PFD and MFD Non-volatile Memory Extraction

NTSB Case No. NYC07FA083

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The MFD unit was able to display the pilot checklist, terrain/map information, approach chart information and other aircraft/operational information depending on the specific configuration and options that were installed. The MFD contained a Compact Flash (CF) memory card. Examination of the MFD revealed that it had also sustained significant damage; however, the CF memory card was readable. All data was successfully extracted. Although the MFD data logs did not contain any MFD diagnostic or maintenance parameters, the MFD data (primarily engine performance parameters) appeared to be normal.

The PFD unit displayed aircraft parameter data including altitude, airspeed, attitude, vertical speed, and heading. The PFD unit also had external pitot/static inputs for altitude, airspeed, and vertical speed information. The PFD contained two flash memory devices. The flash memory stored the information the PFD unit used to generate the various PFD displays. Examination of the PFD at the NTSB laboratory revealed that it had sustained significant impact damage. NTSB investigators removed the Avionics Computing Resource (ACR) circuit card from the PFD. The ACR circuit card (which contained two surface mounted Flash memory chips) was fractured and bent. Visual inspection of the two memory chips showed no signs of damage. The memory chips were successfully downloaded at Avidyne's facility using a surrogate PFD.

Citing proprietary concerns, Avidyne would not provide the decode program which converts the downloaded raw files into engineering units, or the information needed for the NTSB to independently decode the recorded PFD log data. However, the downloading and decoding were performed by Avidyne at their facility in Lincoln, Massachusetts.

The PFD recording contained records of 40 power cycles and approximately 20.4 hours of data. The accident flight occurred on the 38th power cycle. The duration of the 38th power cycle was approximately 21 minutes; the accident flight from the start of the takeoff roll until the end of the data was approximately 14 minutes 46 seconds. The last two power cycles occurred during the download process. The MFD recording contained a total of 208 power cycles. The accident occurred during the last power cycle, which was approximately 20 minutes in duration.

During review of the recorded data from the PFD and MFD, it was revealed that the PFD's AHRS had failed to align twice on the day of the accident; once on the electrical power cycle preceding the accident flight, and again when the PFD was started up for the accident flight. According to Avidyne, the EADI and the EHSI displays would have remained red-X'd if the PFD failed to properly align.

Some of the maintenance and diagnostic information recorded by the PFD provided the validity status of certain parameters (such as pitch, roll, and heading). On the day of the accident these validity parameters for both power cycles showed that the data was invalid for the entire duration of the power cycles. During a successful startup, these validity parameters will start out with these same invalid indications, and then change to "valid" once the alignment successfully completes.

The recorded data did not explicitly indicate the presence or absence of Red Xs. According to Avidyne, by design, the validity indications as recorded on the day of the accident would have resulted in Red Xs being displayed on the PFD.

Diagnostic parameters pertaining to the PFD's Air Data System, which operated independently of the AHRS, indicated that the Air Data System was functioning normally. However, anomalies were found in the data (discussed below). According to Avidyne, the PFD would have continued to display altitude, airspeed and vertical speed presentations on the display.

Although the AHRS did not align, the PFD's logging function continued to record data normally, which included the values computed for the AHRS parameters (pitch and roll attitude, magnetic heading, body axis accelerations and rotation rates) although the PFD had flagged them as 'invalid'. The sense (up/down, left/right, +/-) and trends appeared to generally agree with other independent data sources. Logging of the GPS data, navigational information, and pilot settings appeared to have functioned normally, and the data from these sources were unaffected by the PFD's alignment status. A review of the GPS, Altitude and ATC radar data using a computer simulation model revealed discrepancies in the PFD recorded pitch, roll, and heading data.

Description and Interpretation of Recorded Autopilot Data

With the PFD in an unaligned state, the only functional lateral autopilot mode is the NAV GPSS (GPS Steering) mode. In this mode, the autopilot uses inputs from the blind turn coordinator, and steering commands from the GPS receiver, to the PFD, and then to the autopilot computer. This version of the PFD logging function could not record autopilot status (on/off or mode) as a function of time. However, "snapshots" of the autopilot's annunciator messages were captured under certain conditions as part of the event-based maintenance and diagnostic recordings. Consequently, the autopilot status was recorded only at discrete points in time, and only when certain diagnostic events were triggered. This occurred twice during the accident flight. At approximately 09:15:37, the "AP RDY" annunciator was recorded, indicating that the autopilot was not engaged in any mode. At approximately 09:19:42, at the end of the recording, the "NAV GPSS" annunciator was recorded. This indicates that the autopilot was engaged in the GPS Steering mode, and no vertical mode was engaged.

The autopilot was designed to limit the turn rate of the airplane to a maximum of 130% of a standard rate turn. According to the autopilot manufacturer, if the 130% limit were to be exceeded, the autopilot would attempt to reverse turn until the turn rate was reduced to 130% of standard rate. Additionally, the autopilot had a vertical acceleration limit of 0.6 G above or below the "steady state" of 1 G. If the sensed acceleration is greater than 0.6 G (in either

direction, from 1 G), the autopilot will disengage the pitch servo temporarily, until sensed vertical acceleration are within these limits.

Air Data Anomalies Recorded On the Day of the Accident

Examination of the recorded data revealed that during the accident flight, the pressure altitude recorded by the PFD agreed with the pressure altitude recorded by the radar data. Further examination revealed however, that anomalies existed in the pressure altitude data that was recorded when the accident airplane was stationary on the ground, where a constant decreasing trend in altitude was observed. The trend was generally fairly slow, and differed slightly from one occurrence to the next. The first indication of this anomaly occurred on the morning of the accident during the power cycle preceding the accident flight (cycle 37), where the altitude slowly decreased about 51 feet in 284 seconds, at a relatively constant rate while the airplane was stationary. This occurred twice on the accident flight, although the rate was higher (decrease of about 54 feet in 166 seconds). Additionally, when the airplane began to taxi during the accident flight, the pressure altitude suddenly "spiked" by about 60 feet.

The cause of these anomalies was not determined, and review of the recorded data revealed that they did not occur in any of the other recorded data sets.

PFD's Failure to Align

The PFD failed to align twice on the day of the accident. The recorded data did not explicitly indicate the reason for the failure to align. In both cases, ten parameters (heading, pitch, roll, 3 axis of acceleration, all 3 rates (pitch, yaw, roll), and rate of turn) were marked as invalid and remained so for the duration of power cycles 37 and 38 (the accident flight). Additionally, in both power cycles, a heading flag and attitude flag remained "set" and the MPU indicated that the IRU was "Erecting". These three conditions remained until the end of each power cycle.

Power Cycle 37 began at about 08:49:10, and ended at 08:54:48 on the day of the accident. The pilot was on the phone with Potomac TRACON from 08:55:08 until 08:58:32 (During this time, he received his IFR clearance at 08:57:52 with a void time of 09:08:00). According to Avidyne, the failure of the PFD to align during cycle 37 was most likely due to motion detected (on the yaw axis) during the initial critical AHRS alignment period. During this phase of the startup, the PFD calculates the steady state bias of its rate sensors. In order to perform these calculations correctly, the PFD must remain stationary, and the PFD screen would display the following message before this phase begins:

"INITIAL AHRS ALIGNMENT / REMAIN STATIONARY OK TO TAXI IN xx SECONDS"

This period began at PFD log time 21.6 seconds and ended at 36.2 seconds. The effect of this could be seen in the data as a difference in yaw rate offset before and after the critical bias estimation period. This bias affected the calculation of magnetic heading. This resulted in the heading parameter (as calculated and recorded) indicating that a continuous turn to the right was occurring, though GPS position information revealed that the airplane was actually stationary. The heading was flagged as invalid during this time, and according to Avidyne, the HSI would

display a red-X. Under this condition, the PFD would remain unaligned indefinitely. This behavior was duplicated during testing at Piper in January 2008 and was observed during a startup of another unrelated airplane with the same make/model/revision of the PFD.

Review of the recorded data for Power Cycle 38 (accident flight) revealed that this cycle began about 08:58:40. The data indicates that the engine power was advanced for the takeoff roll at 09:04:50. During the PFD startup for the accident flight, no appreciable motion was detected during the initial AHRS alignment period and the airplane began the takeoff roll at approximately 375 seconds PFD log time.