

Introduction

This report includes analyses of PFD flight log data and MFD engine log data from the accident flight of N5VK on January 7, 2017. The analyses are limited to the time period from the start of the takeoff roll at approximately 15:21 UTC to the end of the flight at approximately 16:52 UTC.

The PFD log records are tagged with elapsed time since the PFD was started, in seconds. Among other data recorded by the PFD are sampled data received from the Garmin GNS430 GPS navigator. Because the GPS timestamps are sampled, there is an uncertain relationship between the time at which any given record is sampled and the actual time at which it was computed (i.e., the GPS time contained in the record). The correspondence between the PFD time base and UTC was determined by assuming that the minimum delay between generation of UTC timestamps on the GNS430 and recording in the PFD log is zero. This is an unrealistic assumption (there must be some non-zero delay) but it is believed to be adequate for present purposes – probably well under a second. Based on the results obtained by using this fitting technique, the first record in the PFD logs is taken to have been recorded on 1/7/2017 at 15:04:16 UTC. Subsequent records in the PFD logs are taken to have been recorded at a time determined by adding the timestamp in the record to that base value; the PFD's internal time base is taken to be sufficiently accurate to reflect elapsed time over the duration of any given flight.

The MFD log records are themselves tagged with UTC. While similar sampling errors exist, the coarse sampling frequency of the MFD does not support the type of fitting used for the PFD. No effort has been made to specifically examine time base consistency between the PFD and MFD.

For the purposes of this report, times are reported in UTC rounded to the nearest second. In the case of times reported based on PFD data, the PFD internal time is also included in order to facilitate location of the data in the logs themselves.

Note that the version of software on the PFD does not record barometrically corrected altitude and I have not attempted to calculate it in my analysis. Consequently, all altitudes in this report are pressure altitudes.

In evaluating engine data recorded on the MFD, it is important to note that out-of-range values are reported by the SIU as zero. In particular, EGTs below 500°, CHTs above 500° and CHTs below 100° will all be reported as zero. As are used in the graphs, C1 through C6 are used as shorthand for CHTs for the respective cylinders and E1 through E6 are used for the EGTs.

Takeoff and climb to cruise altitude

The takeoff roll was initiated on Runway 13 at the Provo Municipal Airport at 15:21:35 UTC (1039.2 sec PFD time). The airplane left the ground at approximately 15:21:52 (1056) on a heading of 137° and at 79 KIAS. Pressure altitude at takeoff was 4097 ft, or about 400 ft below field elevation. The engine logs show 24" MP, 2630 RPM and 23.2 GPH fuel flow. EGTs range from 1340° to 1386° and CHTs range from 242° to 254°. The autopilot was last reported prior to takeoff to be ready but disabled.

The airplane departed straight out (Figure 1).

Between 15:23:49 (1172.8) and 15:23:56 (1180) a series of autopilot mode changes were made, resulting in the engagement of the autopilot in vertical speed mode to a pre-selected altitude (VS ALT) and GPS roll steering navigation mode (NAV GPSS). The airplane was at a pressure altitude of approximately 6030 ft, the vertical speed bug was set to +500 fpm and the altitude bug was set to 7500 ft. The GPS waypoint was YMONT, which is located approximately 15 nm southeast of Provo.

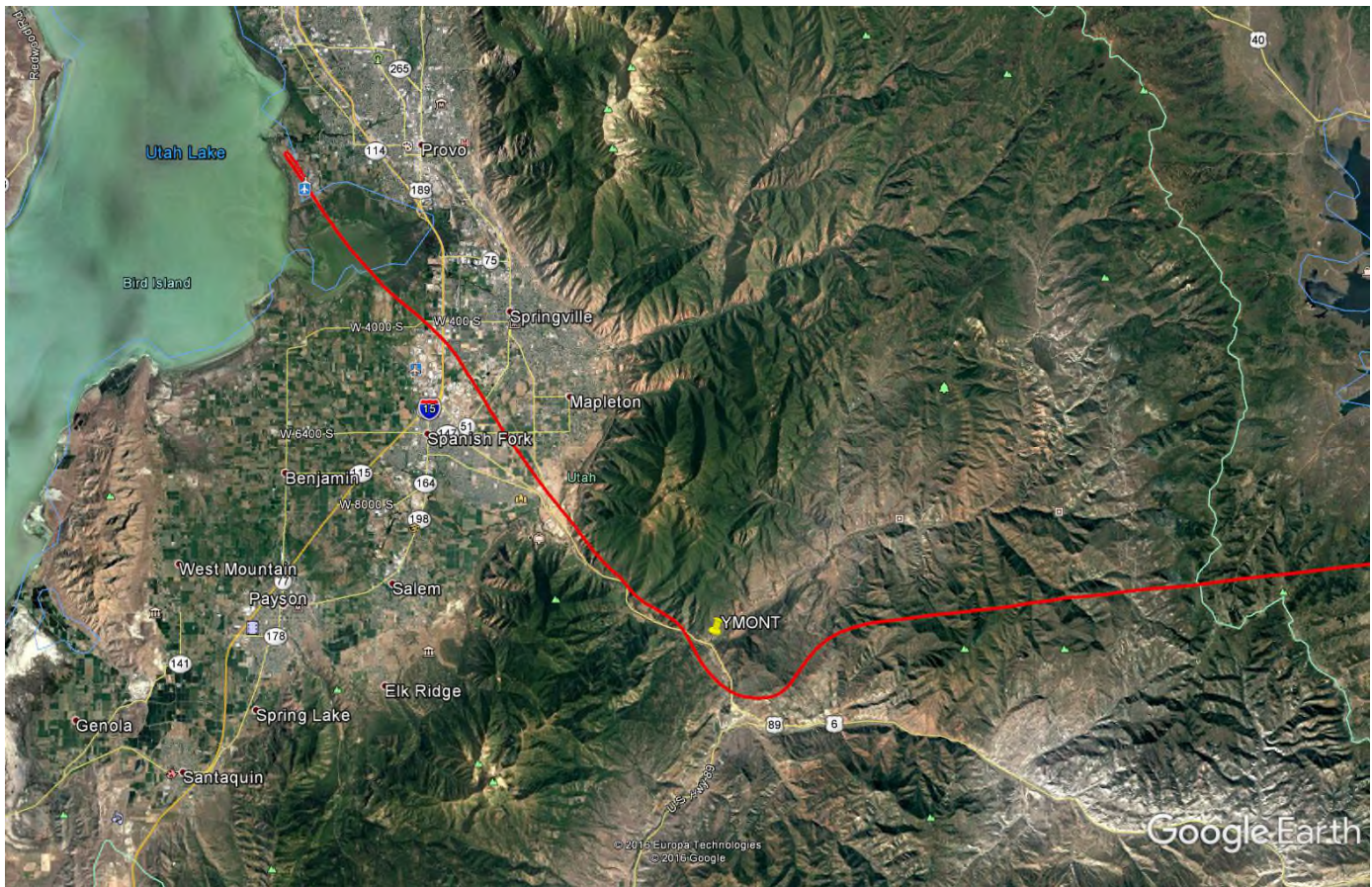


Figure 1: Route of flight, takeoff and initial climb

Beginning shortly after takeoff, cylinder three began to register higher CHTs than the other five cylinders (Figure 2). Within about two minutes after takeoff, C3 read 400° and was increasing rapidly, while the other five cylinders were all at around 300° . C3 peaked shortly thereafter at nearly 500° , then fell, but continued to show readings 25° to 50° higher than the others for a period of time.

In the meantime, fuel flow had been falling slowly but steadily in the climb. At 15:24:00, however, FF appears to have briefly increased slightly, then fell briefly at an increased rate, settling at about 20 GPH at 15:25, then stepping down to about 21.5 GPH at 15:26. Following this step, it resumed its gradual decrease with altitude.

At 15:24:36, cylinder four's EGT abruptly rose from 1325° to 1400° , then fell rapidly below the SIU's minimum of 500° . It remained below this threshold for the remainder of the flight. The cylinder's CHT, which had been around 300° before the drop in EGT, also began to drop. Within a minute and a half, it fell below 200° . Within another minute and a half, it fell below 120° and it maintained values around 100° for the remainder of the flight.

Between 15:25:31 (1275.4) and 15:25:36 (1279.8), the altitude bug changed to 8500 ft with no change of autopilot mode. At 15:27:56 (1420.2), the first of a series of 50 FPM reductions in selected vertical speed were made, the result of the PFD's automatic altitude capture program. Pressure altitude at the time was 7850 ft. VS bug reductions continued until 15:28:49 (1473.2), at which time the selected altitude was evidently captured (at 8115 ft PA). The VS mode was extinguished and the vertical speed bug was changed to zero.

At 15:27:57 the autopilot lateral mode changed from NAV GPSS to HDG. The heading bug was at 139° , unchanged from takeoff. The airplane, which had been on a heading of about 106° , began a right turn, reaching 139° approximately one minute later.

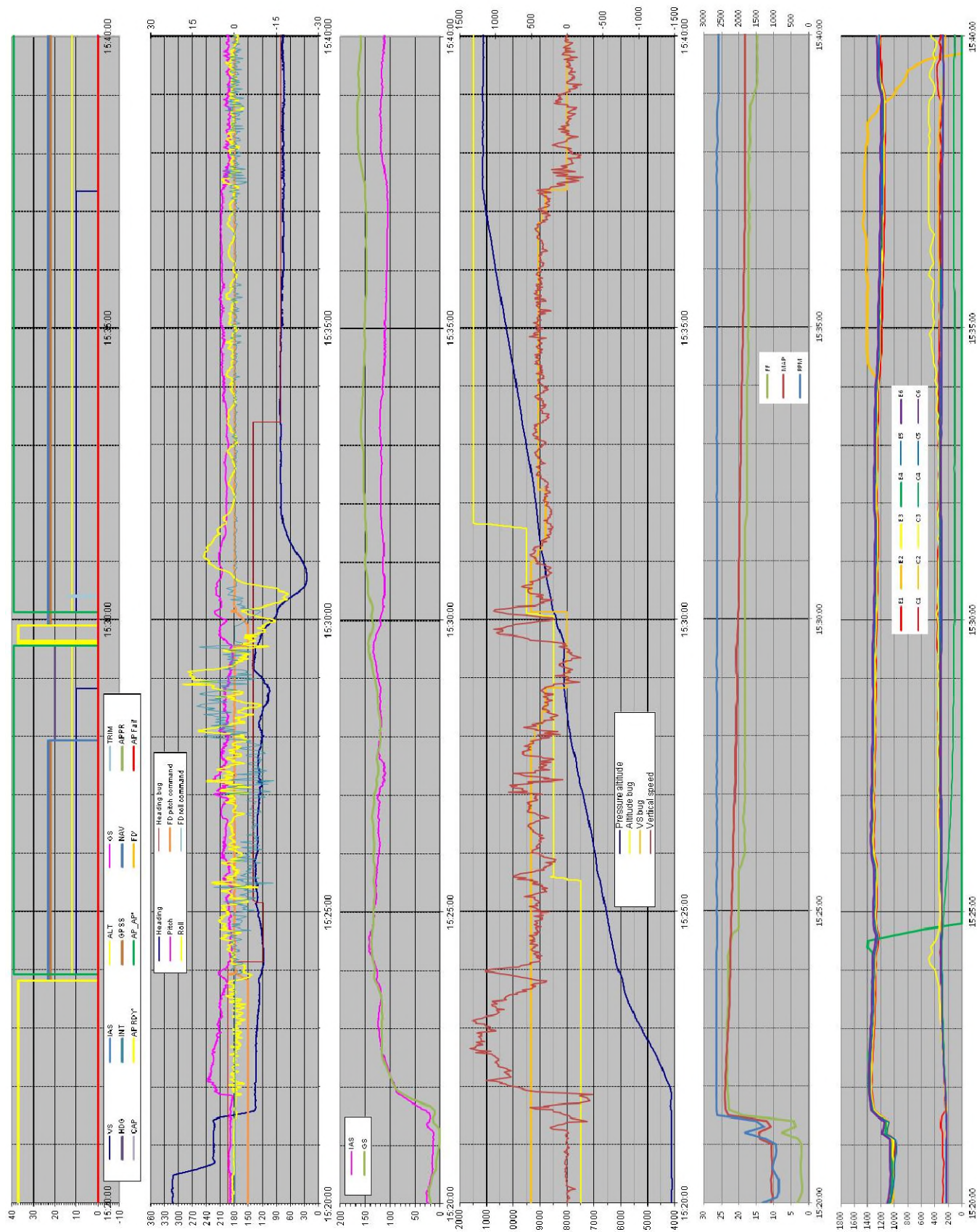


Figure 2: Flight and engine data, takeoff and initial climb

At 15:29:34 (1517.6), the autopilot was disengaged. Up to this point, the airplane had flown at a constant altitude of 8120 ft PA but had come left to about 130°, despite the fact that the heading bug remained at 139°. (The flight director

was commanding a return to the selected heading.) Two seconds later, passing YMONT, the GPS waypoint switched to MTU, the Myton VOR. With the autopilot off, the airplane turned left and began to climb.

At 15:30:08 (1552.4) the autopilot was reengaged in VS ALT NAV GPSS mode. The altitude bug had been reset to 9500 ft, the VS bug was automatically set to +500 FPM and the GPS waypoint remained at MTU, which was then 63 nm to the ENE. By 15:31:36 (1640), the airplane captured the desired nav course on a heading of 74° and was climbing through 9060 ft PA as the altitude bug was reset to 11500 ft. The VS bug had been reduced to +300 FPM, automatically in anticipation of leveling off at 9500 ft, and was increased to +400 FPM about a minute later. At 15:37:21 (1984.6), the autopilot mode switched to ALT NAV GPSS based on arrival at the selected altitude (11133 ft PA).

At 15:34, while the airplane was still climbing, cylinder three's CHT increased its separation from that of the other cylinders and quickly rose above 400°. For the next ten minutes, it ran significantly above those of the other cylinders, frequently reaching 500°. Simultaneously, the C2 EGT rose without a corresponding change among the other cylinders. After about three and a half minutes, at 15:38:30, the fuel flow, which had fallen to about 17 GPH, was further reduced to about 15 GPH. Concurrent with the FF reduction, the C2 EGT fell off rapidly, falling below the SIU sensing range in a little more than a minute. As was the case previously with cylinder four, C2 fell following the drop in EGT. Neither C2 nor E2 increases to the normal range for the remainder of the flight.

Cruise

At 15:40 (2143.6), the airplane was established in cruise (Figure 3) at 11100 ft PA, which is taken to be 11500 ft MSL, the altitude bug value. The autopilot was engaged in ALT NAV GPSS mode. The current GPS waypoint was MTU, 38 nm to the ENE. The airplane's heading was 76°, its airspeed was 112 KIAS and its groundspeed was 160 kts (Figure 4). The engine was operating at 18.2" MP and 2580 RPM, drawing 14.7 GPH. EGTs for cylinders one, three, five and six were between 1200° and 1260°. CHTs for one, five and six were stable between 275° and 320°. CHT for cylinder three was fluctuating between about 400° and 500°. EGTs for two and four were off-scale low. CHT for two was below 250° and dropping. EGT for four was just over 100° and stable.



Figure 3: Route of flight, cruise

Over the next 15 minutes, there were fluctuations in fuel flow with corresponding fluctuations in EGT and some variation in CHT. E1, E3, E5 and E6 were strongly correlated initially, but after a few minutes E1 began to show a negative correlation with respect to the others.

At 15:54:40 (3024), as the airplane passed MTU, the GPS waypoint changed to PENEY, in the general vicinity of Fraser and Tabernash, CO, or about 200 nm east of the aircraft's position at the time. Flight and engine operating conditions

were generally similar to those reported above. The autopilot was still engaged, as before, and made a brief turn on course.

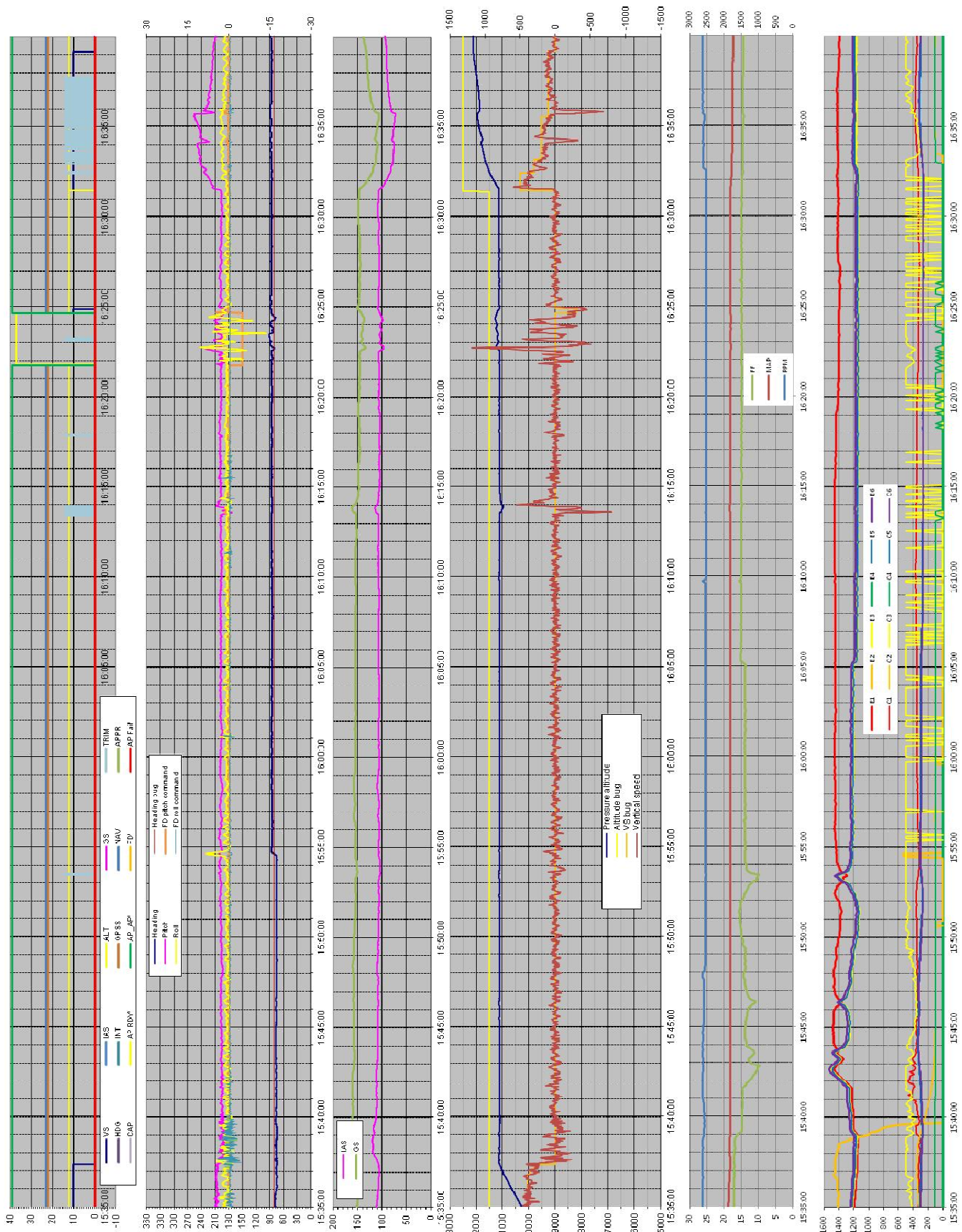


Figure 4: Flight and engine data, cruise

At 16:21:43, the autopilot was disconnected. At 16:24:39 (4822.6), the autopilot was reengaged in VS ALT NAV GPSS mode. While the autopilot was disengaged the airplane's heading and altitude changed only minimally.

At 16:31:26 (5230), as the airplane neared Meeker, CO, the altitude bug changed from 11500 ft to 12500 ft. An area of rising terrain underlies the route of flight beyond Meeker. Shortly thereafter, the autopilot switched from ALT NAV GPSS mode to VS ALT NAV GPSS mode to fly the climb. The new altitude was captured at 16:39:11 (5695.2).

Descent and landing

At 16:44, the airplane was stable in cruise (Figure 5). The autopilot was in ALT NAV GPSS mode, maintaining 12110 ft PA (taken to be 12500 MSL) on course to PENEY at 105 KIAS (Figure 6). The engine condition readings, as before, showed EGTs in the normal range for cylinders one, three, five and six. (Though in the normal range, E1 was several hundred degrees above E3, E5 and E6, as had been the case since the changes noted in the previous section.) CHTs for cylinders one, five and six were in the normal range. C3 read approximately 450°. EGTs and CHTs for cylinders two and four were near or below the SIU's sensing range.

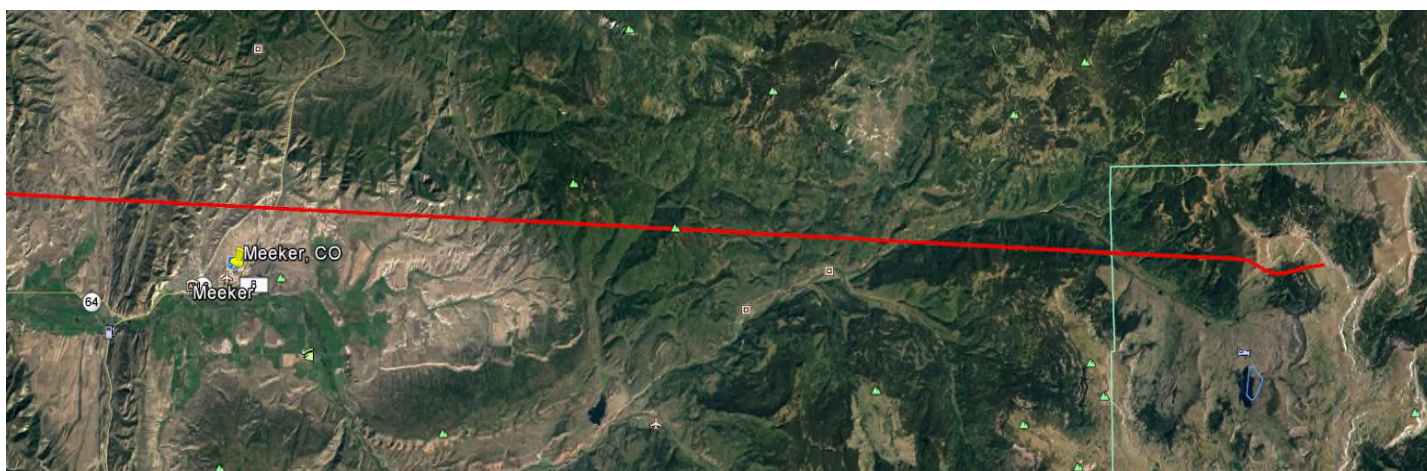


Figure 5: Route of flight, descent and landing

Immediately thereafter, E1 began to drop – slowly at first, then rapidly, reaching 1000° in a little more than a minute and falling below the SIU's sensing range less than a minute later. It never returned to the normal range. As with cylinders two and four, C1 dropped following the reduction in E1.

Fuel flow dropped concurrent with the drop in E1, from 15 GPH to 13 GPH. MP and RPM remained constant.

Simultaneously, the airplane's airspeed fell off. The autopilot began trimming almost constantly in an unsuccessful attempt to maintain altitude. By 16:48 (6224), the airspeed had fallen from 105 KIAS to 80 KIAS and altitude from 12110 ft PA to 11900 ft PA (and falling).

Beginning at approximately 16:50:20 (6364), the airplane began a series of pitch and roll excursions (Figure 7). The autopilot was still engaged at the time and the flight director commanded corrections opposite to these excursions. This often indicates that the pilot is on the stick, overpowering the autopilot. This condition remained until the end of the flight.

The airplane appears to have crossed the edge of the plateau (elevation 11400 ft MSL; Figure 8) at 16:51:32 (6436). At the time, it was at 11530 ft PA. The final resting altitude of the airplane was 11370 ft PA, which is, based on the topographical map, 11660 ft MSL. Using the same correction from PA to MSL (290 ft), the corrected altitude crossing the edge of the plateau was approximately 11820 ft MSL, or about 400 ft AGL.

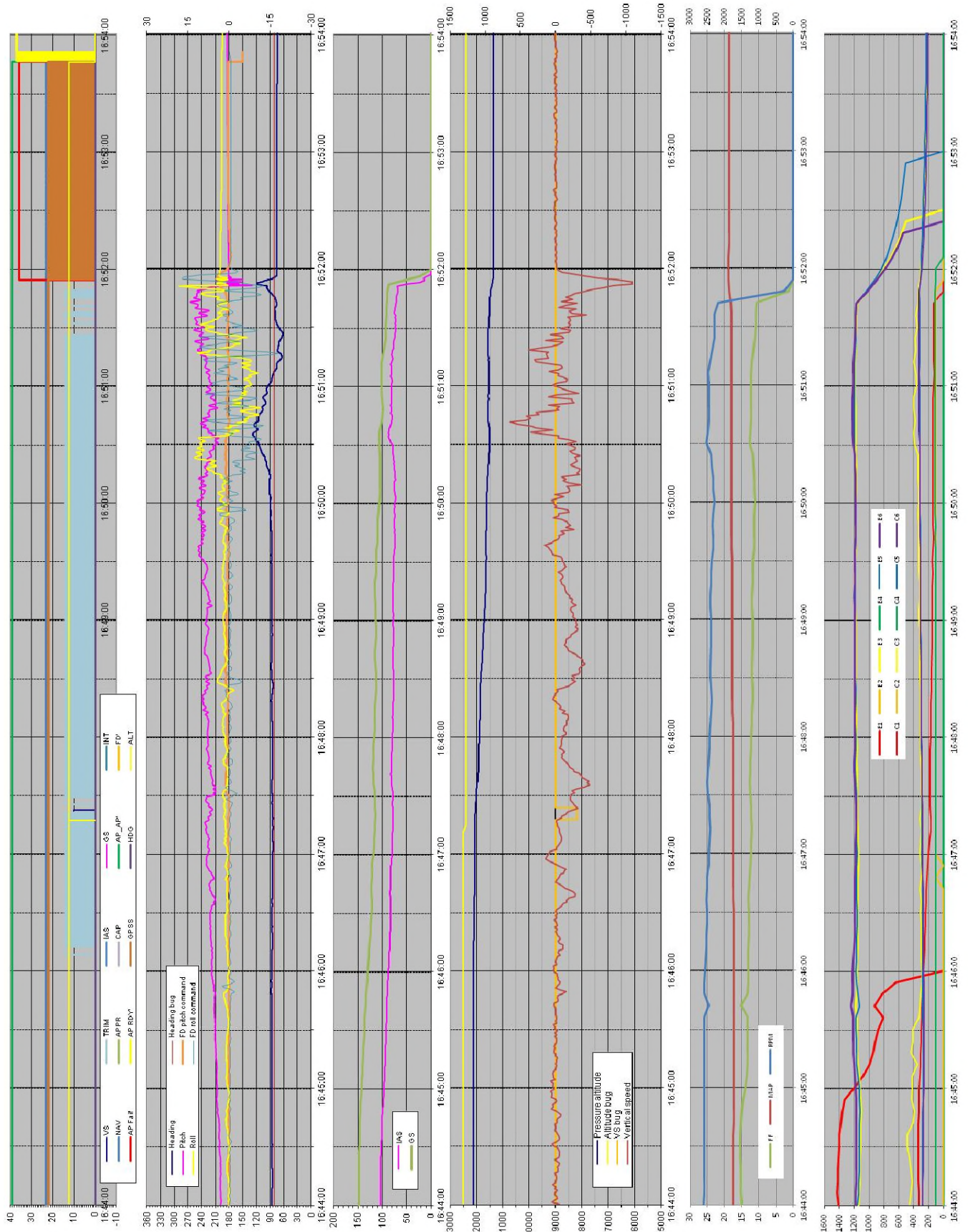


Figure 6: Flight and engine data, descent and landing

The airplane experienced no more than about 3g vertical and 2g longitudinal at touchdown, with significant accelerations only over about a five second period.

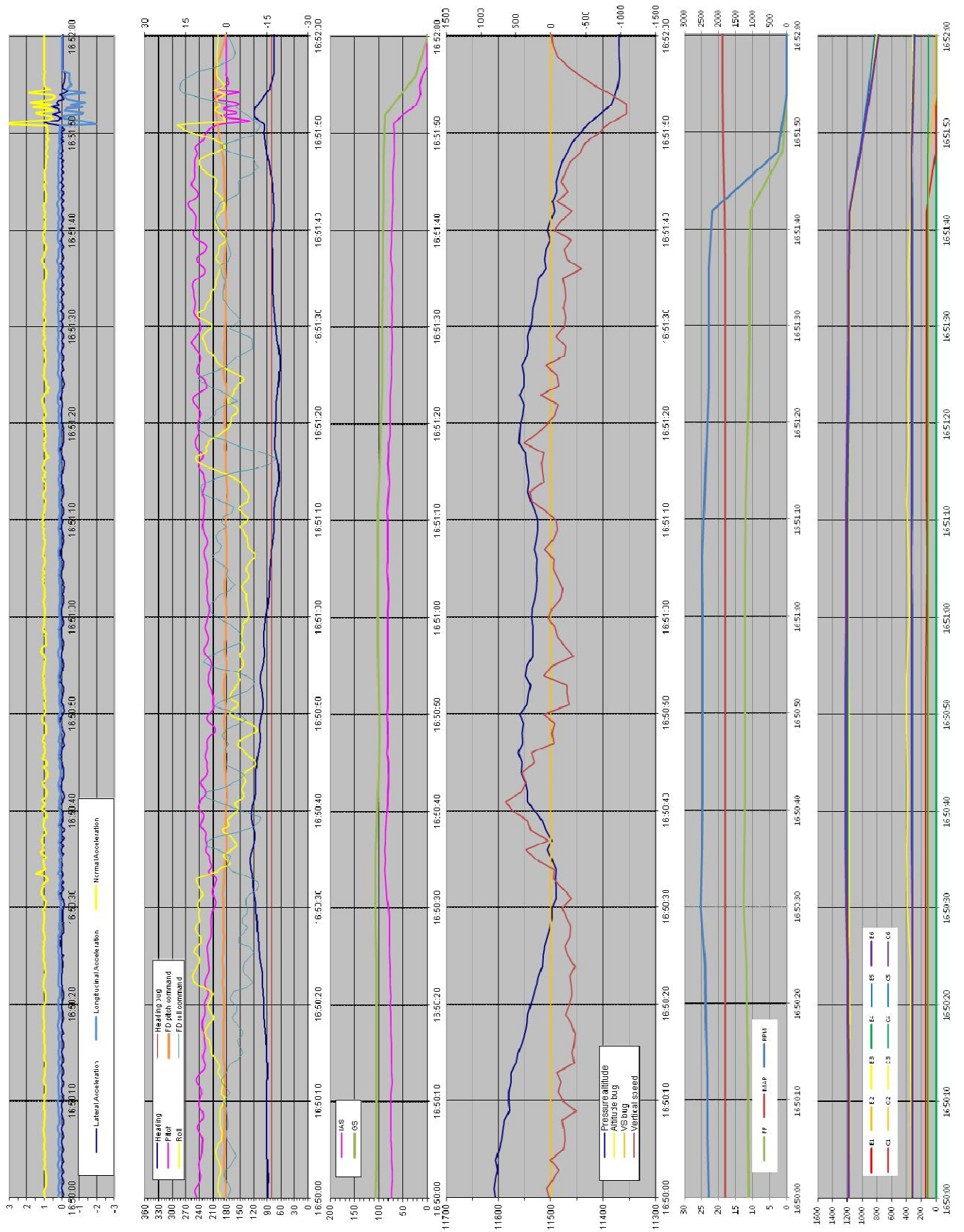


Figure 7: Flight and engine data, landing

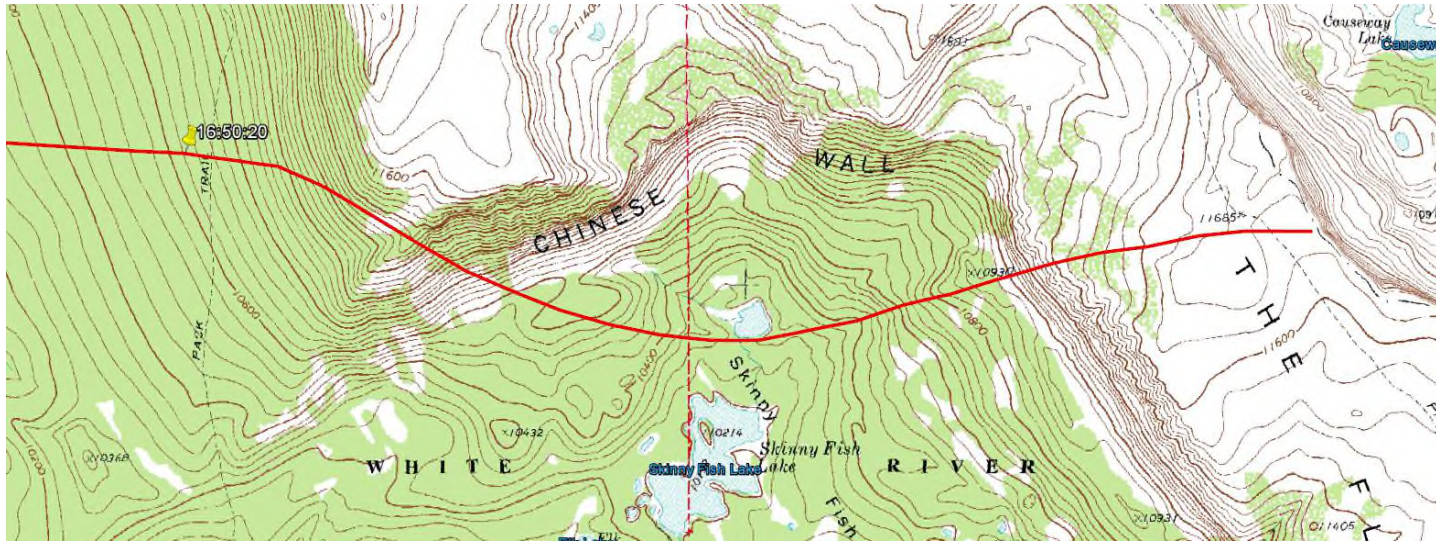


Figure 8: Route of flight, landing

MFD data

Due to the unusual nature of the engine readings in the course of the accident flight and the fact that the pilot reported that "he had had previous trouble with the sensory input unit (SIU)", a survey of the engine readings recorded on previous flights appeared to be in order. Briefly, here are the results.

The MFD log files record data beginning on March 15, 2016. Each file represents one power cycle of the MFD. Some of those power cycles represent flights, some represent ground operation of the engine and some represent ground operation of the MFD without operation of the engine. For the purposes of this assessment, only those log files that appear to include actual flight are considered.

In the period from March 15 to September 1, 2016, there appear to have been 33 flights. Of these, eight of the flights include data that are of questionable validity. The questionable indications include unusually high CHT readings for cylinders three and six and intervals with missing engine data. The flights on which questionable readings were recorded tend to be clustered and there are lengthy series of flights that appear completely normal.

On September 1, it appears that the SIU was removed from the airplane or otherwise disabled, as there are several power cycles, including two flights, during which no engine data are recorded.

On September 7, recording of engine readings resumes. The first cycle appears to be a very brief ground test run, including operation of the engine. The next appears to have been a flight in the general vicinity of the owner's home airport, with no logged irregularities. After nine flights without obvious anomalies, a flight on September 15 once again shows abnormally high CHTs on cylinder three.

On October 26, it appears that the SIU was again removed from the airplane. Between reinstallation of the SIU and its second removal, there appear to have been sixteen flights, seven of which show questionable log data. These include unusually high CHT readings for cylinder three and intervals with missing engine data.

On December 29, recording of engine readings again resumes. As before, a brief ground run of the engine is conducted. This is followed by a flight from Arapahoe County Airport (KAPA) to Meadow Lake Airport (KFLY). In the course of this

flight, for the first time in the available logs, a cylinder (number five) is seen to rapidly lose EGT, followed by a loss of CHT – a pattern that recurs on two subsequent flights, including the accident flight.

On January 6, 2017, during a flight from Meadow Lake Airport to Provo on the day before the accident flight, cylinder five fails to reach a normal EGT after engine start. Its EGT falls out of the SIU's measurement range at power-up for takeoff, the CHT falling thereafter (Figure 9). In addition, unusually high CHTs are recorded for cylinder three. The unusually low values for E5 and C5 persist until late in the flight, just under three hours after the start of the log. During the airplane's descent toward Provo, as the power is reduced, E5 climbs into the normal range after which C5 does the same (Figure 10). Readings for the cylinder remain within the normal range for the remainder of the log.

It is not possible at this time to say with certainty from the log data alone which, if any, of the questionable readings were actually faulty. Nevertheless, it can be stated with some confidence that the basis for the pilot's mistrust of the readings is evident from the recorded data.

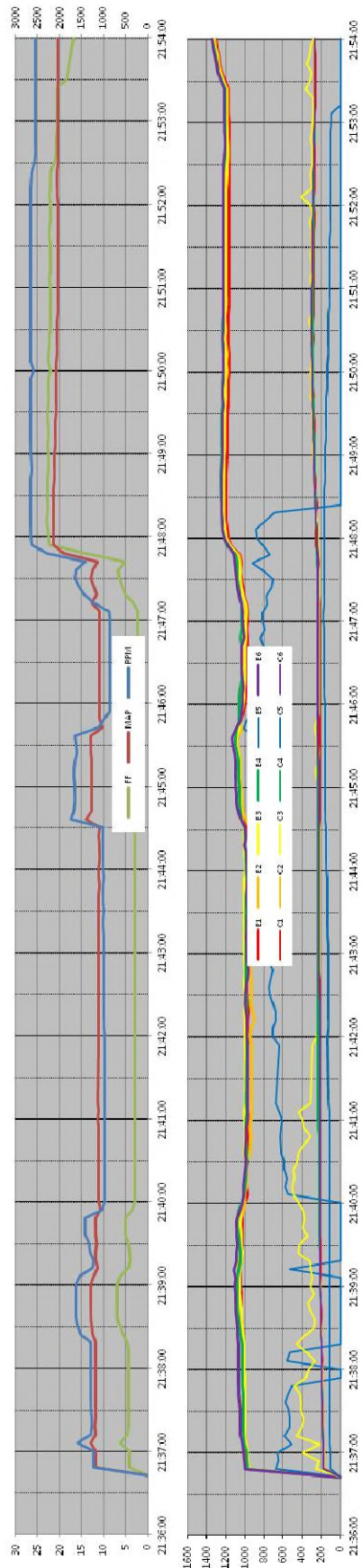


Figure 9: Engine data, start of 1/6 flight

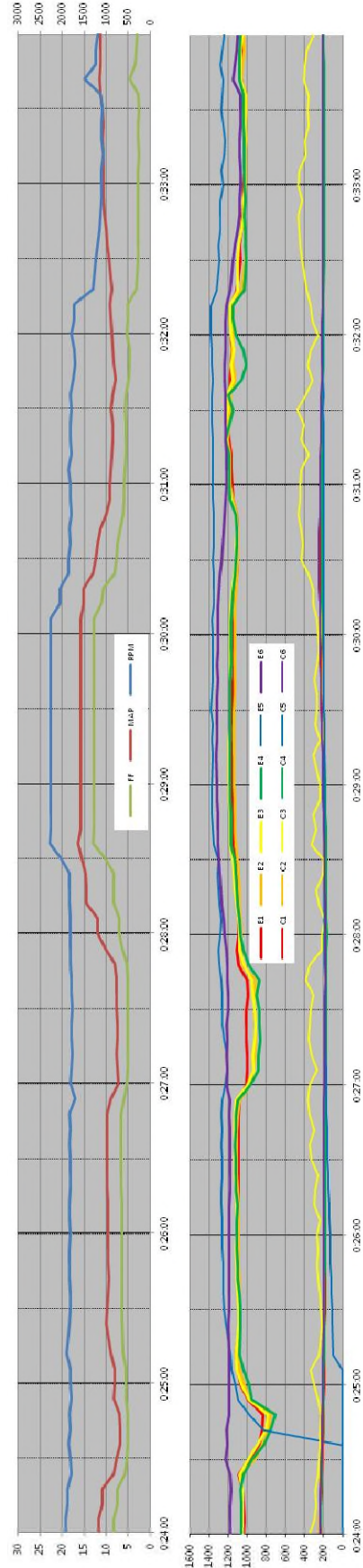


Figure 10: Engine data, end of 1/6 flight