



# Physical Reconstruction of CD-ROM and DVD Discs: The Humpty Dumpty Scenario (Part 1)

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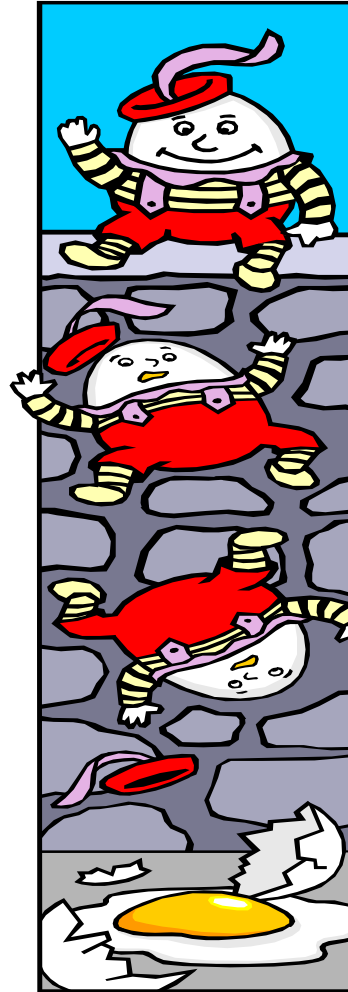
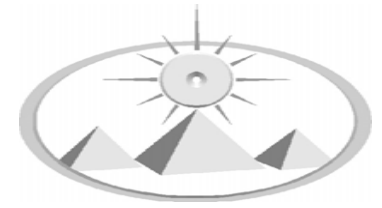
**Presented at the THIC Meeting at the National Center for Atmospheric Research, 1850 Table Mesa Drive, Boulder CO 80305-5602**

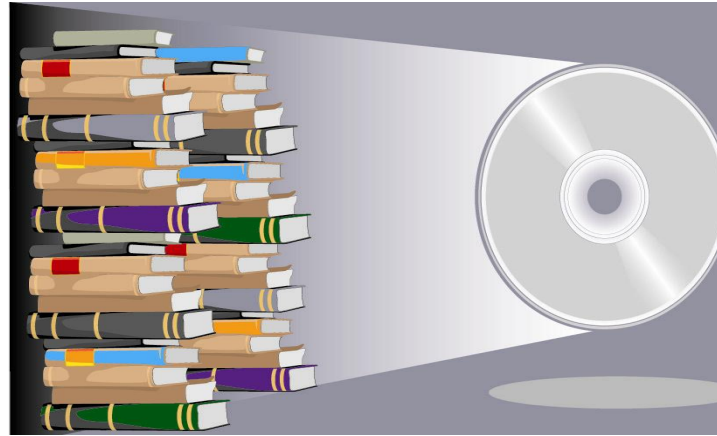
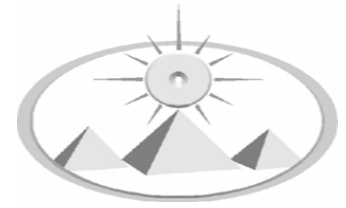
**June 29-30, 2004**

**THIC Inc.**

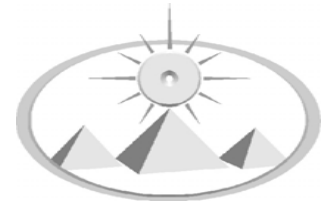
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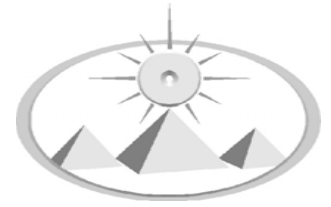
- CD-ROMs are capable of holding ~ 300,000 pages of data on a single disc which is equivalent to several filing cabinets.
- Single layer DVDs are capable of holding @ 2 million pages of data on a single disc which is equivalent to a roomful of filing cabinets.



## The Technology

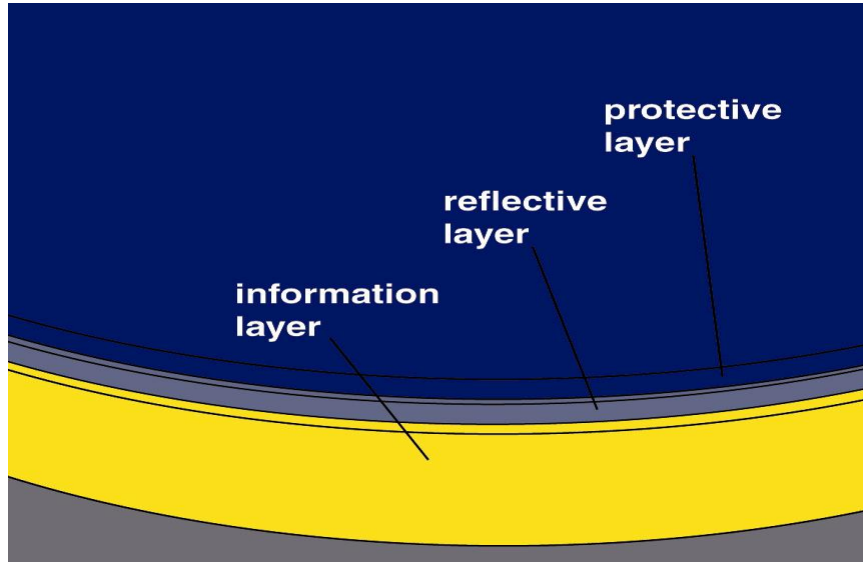
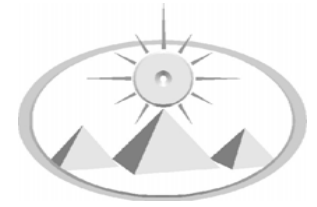


- CD-ROMs are a storage media that has grown to over twenty (20) billion units sold by the end of 2003.
- DVD-Rs are 10% of the market and growing slowly.



## The Technology

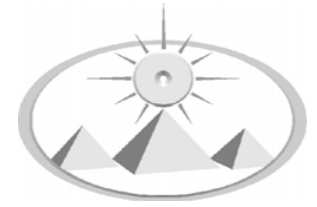
On a CD-R, DVD-R, CD-RW or DVD-RW a laser induced polymerization (dye-based), or a reversible phase transition (rewritable phase change between amorphous and crystalline states) create a delta in the reflectivity of the surface.



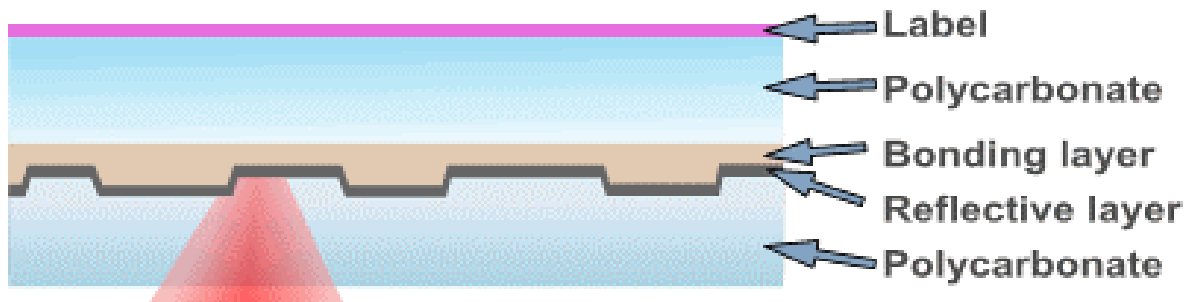
## The Technology:

# CD-ROM Construction

A CD-ROM is made up of multiple layers: Data resides in the “information layer” of pits and lands. Data is a sequence of 9 unique spaces of lands and 9 unique sizes of pits. Data is imbedded in the polycarbonate.

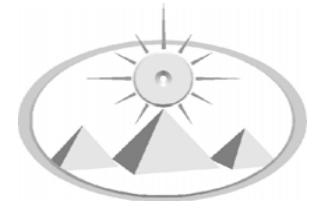


## The Technology: DVD Construction

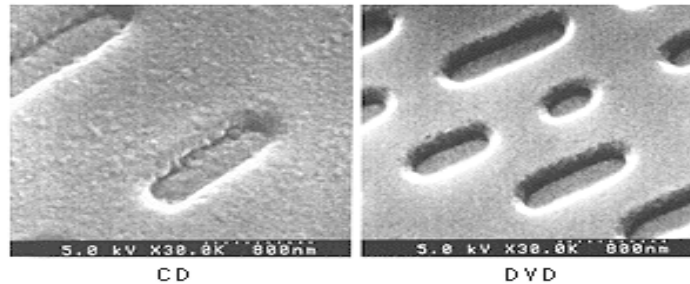


- DVD-5 Single Sided / Single Layer
- Capacity of 4.7GB
- Two 0.6mm Substrates



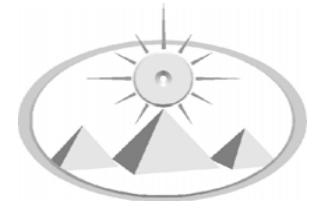


## Differences Between a CD-ROM and DVD Disc

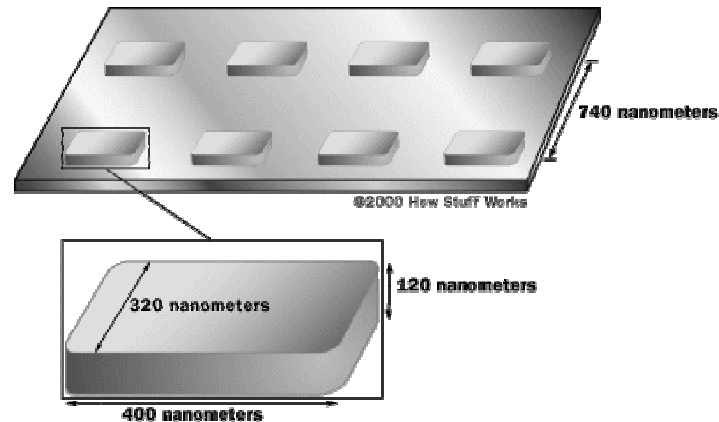


- Pits of a DVD disc are smaller and closer together
- CD-ROM is a giant spiral @ 3.5 miles long
- DVD disc is @ 7.5 miles long per layer

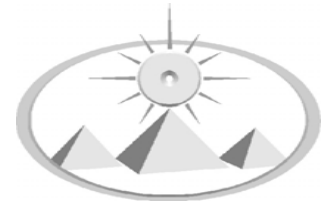




## Differences (continued)



- Tracks are separated on a DVD by 740 nanometers
- Tracks are separated on a CD by 1600 nanometers
- The minimum length of the pit on a DVD is 400 nanometers or roughly 2.08 times smaller than on a CD



## The Fundamental Question: Exactly How Much Data Can be Retrieved from a Particle Size Off a CD-ROM and DVD Disc?

The following assumptions will be used throughout these calculations:

- Data can be stored within an annular ring on a CD, with an inner and outer radius of:

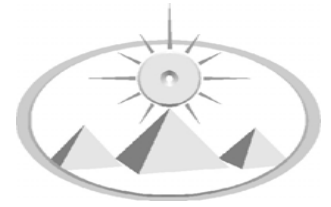
$$r_i = 23 \text{ mm}, r_o = 59 \text{ mm}$$

- The minimum amount of data which can be stored on a CD is:

$$C = 650 \text{ MB} = 650,000,000 \text{ bytes}$$

- CD data is written on a continuous spiral from  $r_i$  to  $r_o$ , resulting in a track length of:

$$L \approx 3.6 \text{ mi} = 5797 \text{ m}$$



## Length Calculation Based on L

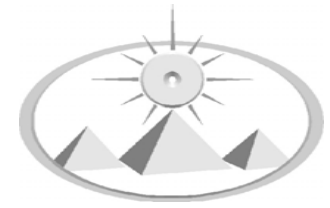
If we use L and C as indicated above, we can estimate the number of bytes of data per millimeter as follows:

$$\frac{C}{L} = \frac{650,000,000 \text{ bytes}}{5797 \text{ m}} \cdot \frac{1 \text{ m}}{1000 \text{ mm}} \approx 112.127 \frac{\text{bytes}}{\text{mm}}$$

Therefore, the number of bytes which can be stored in a linear track 1 mm in length is  $\approx 112.127$ .

Length: If we instead approach the problem from the standpoint of area, we find the writeable area of the CD is:

$$A = \pi r_o^2 - \pi r_i^2 = \pi(59)^2 - \pi(23)^2 = 2952\pi \approx 9273.982 \text{ mm}^2$$

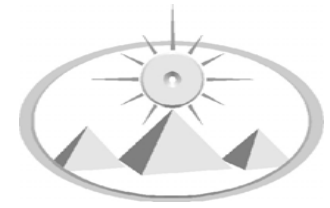


For a CD containing 650 MB of data, it follows that:

$$\frac{C}{A} = \frac{650,000,000 \text{ bytes}}{9273.982 \text{ mm}^2} \approx 70,088.56 \frac{\text{bytes}}{\text{mm}^2}$$

To translate this calculation based on area to a linear value, we need to determine the number of linear tracks contained in one square millimeter on a CD. If each track is at most  $w = 1.6 \mu = .0016$  mm apart, then we can determine the total number of tracks in the CD's writeable area as:

$$T_{total} = \frac{r_o - r_i}{w} = \frac{59 - 23}{.0016} = 22500$$

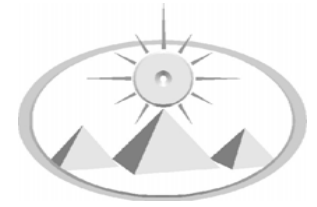


Alternatively, we can find the number of tracks per millimeter of radius as:

$$T_1 = \frac{1}{w} = \frac{1}{.0016} = 625$$

So, for one square millimeter containing 625 linear tracks, and 70,088.56 bytes/mm<sup>2</sup>, we have:

$$\frac{70,088.56 \text{ bytes/mm}^2}{625 \text{ tracks/mm}} \approx 112.1417 \text{ bytes/mm}$$

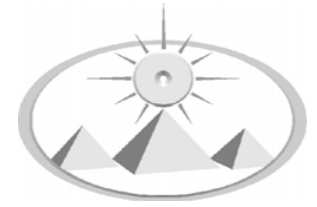


## Additional Requirements for Reconstruction

1. Locate EFM frames (8 to 14 modulation)
2. Find two sequentially recorded EFM frames

*Note:*

Minimum length of EFM frame is 0.1633mm; therefore, 0.3266mm or 326.6 microns is minimum useful data track. Ergo – 250 micron current standard for CD-ROM.



## Additional Requirements for Reconstruction (Part 2)

- Determine format changes for DVD (less error correction)
- Determine if encryption or compression has been applied
- Descramble the bits with a “look up table”
- Compute the results with a massive processor.

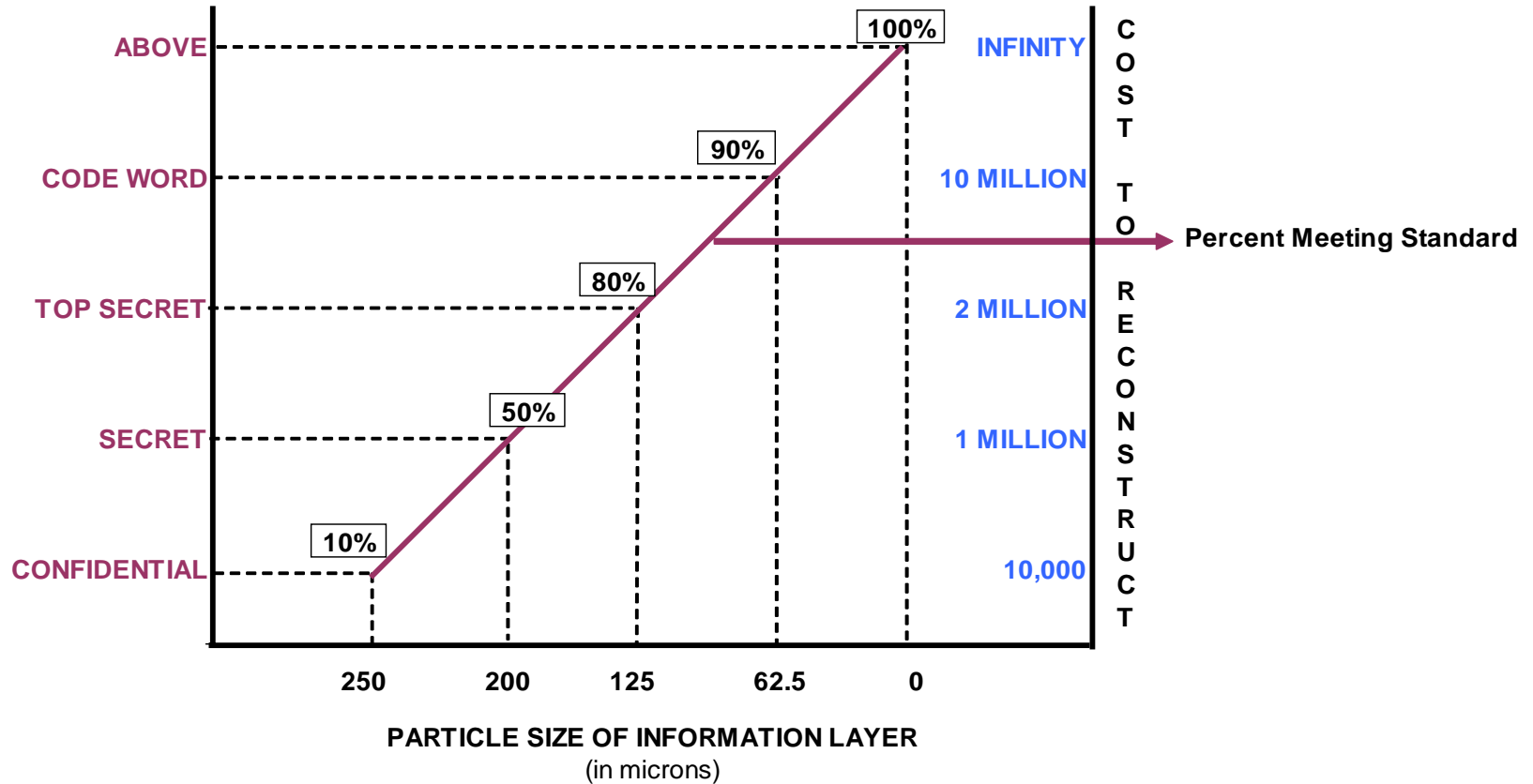
\* U.S. Patents 5,668,970 and 6,584,520



# THE "HUMPTY DUMPTY" SCENARIO

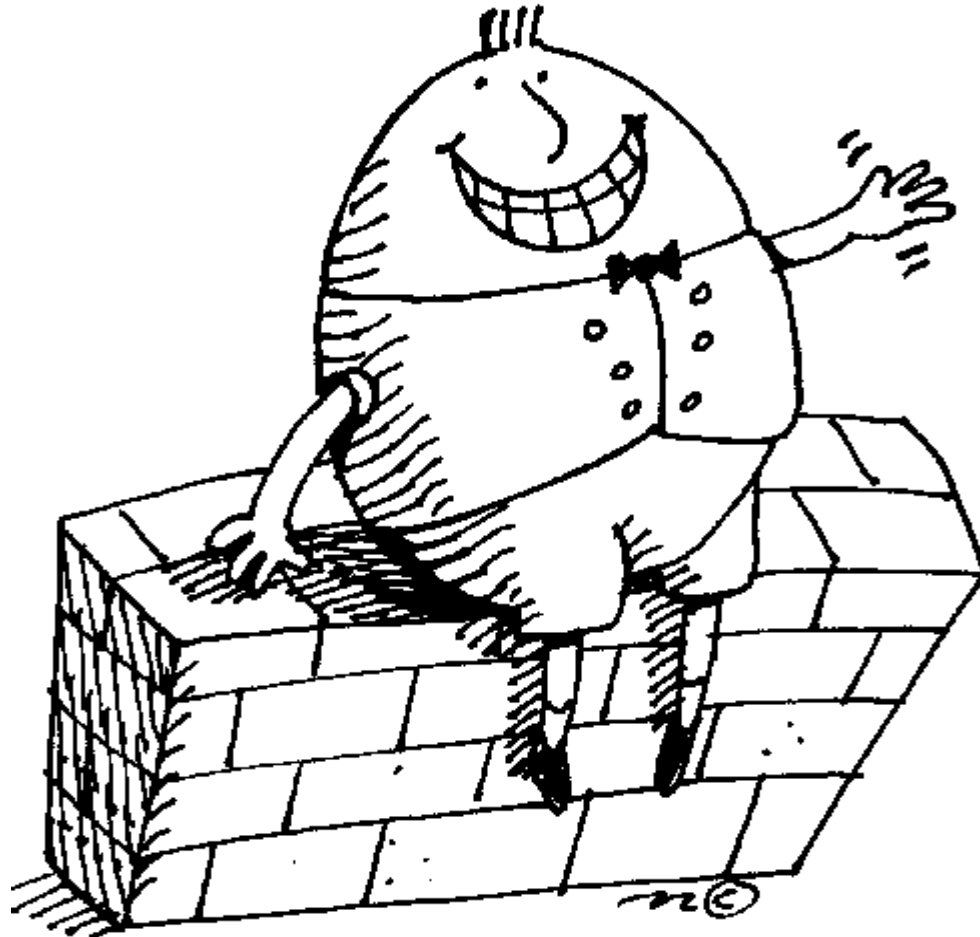
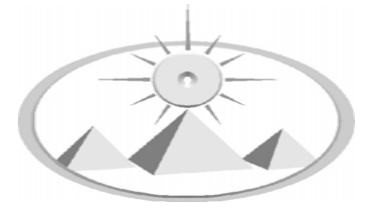
## New Proposal for Classified Data Destruction

### (Part 3)



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