.

RPM, and fuel flow all began to increase. Thereafter, values fluctuated consistent with a subsequent climb from DIJ.

Tabular data used to generate figures 15 through 17 are included as attachment 2 in electronic comma-delimited (.CSV) format.

Figure 15. Accident flight.

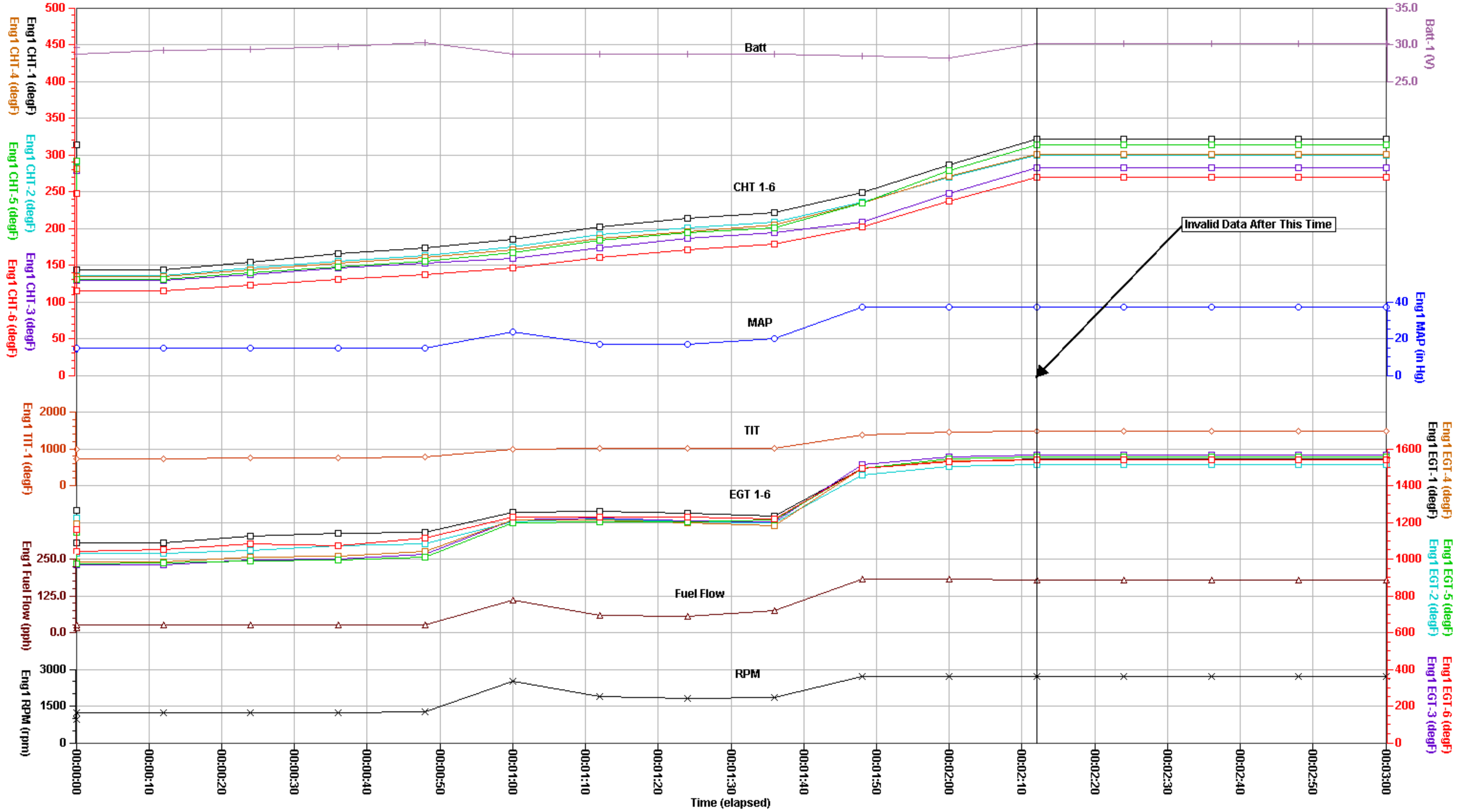


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Figure 16. Prior flight from DIJ to U72.

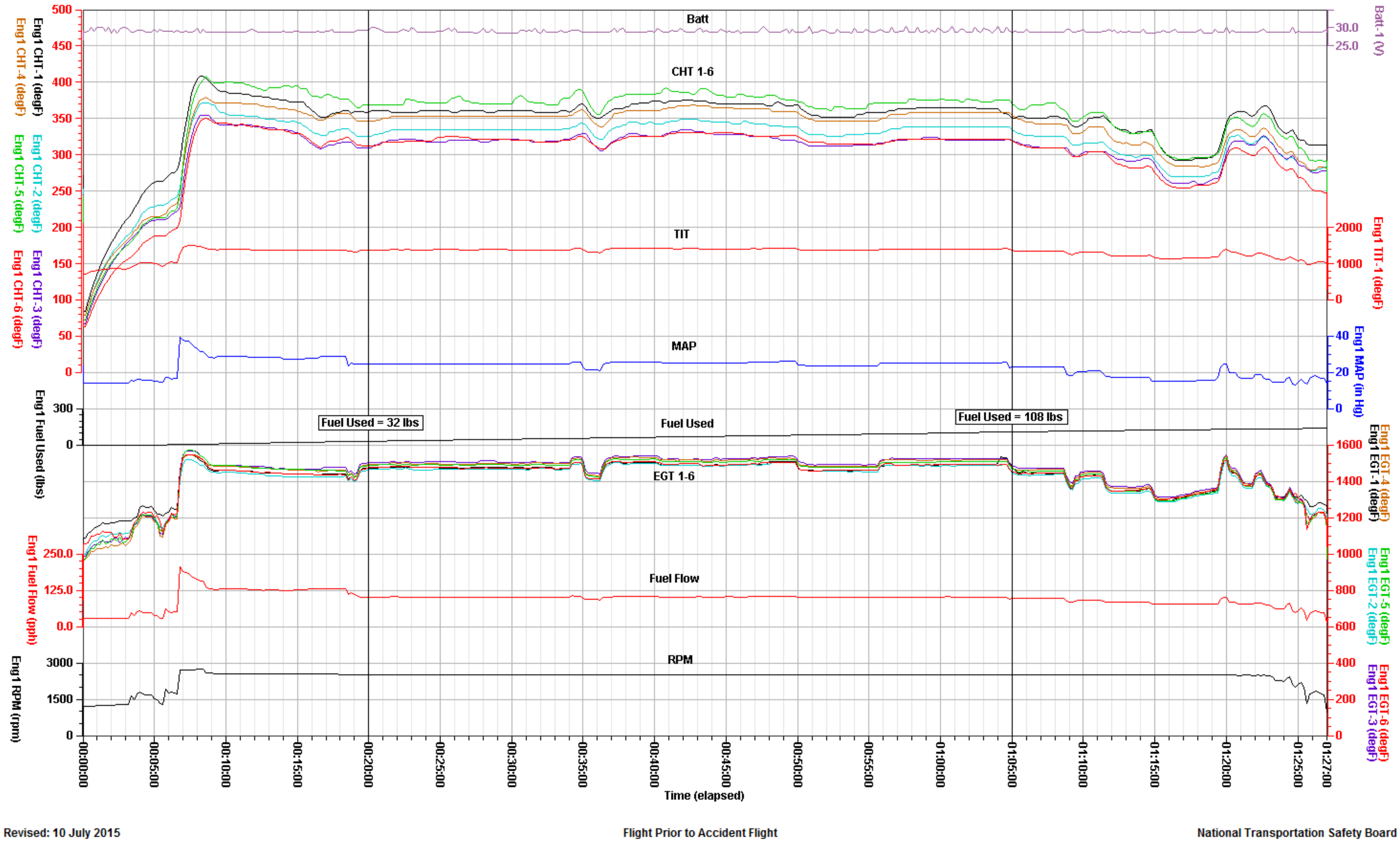
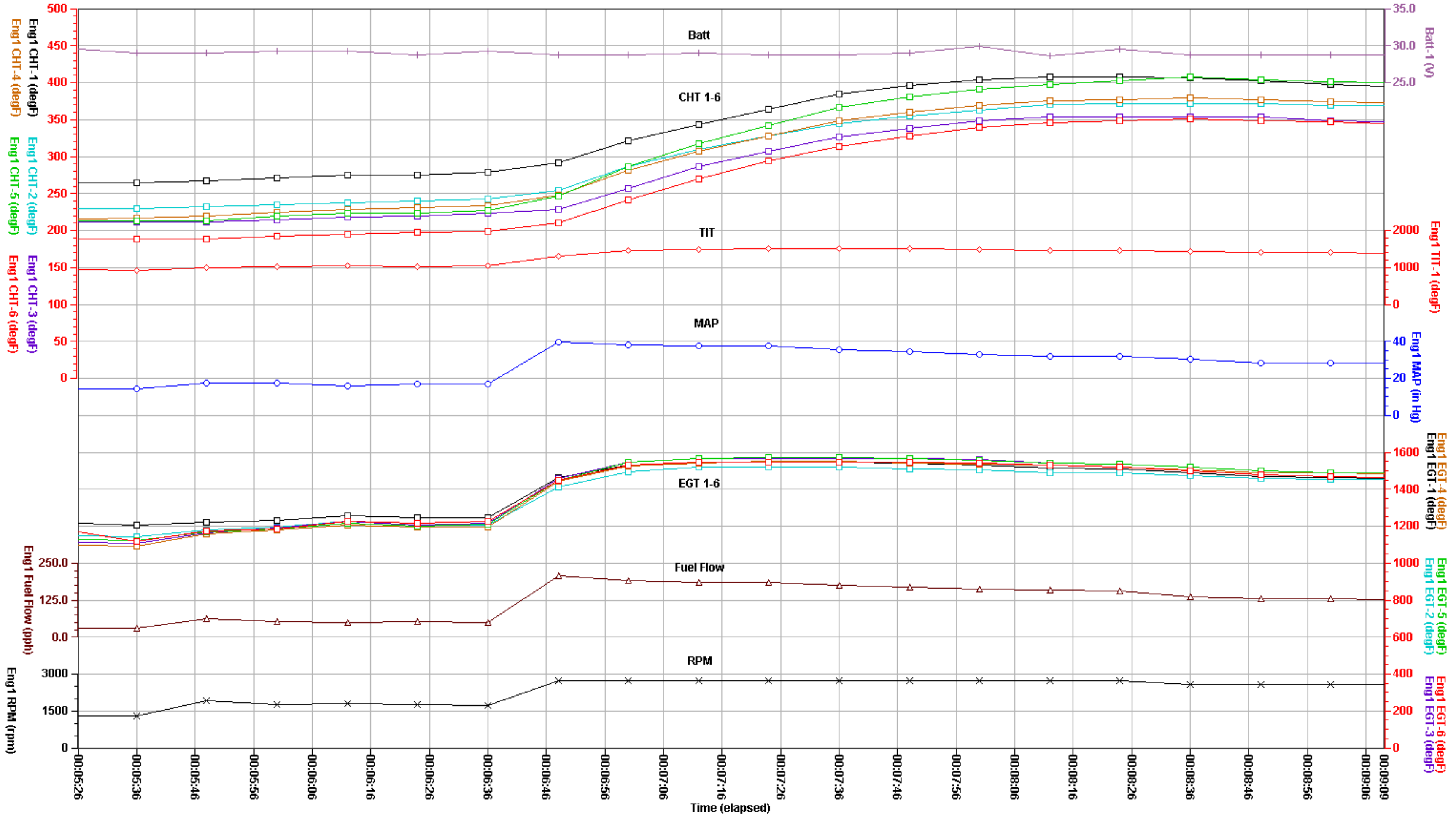


Figure 17. Prior flight from DIJ to U72 (takeoff focus).



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Flight Prior to Accident Flight - Take-off

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