NATIONAL TRANSPORTATION SAFETY BOARD
Vehicle Recorder Division
Washington, DC 20594

February 6, 2020

Onboard Image Recorder – Solid State Hard Drive

Specialist's Factual Report
By Sean Payne

1. EVENT

Location:	Charlottesville, VA
Date:	August 12, 2017
Aircraft:	Bell 407, N31VA
Operator:	Virginia State Police
NTSB Number:	ERA17FA274

2. SUMMARY

On August 12, 2017, about 1649 eastern daylight time, a Bell 407, N31VA, operated by the Virginia State Police (VSP), was destroyed after impacting trees and terrain in Charlottesville, Virginia. The airline transport rated pilot, and private pilot-rated observer, were fatally injured. Visual meteorological conditions prevailed, and no flight plan was filed for the public use aerial observation flight that departed Charlottesville-Albemarle Airport (CHO), Charlottesville, Virginia about 1554.

3. DETAILS OF INVESTIGATION

On August 24, 2017, the National Transportation Safety Board (NTSB) Vehicle Recorder Division received the following Solid State Hard Drive (SSD) from a Forward Looking Infrared (FLIR) System:

Recorder Manufacturer/Model:	**InnoDisk FID 2.5" SSD**
Recorder Serial Number:	**BCA1140219019001**

3.1. Recorder Description

A SSD is a hard drive comprised on non-volatile memory (NVM). The SSD can be programmed to contain different types of filesystems. In this particular installation, the SSD recorded data from a camera system onboard the helicopter.

3.2. Recorder Damage

Upon arrival at the NTSB Vehicle Recorder Division, it was evident that the SSD had sustained impact damage. Figure 1 shows the condition of the outer casing.

Figure 1. The condition of the SSD's outer casing.

The outer casing cover was removed and the SSD was found to be filled with earthen debris (figure 2). The SSD's board was removed from the outer casing. Figure 3 is an annotated view of the SSD's internal memory board after being removed from the outer casing. Micro-hardware (circled in red) and one non-volatile memory (NVM) chip was found to be displaced from the board.

Figure 2. The SSD with the outer casing removed.

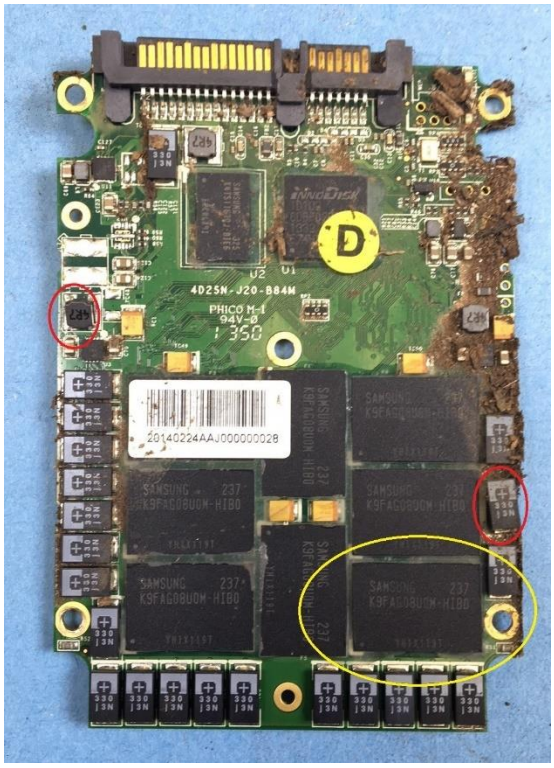

Figure 3. Damage on the SSD's main board, annotated.

Figure 4 is an x-ray image of the affected area of the displaced memory chip. Ball Gird Array (BGA) style solder connections were found to be displaced between the interface of the memory chip and the board.

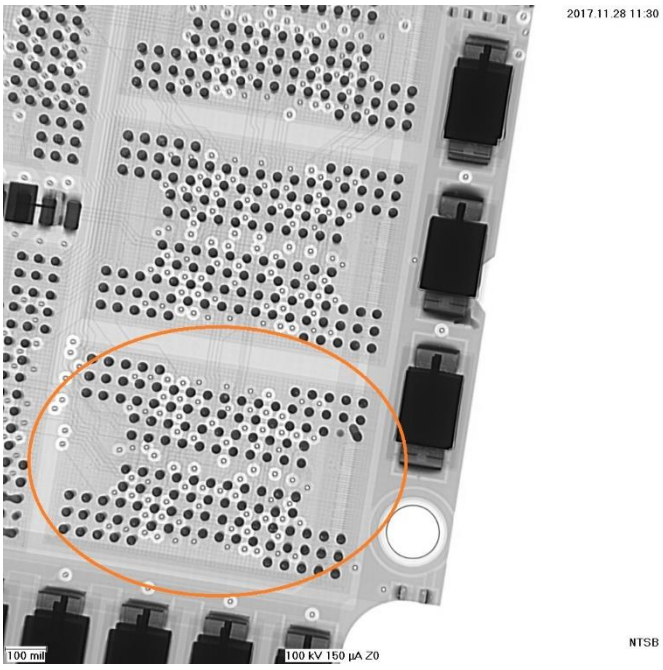

Figure 4. An x-ray image of the SSD's board. The affected area is circled in orange. Microsolder connections in the upper right portion of the chip appear to be displaced.

A visual inspection confirmed displacement of the affected memory chip. Additional visual inspection revealed no other anomalies of the main board or its components.

3.3. Data Recovery

After initial inspection, laboratory employees began conducting research on available repair methods for the SSD. An identified risk area included the possibility of attempting repair of the known areas of defect, but not detecting other areas of damage. If powered with existing but unidentified damage, a risk was identified of the SSD's hardware controller reorganizing data when power was applied and potentially corrupting data permanently. For several months, the NTSB lab interfaced with other government and third-party labs as to how to repair the drive while avoiding areas of identified risk. Ultimately, it was decided that each of the 8 NVM chips would be removed, independently read, and then virtually reconstructed using a virtual NAND[1] reconstructor.

Over the next few months, the NTSB lab contracted with a commercial vendor who supplied training on a BGA hot air rework machine which was capable of removing each of the 8 chips given their tight proximity to each other. During training with the manufacturer, the accident board from this case was used as an example of how to remove memory chips from the board and all 8 memory chips were successfully removed.

The NTSB lab then contracted with a forensic vendor who offers chip readout solutions. Specifically, this vendor provides software to first read and then virtually reconstruct a file-system. The vendor conducted training and the NTSB received a license to use the vendor's specialized software to read and virtually reconstruct the file-system from the accident SSD.

Initially all eight of the accident SSD chips that were removed from the board were unable to be read using the forensic vendor's software. The NTSB lab worked with the vendor for a solution and after a number of months, the chips were then able to be successfully read using the vendor's hardware adapter and related software.

The forensic vendor then assisted with the virtual reconstruction of the accident SSD's file system using their proprietary software. After several months of attempts to reconstruct the data, the vendor was ultimately unsuccessful in doing so.

A third-party data recovery lab was then contracted with in an attempt to virtually reconstruct the eight chip images files that were read from the eight removed accident chips. The third-party vendor retained the physical evidence and digital chip images for approximately eight months while they attempted to virtually reconstruct the file system. Ultimately the third-party data recovery lab was unable

[1] NAND – A type of non-volatile flash memory that does not require power to retain data.

to reconstruct the file system. The physical evidence was then returned to the NTSB lab.

Upon return of the physical evidence, the NTSB lab then contracted again with the manufacturer of the hot-air re-work station, this time focusing on how to properly place the eight BGA style memory chips. The NTSB procured a surrogate SSD of the same make, model and production lot number from the SSD manufacturer and all eight chips were replaced to the surrogate board. Additionally, the accident board's hardware controller was removed and placed on the procured surrogate. The placed chips on the surrogate drive were then x-rayed for quality control and verified that over 1,000 BGA style solder connections were successfully created and no anomalies were noted. Figure 5 is a photo of the reworked surrogate SSD with the accident chips and controller placed.

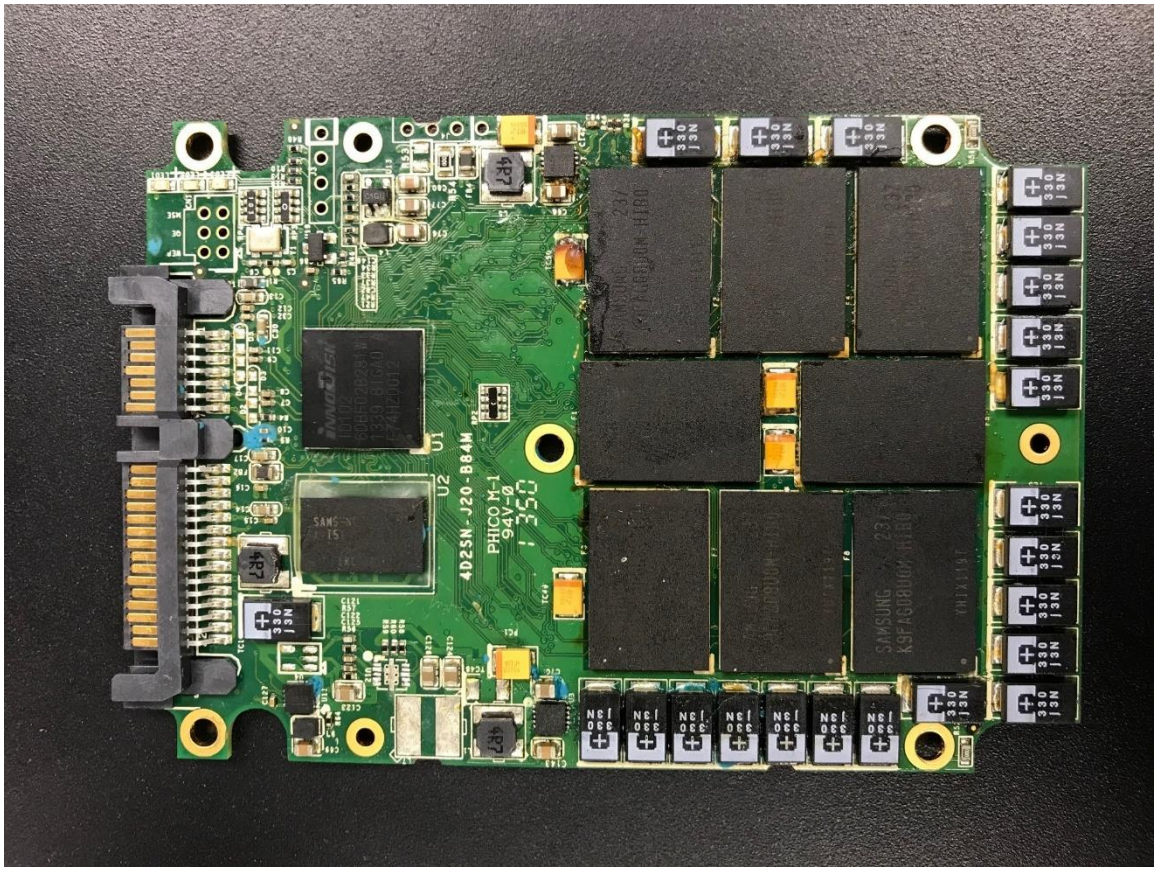

Figure 5. The reworked surrogate SSD with the accident chips and controller placed.

The surrogate drive with the placed accident chips were then attempted to be read using a forensic write blocker on a PC. Using a variety of methods and settings, the PC was unable to detect or access the surrogate hard-drive.

One of the eight originally accident chips was then removed from the surrogate and read to create another chip image file. This chip image was then compared to the initial chip image file from when the accident chip was initially removed. The

result of comparison between these two chip reads showed that the data differed, and it was likely that the hardware controller had reorganized binary data on the placed memory chips when powered was applied. Ultimately, the data was unable to be recovered.