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**In Hard Disk Drives (HDDs), firmware consists of (a) a microcode program that is embedded in a Memory chip on the Printed Circuit Board (PCB) and/or (b) 'adaptive' data that is stored on the magnetic platter surface. This microcode program consists of a number of different individual modules that have been assigned to carry out different functions. The total number of these modules varies between different manufacturers.**

Corruption of the important modules may result in the drive not being 'recognised' by the computer. In extreme cases, where the 'P-list' module is severely damaged, it may also result in data being lost.

### P-List

HDD data density grows ever higher and the storage capacity per platter now easily exceeds 40 GB. Despite manufacturers using more and more advanced technologies, they still cannot ensure 100% perfection; there are always a certain number of defects on the platters. As part of the Low-Level Format process performed by manufacturers on all drives before they leave the factory, any defective sectors/tracks found on the user data area of the disk are identified and recorded in the P-List ('Permanent' List). There may only be tens of defects at fewest, or tens of thousands at most. All the defective sectors will then be replaced by reserved sectors, and the defective sectors will never be used by the drive.

During general operation of the HDD by computer users, the P-list is used as a part of the physical address translator. The address translator translates the Logical Block Address (LBA) which is used by computer, to the physical Cylinder/Head/Sector (CHS) address



that is used to correctly position the read/write head to access the raw data on the magnetic surfaces. Corruption of the P-list will scramble the actual locations of the defects, which will also disrupt the addressing translation. As a result, the correct sequence of the user data will be lost, making the data inaccessible by the computer due to the resultant CRC errors.

By means of sophisticated data recovery software and hardware, this problem can be overcome. Manufacturers also employ advanced technology to protect their HDDs by allowing the P-list to be regenerated in some cases from other ancillary modules.



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### G-List

In the normal course of using a drive 'new' defective sectors may be encountered or generated. It would be a major headache for the manufacturer's after-sales service if they had to exchange/repair HDDs with only a few defective sectors. Therefore, manufacturers incorporate a built-in self-repair function into their drives, referred to as "Automatic Reallocation". Most HDDs have such a capability. Where a defective sector is found as part of the read/write process it will be recorded in the G-List ('Grown' Defect List). A replacement reserved sector will be assigned for the data and the defective sector will not be used again. In this way, even where a few defective sectors occur, they should not be a problem to the user. The G-list doesn't contribute to the address translator at all. Thus, it doesn't affect the functioning of the HDD.

Each manufacturer assigns a certain amount of space on the magnetic platter to store the firmware. This space is not accessible by general users. To ensure the integrity of the firmware, some HDD manufacturers store multiple copies of firmware (up to 3 copies currently) within the limited space on the magnetic surface. Another reason for manufacturer employing multiple copies is because the adaptive data which is used to fine-tune the drive's operation may be stored in some of the modules. This data is unique to a specific drive and therefore is not replaceable from donor drives. Using the multiple copies approach, there will be another copy to recover this adaptive data from, if one of the copies becomes damaged.

Regardless of the variety of powerful data recovery tools available on the market, there is still no effective way to recover this adaptive data after damage.

