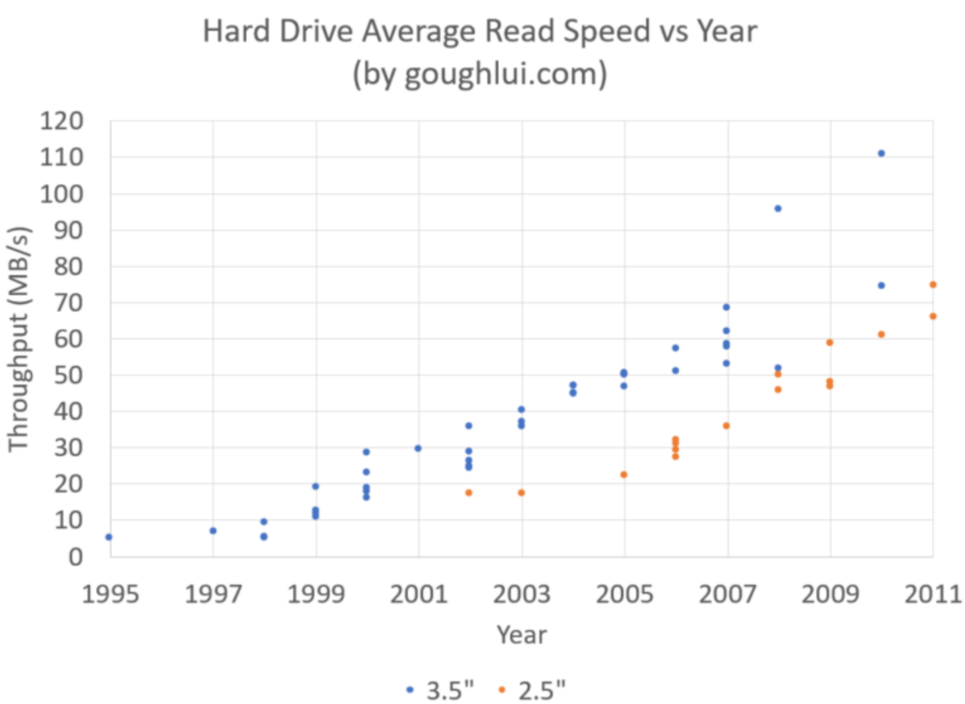
*Reversing the mindless enslavement of humans by technology.*

### Hard Drive Performance Over the Years

One of the primary motivators of The Hard Drive Corner was to understand how hard drive performance has changed over the years. With subtle incremental upgrades, it's often easy to be unaware of the trajectory of progress over time. As hard drive performance is one of the parameters which is often claimed to be almost-stagnant relative to processing power, it would be worthwhile looking at how much progress has actually been made using the sample of drives tested.

## Results

For these results, I have gravitated towards the read benchmarks for both HD Tune Pro and CrystalDiskMark as it was understood from the performance of most of the older drives that the write performance tends to degrade first as the drive ages – there are some minor exceptions to the rule, however.

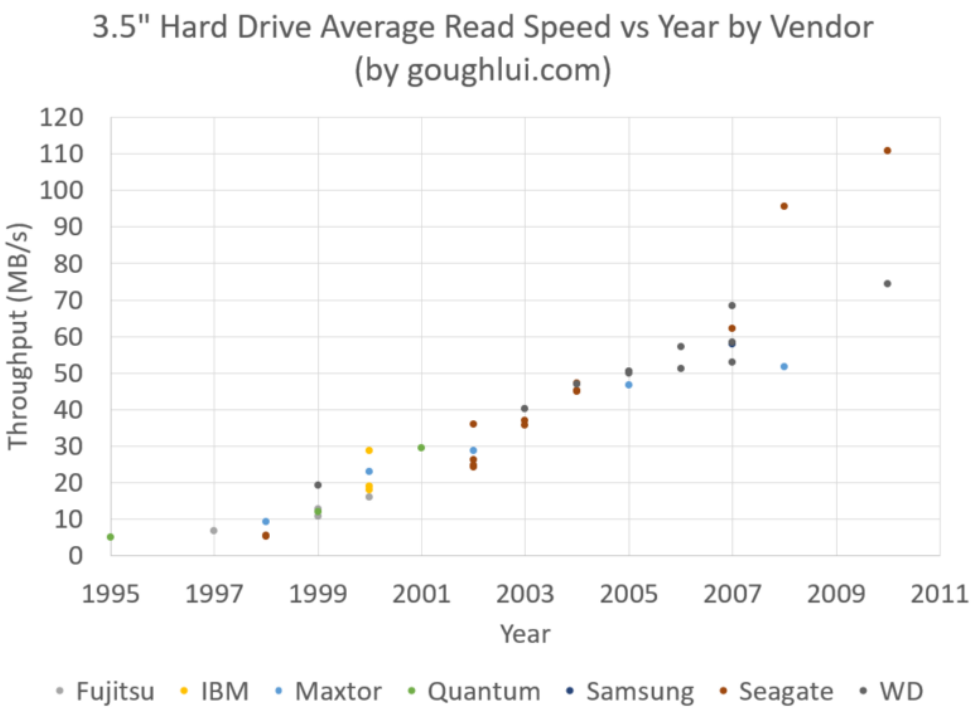



At the time of posting, the drives span from 1995 through to 2011. Performance can be seen to follow an almost-linear trend through the middle, although for any given year, there is quite a spread of performance. This is the difference between buying a "fast" drive and an ordinary one.

For 3.5″ drives, by about 1998, 10MB/s of average read throughput across the surface of the drive was considered normal with 20MB/s being reached by about 2000. It would not be until 2008 that I would see a drive that would be capable of 100MB/s of average throughput – implying an average rate increase of about 10MB/s for every year in that period. Within the graph, there are multiple "hidden" break-points, as head technologies changed and recording shifted from longitudinal recording to perpendicular recording.

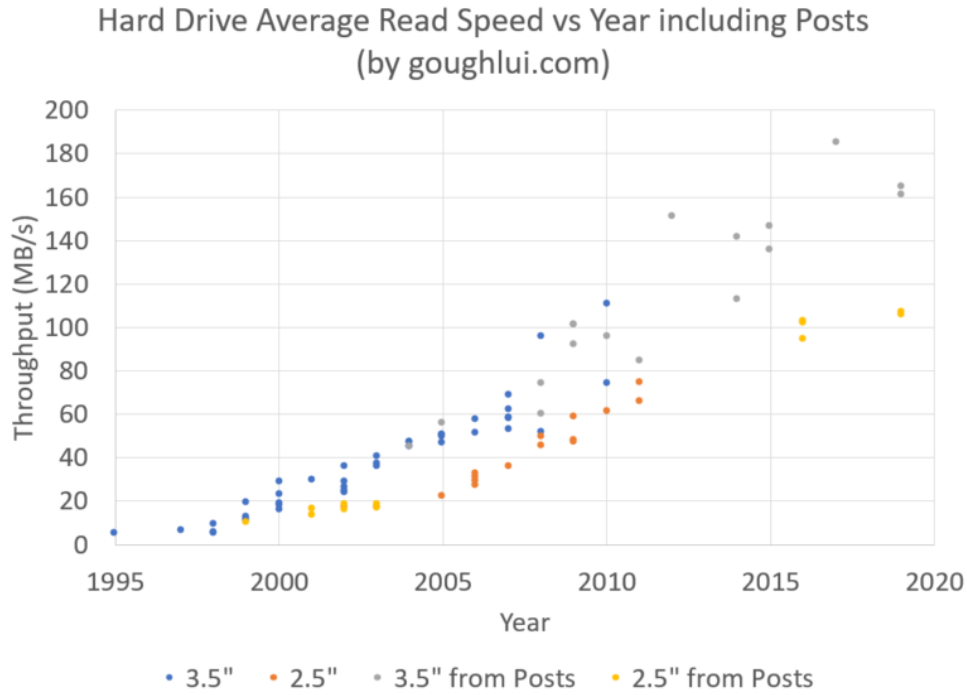
Regardless, 2.5″ drives owing to their smaller size and (often) lower spindle speeds lag around one to four years behind in terms of average throughput for this sample of drives.

Looking at the throughput, it clear why the IDE interface continued to evolve over time, over various DMA modes to push throughputs up to a maximum of 133MB/s, before finally being replaced by SATA which has also evolved through a number of generations to offer 6Gbit/s (or about 600MB/s at most).

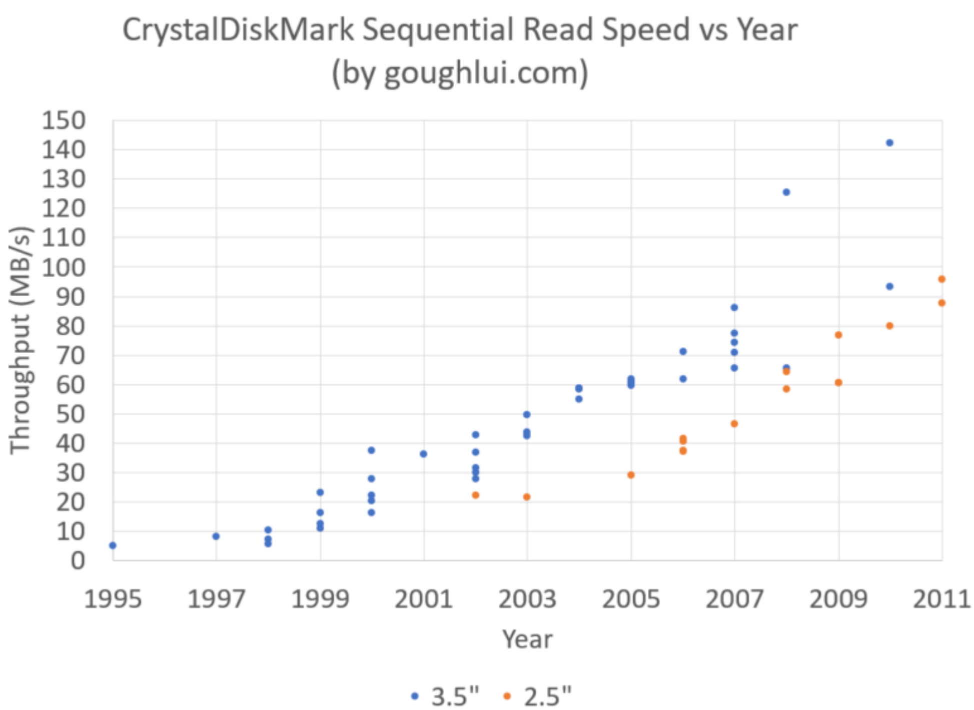



Broken down by vendor, there is no consistent leader, which is expected, but the small sample size makes it hard to gauge as well. For the most part, vendors seem to be competing well, trading places every few years.

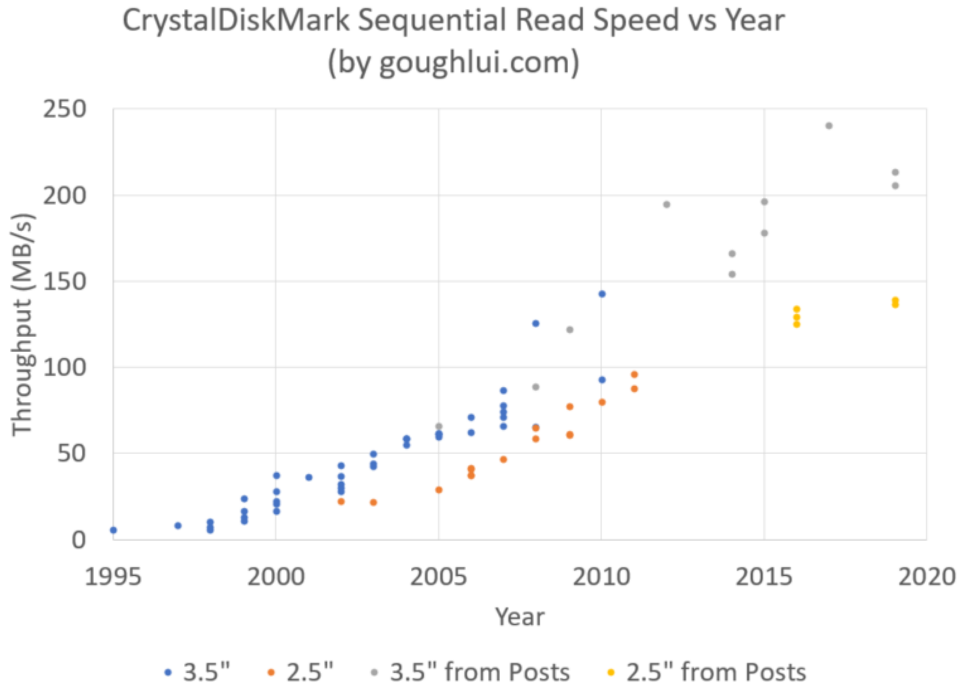
It would be foolish to expect the trend to continue unbroken – performance increases require increases in areal density and signal processing capabilities that may not always occur due to physical constraints. But perhaps, lets expand on this graph by **mixing in data from postings** where drives are tested after they are salvaged or at the beginning of life when it is still new.



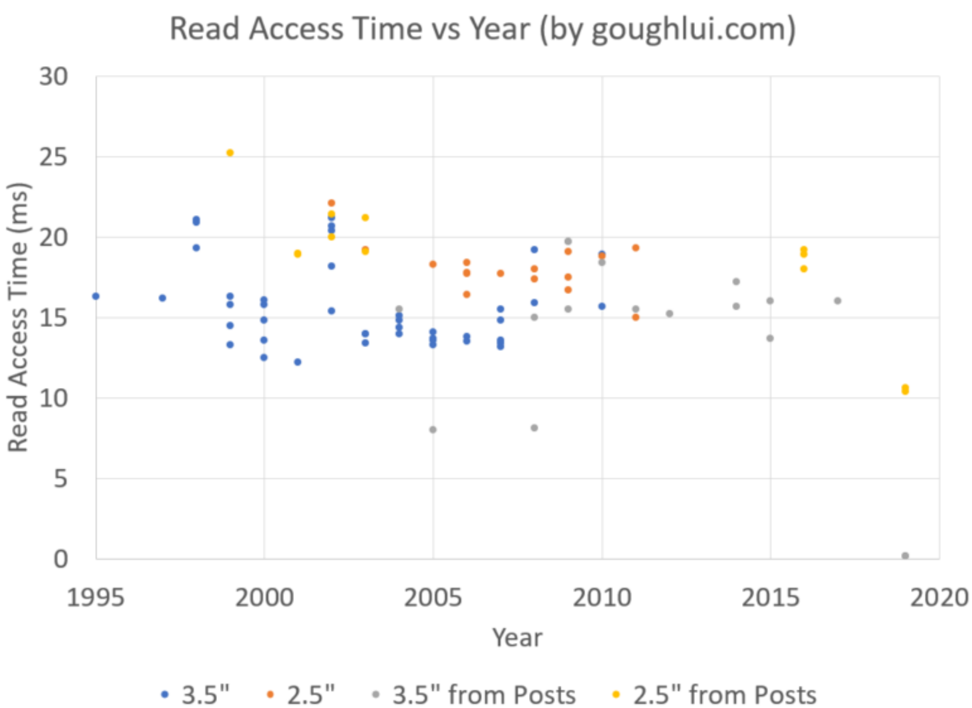

Interestingly, despite there being a "hole" where I have some drives that are still in service or as cold-storage and not ready for retirement, the new drives suggests that the trends are maintained to some degree while the variance in performance seems to increase. For 3.5″ drives, we are trending towards 200MB/s of average throughput in 2020 – which is still fairly on-trend. The 2.5″ drive trend seems to show a bit of a plateau, however.




Looking at the CrystalDiskMark benchmarks, we can appreciate the outer-track speed for a 1GB test file. This shows that of the drives in the corner, performance was sub-10MB/s at 1997 but reached over 100MB's by 2008.

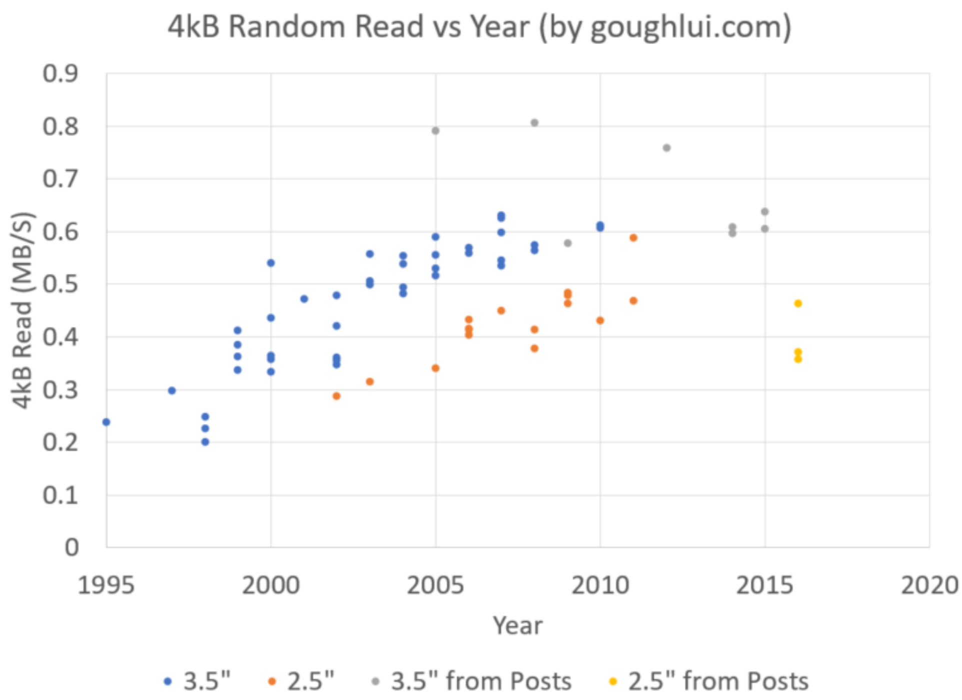



Adding in the data from the other postings shows that the trends seem to be very similar for this metric, lending credence that there is a seemingly consistent rate of progress throughput the years (with a number of sudden "jumps"). The outer-track sequential speeds of modern drives are likely to exceed even 300MB/s in a few years.

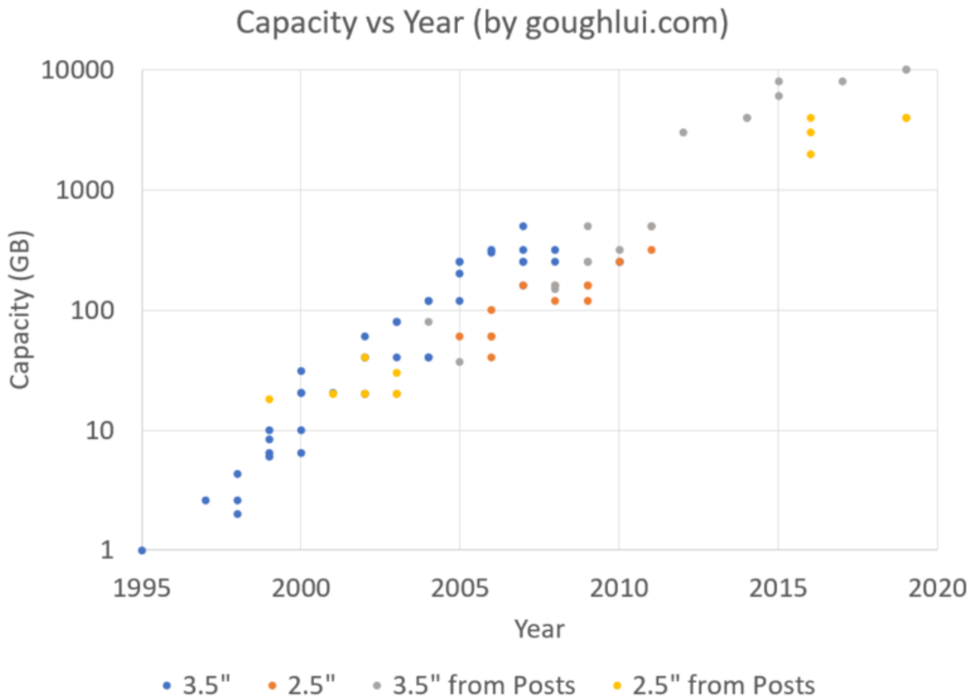



However, there is one thing that hasn't made progress – namely the read access time. Note that the two sub-10ms measurements are from 10,000rpm Raptor drives, the remainder are from 4200-7200RPM drives. There is a near-zero record from the Seagate Archive 8TB drive due to its internal cache interfering with the benchmark and should be considered invalid.

This is due to the mechanical constraints of the hard drive itself. Assuming half a revolution is needed to find the next sector (on average), a 7,200rpm hard drive already loses 4.17ms – adding additional time to reposition the head and settle on the intended track, it's hard to get it to the 10ms mark. Even at 10ms, this limits the achievable IOPS figure to just 100 – which pales in comparison to SSDs which often offer upwards of 3,000 (often up to 500,000 for modern NVMe drives). As a result, the random access capabilities of hard drives will likely never match SSDs – but the idea to augment hard drives with SSD storage for the best of "both worlds" has been realised in the form of hybrid drives and SSD caching solutions which have become less important as SSD prices have decreased and capacities have increased.




It is often recognised that 4kB random read accesses are an important metric when it comes to predicting the responsiveness of a system under load. Looking at the CrystalDiskMark metrics for 4kB (non-queued) reads, we can see that while some progress in the metric have been made over the years, the amount of progress is quite a bit less than for sequential accesses. This is because the constraints on small-block random performance are mechanically related and cannot be solved just by increasing areal density.




While I do know my selection of drives hardly represents the “leading” capacity for any given time and thus makes for a poor fuzzy representation of capacity over time, when plotted on a semi-log graph, it seems that capacity is increasing nearly exponentially, with a ten-fold increase in storage every five years. Does this mean we will see a 50TB hard drive by 2025? I somehow don’t think so … but there’s a slim possibility!

If you are interested, you [can download the spreadsheet with the data here](#).

## Conclusion

It seems clear that hard drive manufacturers were pushing capacity and performance boundaries over the years, but the mechanical nature of hard drives put an upper bound on its random I/O performance which made them less attractive for many applications which have such access patterns, such as boot drives and servers. The increase over time is almost linear, likely in line with increases in areal density, but increases in spindle speed ultimately capped at 7,200RPM for mainstream, 10,000RPM for high-end workstations/servers and 15,000RPM for specialised servers.

As a result, it seems that the solid state drive was poised to take over sooner rather than later – however, initially the cost and capacity were the main drawbacks. Decreasing semiconductor node sizes, increased encoding density through use of MLC/TLC/QLC technology and increasing supply ultimately pushed the price of SSDs well within reach of mainstream consumers with a majority of new computers today using an SSD of some description. In return, IOPS figures far in excess of that available from hard drives became commonplace, along with reduced power consumption, smaller form factors and increased mechanical rigidity.

Despite this, hard drives still retain their role in high-capacity bulk storage, where random I/O performance is of less importance. To that end, it seems that capacity seems to be increasing by ten-fold every five years or so, on a nearly consistent basis. I wonder if this trend will continue though …