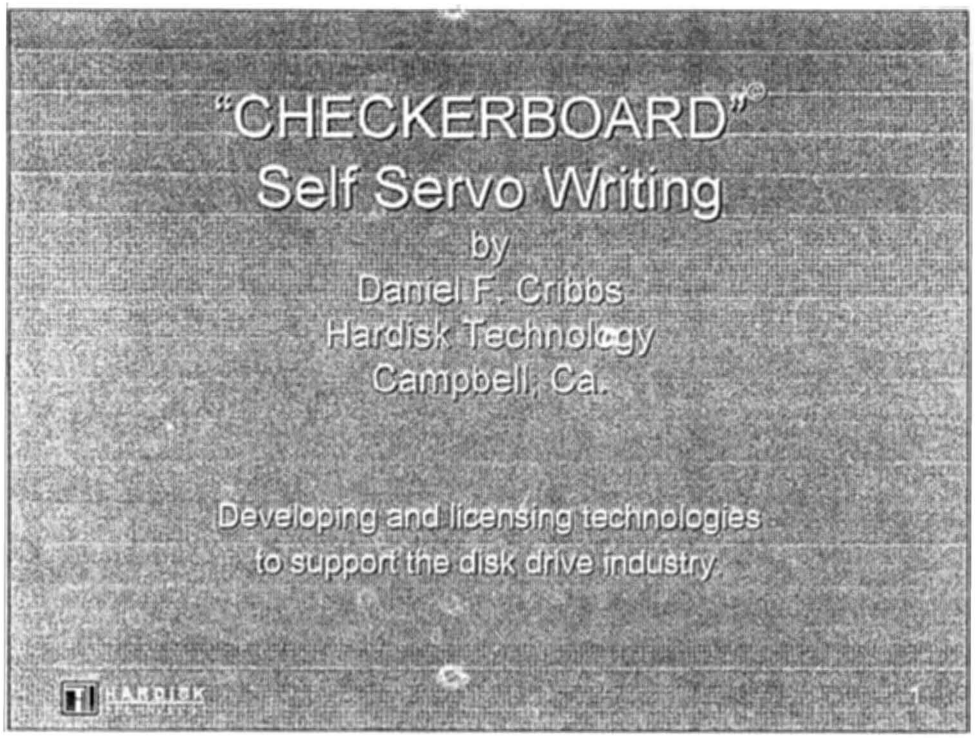
IBM - takes
Seagate
use
this
technology
Working
on others

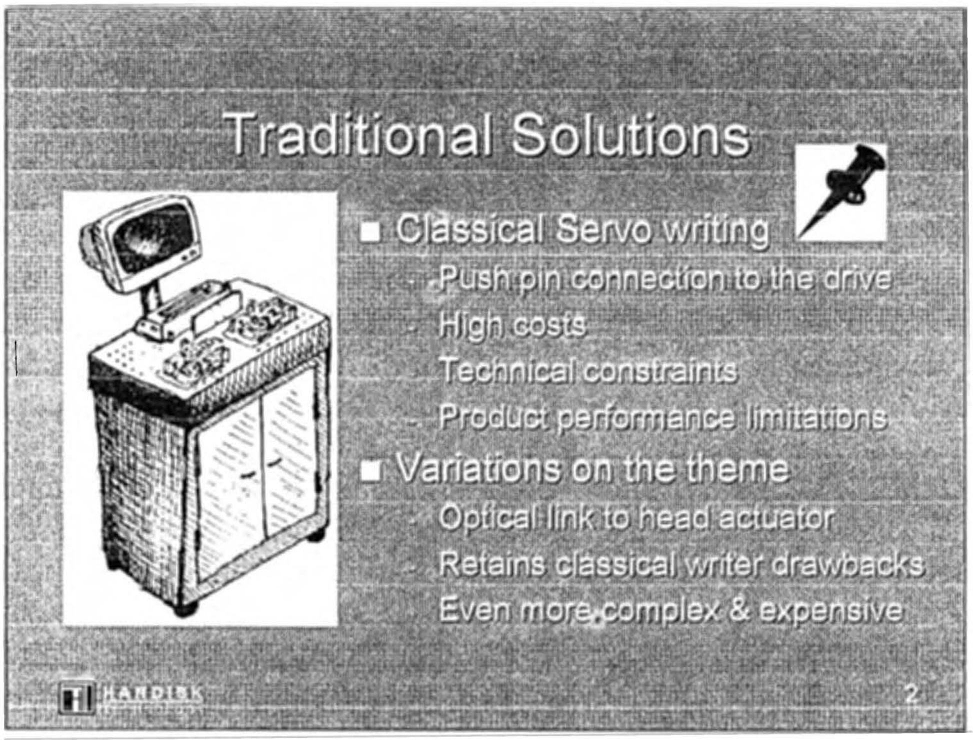


Hardisk Technology is a research and development company developing new magnetic and optical disk drive servo, servo writing and other technologies. The staff of Hardisk Technology, augmented by key consultants, posses analytical and working knowledge in many aspects of disk drive design and manufacture.

Hardisk Technology was founded in 1985 by the current president, Daniel F. Cribbs. Mr. Cribbs has 32 years experience in the electronics industry, 21 years of which are disk drive related. His background is well founded in a number of fields including sub-micron metrology, engineering, marketing, product management and technical support, as well as domestic and international distribution.

After receiving his engineering training at the University of California at Berkeley and prior to starting this company, he worked for technology-based companies including Bausch & Lomb, Ball Corporation, and Shugart Associates. He has patents pending and issued in his current and former companies' names.

Chief Technical Officer, John Wade Hassler, has been with Hardisk for 8 years. Wade is a graduate of San Jose State University and is experienced in both hardware and software design of disk drives and disk drive test equipment.



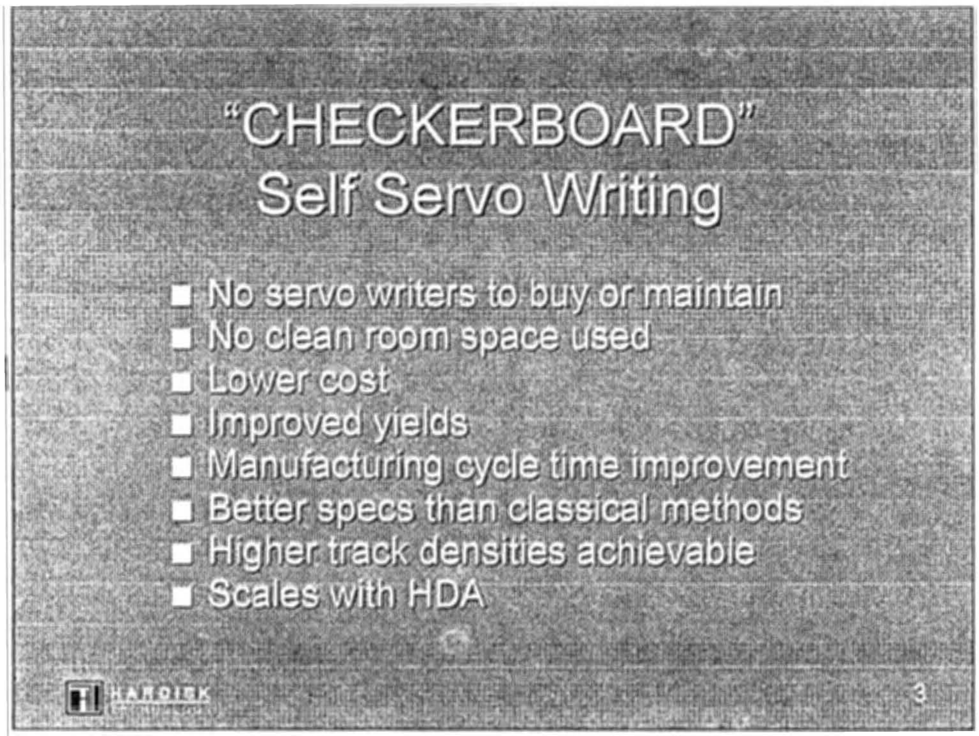
Classical servo writers must hold the drive very accurately during writing yet allow drives to be changed quickly. This and the invasion of the drive by a push pin and clock head prevent some small form factor drives from being written easily. Providing access often compromises contamination and structural considerations and thus causes yield problems.

The true physical head position and, more importantly, the magnetic head gap is only <u>indirectly</u> located by the push pin.

Classical writers strive to write geometrically round tracks as determined by an external, absolute and independent means. This is not what the drive needs right where the gap meets the disc.

Innovative methods have been devised to provide head positioning by optically tracking the arm or even the head slider itself, but these provide only incremental improvement. To obtain even higher TPI, reduced position error is the true goal, not absolute <u>physical</u> location of the head.

Optical approaches do eliminate stress on the arm and invasion of the HDA by a pushpin, but, access for the clock head must still be present. These are still classical servo writers, yet even more complex and expensive.



THE BEST IMPROVEMENT TO A PIECE OF PRODUCTION EQUIPMENT IS TO TO ELIMINATE THE NEED FOR IT!

Hardisk Technology's "CHECKERBOARD" self servo writing process eliminates the classical servo writer.

Just imagine, no servo writers to design, buy or maintain. Self servo writing can be done outside the cleanroom, on the burn-in rack, so the costs are dramatically reduced.

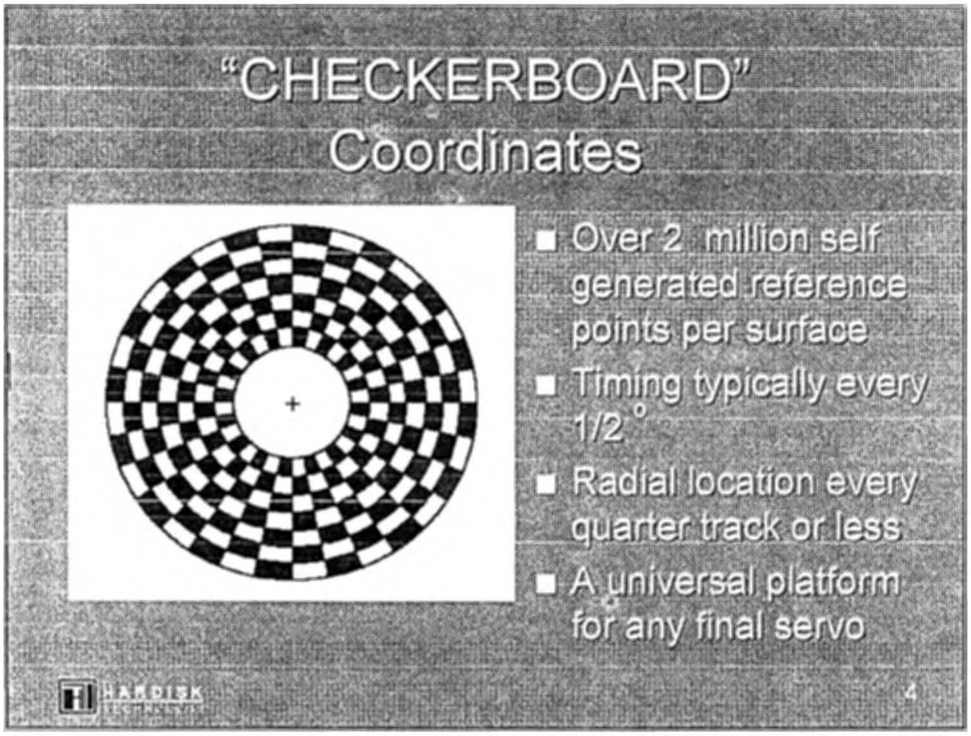
Self servo writing can be done as the initial stage of burn in, thus manufacturing cycle time is improved and WIP is reduced.

Self servo writing enables the writing of track shapes that are better for achieving high track density. The characteristics of each drive are different. Self servo writing can adapt to these changes and report them. Importantly, self servo writing can actually compensate for ***some*** otherwise unacceptable tolerance problems.

THE ONLY LIMITATIONS OF "CHECKERBOARD" SELF SERVO WRITING ARE THOSE OF THE DRIVE ITSELF, SINCE EVERY DRIVE IS ITS OWN SERVO WRITER.

- batch servo writing out of clean room

- 10X longer than current drive servo write but do several @ once.



1-2 hr 18-GB drive

- Single surface like dedicated surface drive

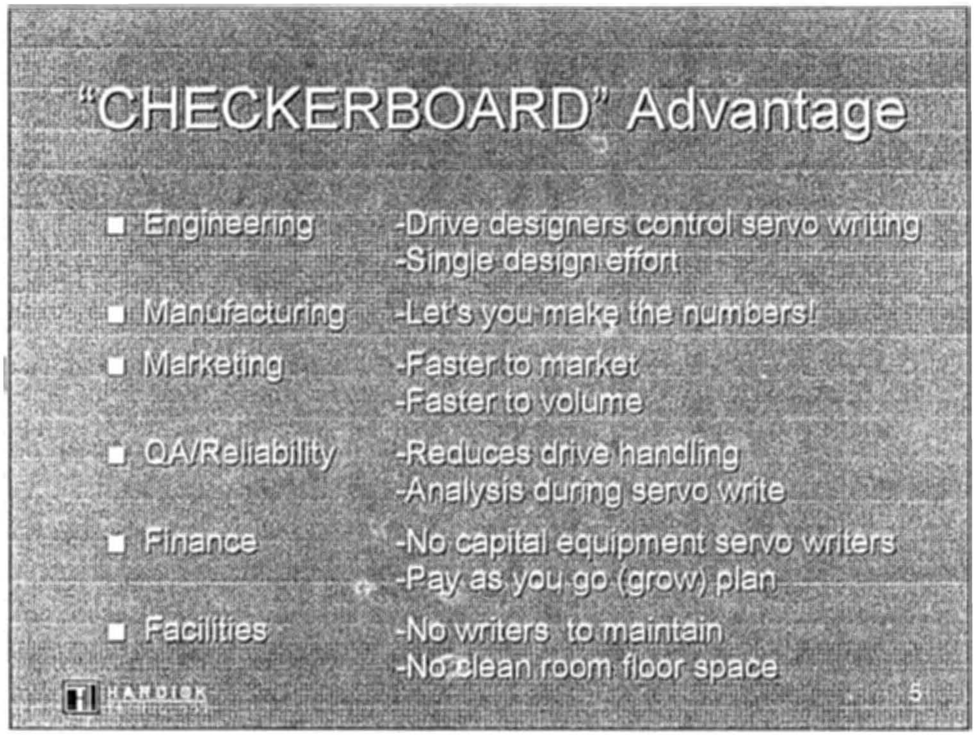
- best SNR surface, wider TW.

- 2 to 3 patterns to each track

- temporary ref. surface, then used @ a data surface

"CHECKERBOARD" Technology is a patented and <u>industry proven</u> process that uses the drive itself to write a very precise set of universal references that are in turn used for controlling the writing of any final drive servo information. This technology has been licensed to, and used in production by the largest manufacturer of disk drives in the world.

Flash to drive
- servo
- read back / analysis



"CHECKERBOARD" Self Servo Writing offers advantages to every group within a disk drive company.

Even those who have been involved with the support roles of buying, building, and maintaining classical granite block servo writers can now contribute more to the direct tasks of designing, producing and testing drives.

Will "CHECKERBOARD" work on any drive?

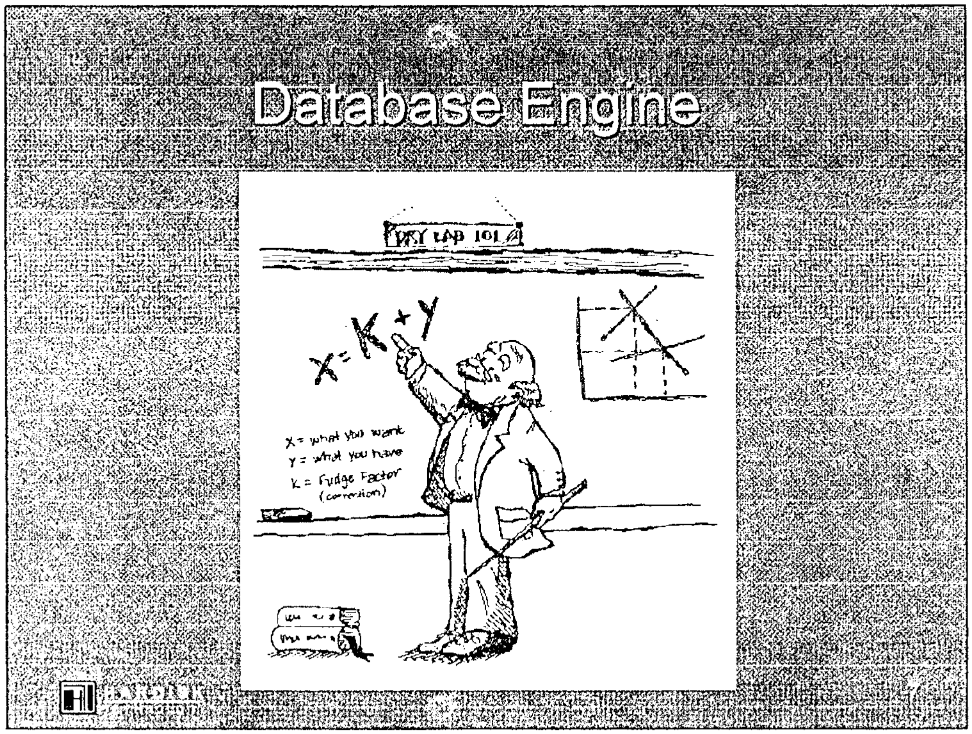
Figuratively, ... hold the drive up to a mirror.

If the hardware can operate as a drive provided the necessary servo pattern where somehow present, it can start with blank media, write its own servo pattern and it will operate better as a final drive.

Self servo writing is adaptable and independent of head or read/write technology, RPM and form factor.

As a result drives can be built that couldn't otherwise be servo written.

All efforts to improve elements of the drive naturally results in improvements to the elements of the servo writer... **they're one and the same.**



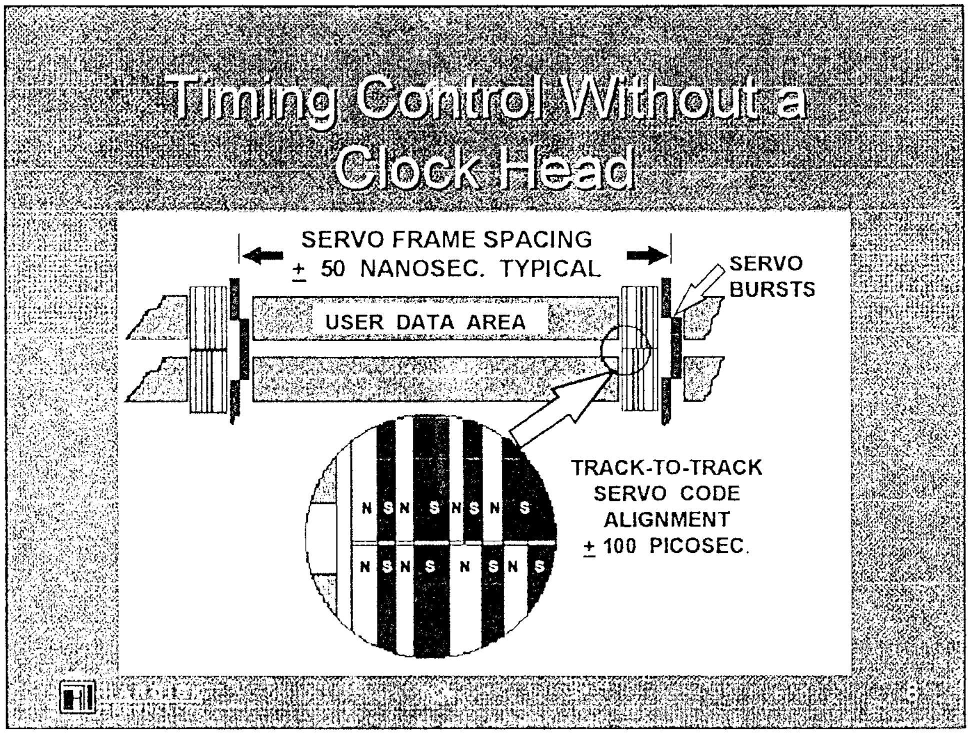
Both timing and position control are derived from localized temporary or previous track references. After eliminating repeatable error and averaging random error information, the output of the database engine is used for adaptive feed-forward compensation while writing subsequent position and timing.

You know, this whole process is like a "dry lab" experiment. Given the problem and knowing the desired answer, one can fill in the lab book without doing the lab work. The equation is immaterial, ... as long as it contains a constant "K". Fudge factor K is equal to what ever is necessary to cause any given set of conditions to yield the right answer.

With the right " K ", the problem can always be solved.

"CHECKERBOARD" works backwards to find "K".

This is a radical departure from after-the-fact servo correction. It eliminates the need for complex, high speed DSP calculations and large amounts of memory. There are no FFTs employed, just simple arithmetic.



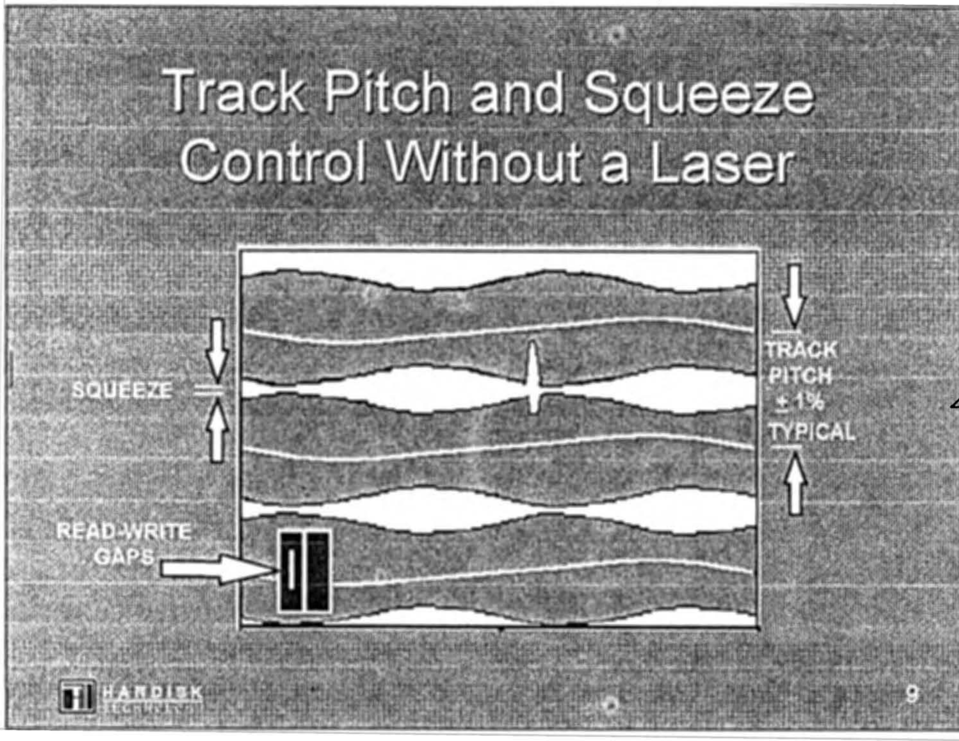
< 100ps tra to track alignmt for coher

By recording timing relative to the adjacent track, not a remote clock head, the true goal is achieved with much higher accuracy.

Consider, for a moment, jets flying in formation. To keep from killing themselves, the pilots don't ask the air traffic controller, how close the wing man is, they look out the window and check their wing tip. Radar is great for keeping the formation on the flight path but the relative reference of the adjacent wing tip provides tighter spacing with greater safety.

The servo frame to servo frame accuracy is like scheduling groups of jets past the review stand, not too tricky.

The key to timing takes place inside the indicated circle on this slide. The alignment of Gray code on adjacent tracks is life or death to a servo system. As the heads seek across tracks, the head gap must read while spanning two tracks. Unless the flux transitions are very accurately aligned, resulting errors will render the drive unusable.



← [illegible] defect.

each track written independent of edge profile of adjacent tracks

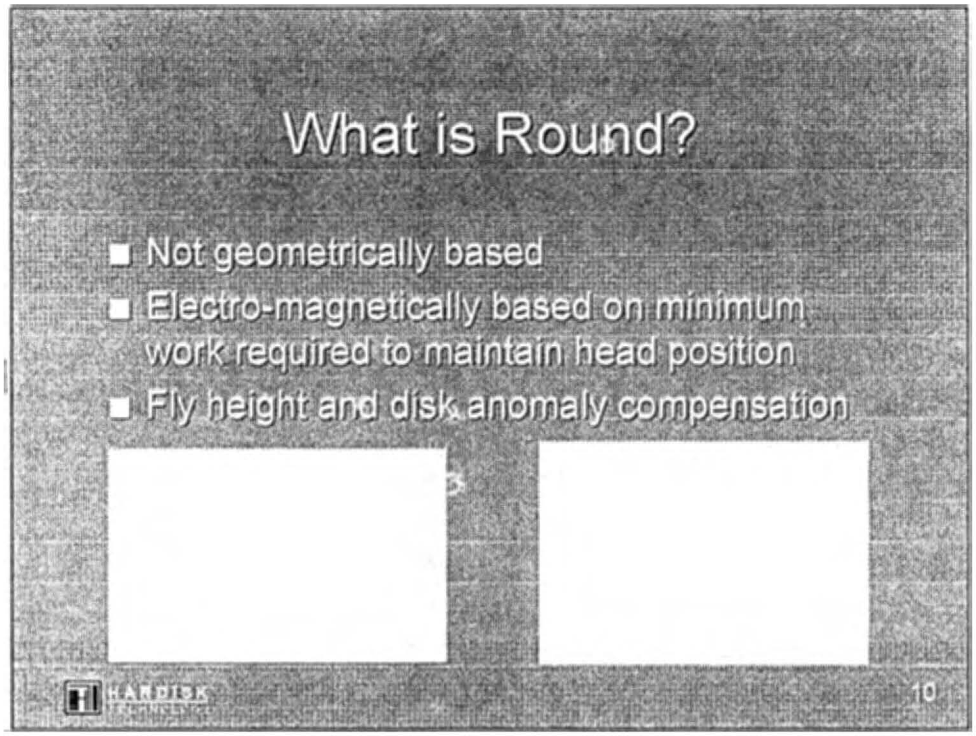
Track width, pitch, and centerline placement all determine the amount of squeeze between tracks. Classical servo writing controls centerline placement and pitch. The effective magnetic track width, however, varies with flying height due to different "fringing" at the ends of the write gap.

One of the major causes of soft error rate in disk drives results from adjacent track interference if the head does not read on the written centerline. Squeeze, not pitch, is the true measure of the safety guard zone.

"CHECKERBOARD" SERVO TECHNOLOGY

REDUCES SQUEEZE AND POSITION ERROR

Controlled squeeze and improved track following allows track density increase without narrowing the head gap.



= magnetic, not geometric round.
- FH variation on disk

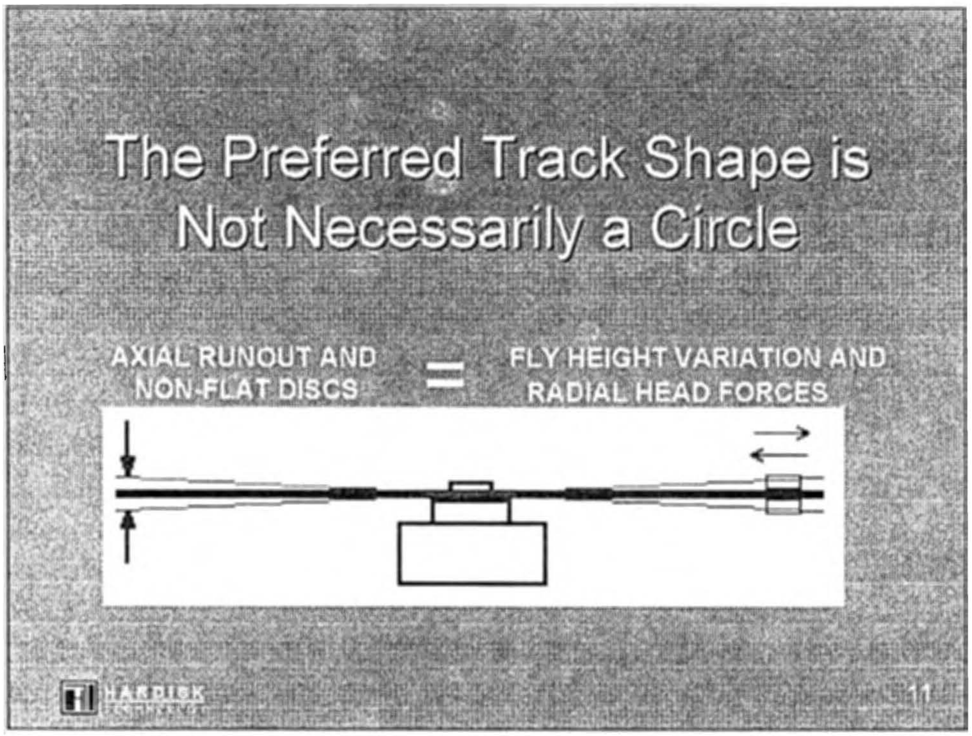
WHAT IS ROUND:

Round circular tracks are correct only on perfectly flat discs with no periodic forces on the heads.

Forcing a head to maintain a fixed radius in the presence of repeatable forces requires work by the servo system and may not be correct for controlled squeeze as the track changes width.

That work to stay on track is in response to position error (PES) generated by the head being off track, the very thing to be avoided. The servo should do all its work correcting non-repeatable and external forces.

PES of a drive following a "CHECKERBOARD" written servo pattern can be one third, or less, that of the same system trying to follow a “circular” pushpin written pattern.

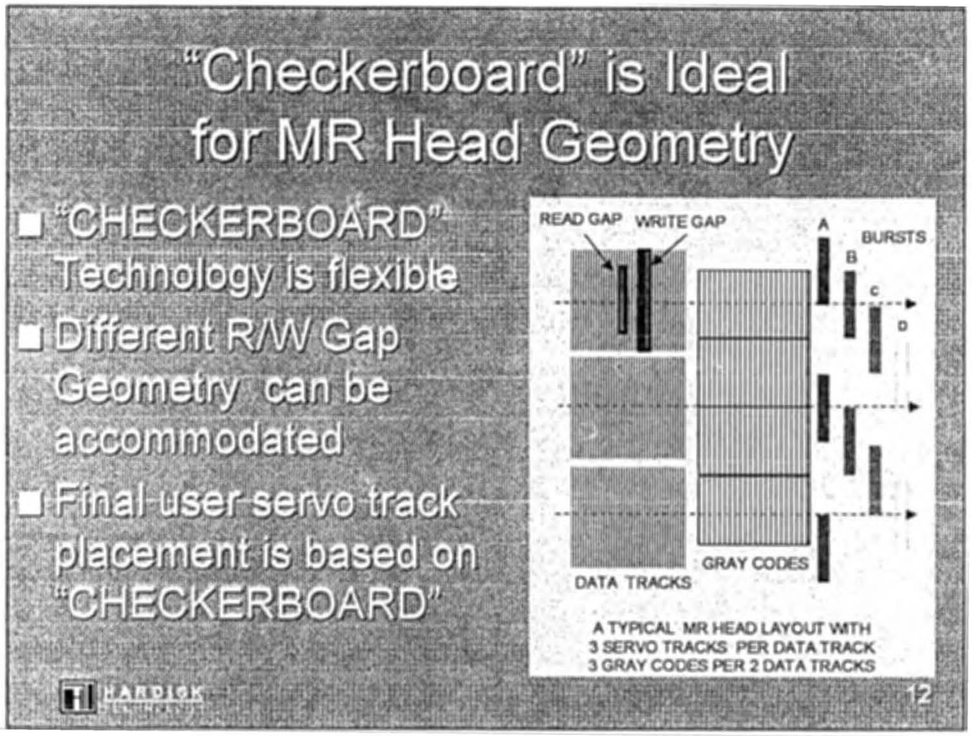


3.5 inch disk @ OD 200-300X head FH flutter – compression on susp., changes drag of susp. on head. radial & circum. trk error unless dc @ gap.

Our experience also indicates that once around forces from flying height variant drag often appear as eccentric servo tracks. Actually the heads want to move in and out by a fraction of a track once or more often per revolution. It's nearly impossible to eliminate. We have found these forces to vary from drive to drive and versus radius within a drive.

In fact, servo systems must work hard to keep the head at a fixed radius while trying to follow a push pin written track.

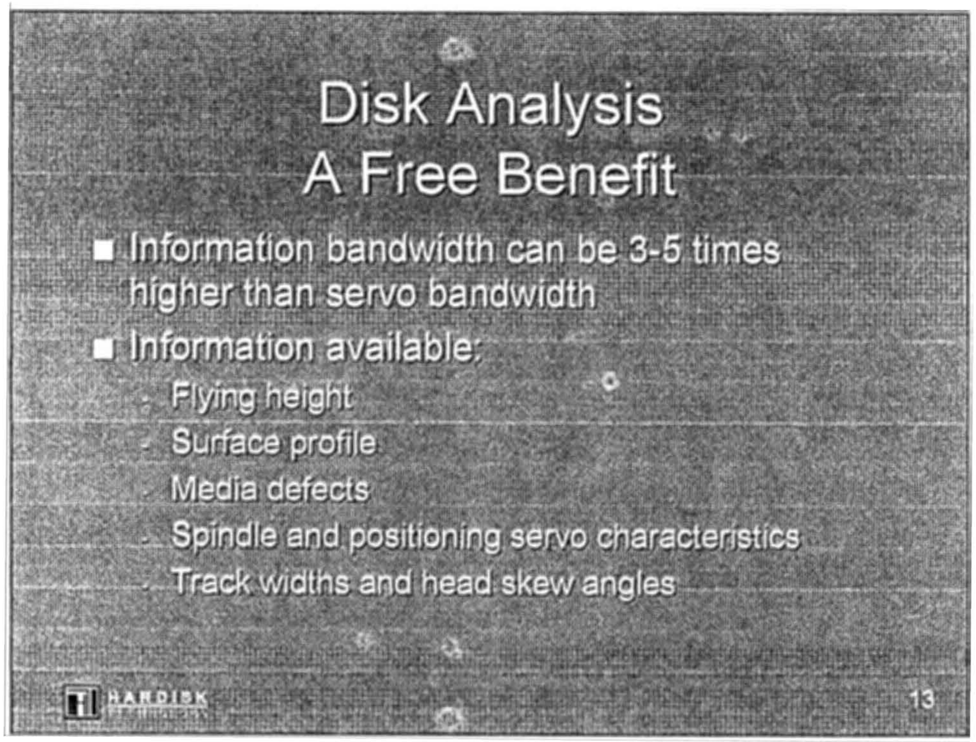
All of this is taken care of by using each drive to write its own "CHECKERBOARD" servo pattern. Reduced PES is the result.



- Switch back & forth from refs to writing servo head

1) "CHECKERBOARD" Technology is well suited to MR heads due to the intrinsic temporary reference approach. For MR head technology it is very desirable to control squeeze such that track edges just touch.

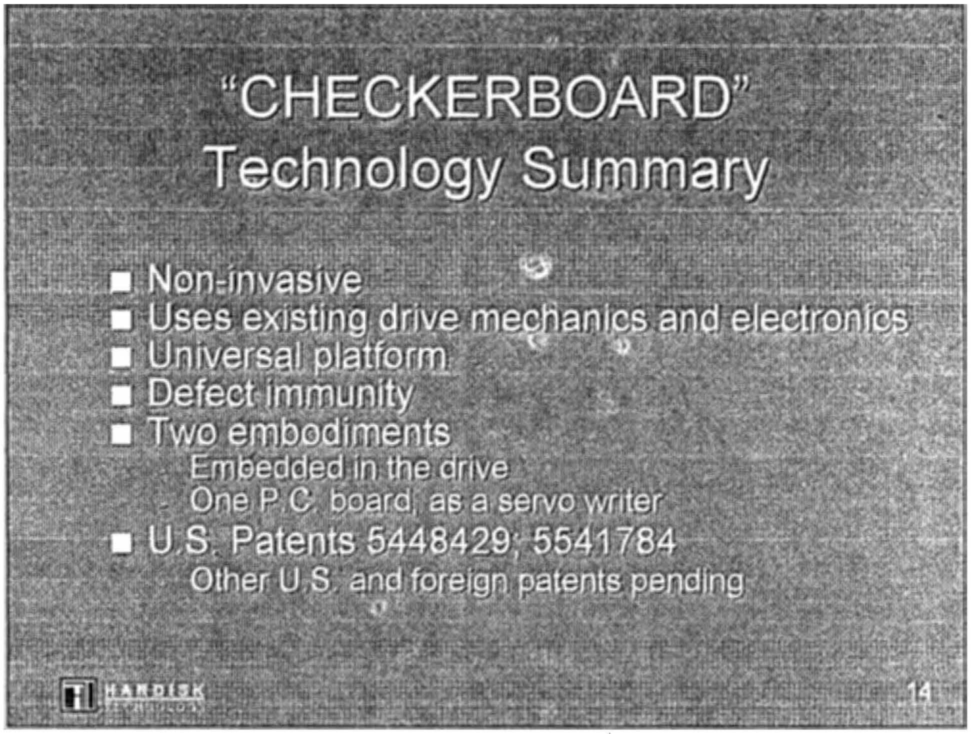
2) MR head geometry or asymmetry are not issues and the sub-track pitch resolution of the "CHECKERBOARD" pattern allows the final servo placement to even accommodate a read gap centerline that differs from that of the write gap.



Since the "CHECKERBOARD" Technology uses a database engine, it is trivial to report what was observed during the process.

The cost of classical servo writers precludes taking the time to analyze each drive. In fact, in the interest of throughput, many manufacturers write servo patterns “open ended” with no checking on the writer. They wait until the drive is tested to find bad servo patterns. One marginal servo writer can generate a lot of rework.

"CHECKERBOARD" servo writing takes place as the first part of a necessary burn-in and test cycle. The process does not tie up expensive capital equipment, add to WIP or extend the burn-in time.



Drive yields improve by not invading the HDA. Mechanical design is also simplified and provides a more rigid drive structure.

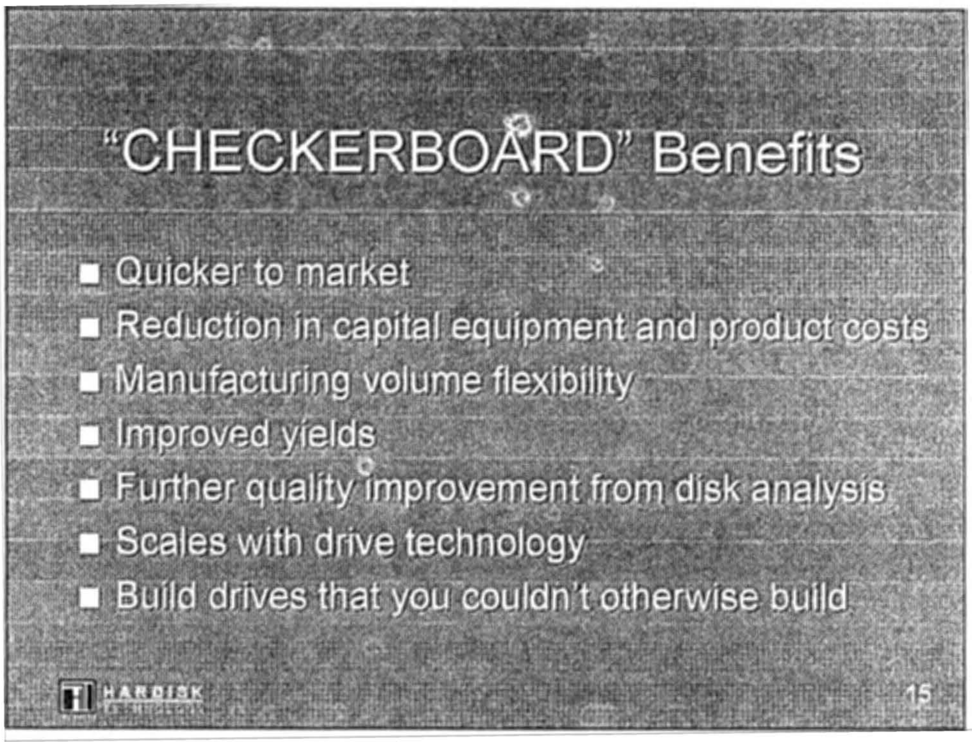
This technology is not expensive to implement. Using the normal drive components, it requires absolutely no mechanical design considerations and only a small increase of used gates within an existing ASIC chip. Firmware code can be loaded to write the servo and overwritten later.

The technology is easily adaptable to new drives. Because it lays down an intermediate pattern, it needn't be changed for each new drive.

The technology is immune to most defects and is able to report them. This is a key point. The system is driven by a database engine that measures the nature of the head/disc interface and adapts for defects, tolerances and both repetitive and non-repetitive errors. This technology even compensates for some ills in the drive.

The "CHECKERBOARD" Technology can be done two ways. For new drive designs, it can be put right into the drive. This will need a few more gates, but may even reduce costs of mechanical components.

Alternatively, to address drives already in production, it can be designed into a low cost "writer/burn-in" board similar to, or as an add-on to, the standard drive P.C.B.



What we've found in this technology has gone beyond even **our** original intentions.

• "CHECKERBOARD" technology offers tremendous advantages to reduce costs and increase TPI.

• Marketing need never delay product introductions for lack of servo writers.

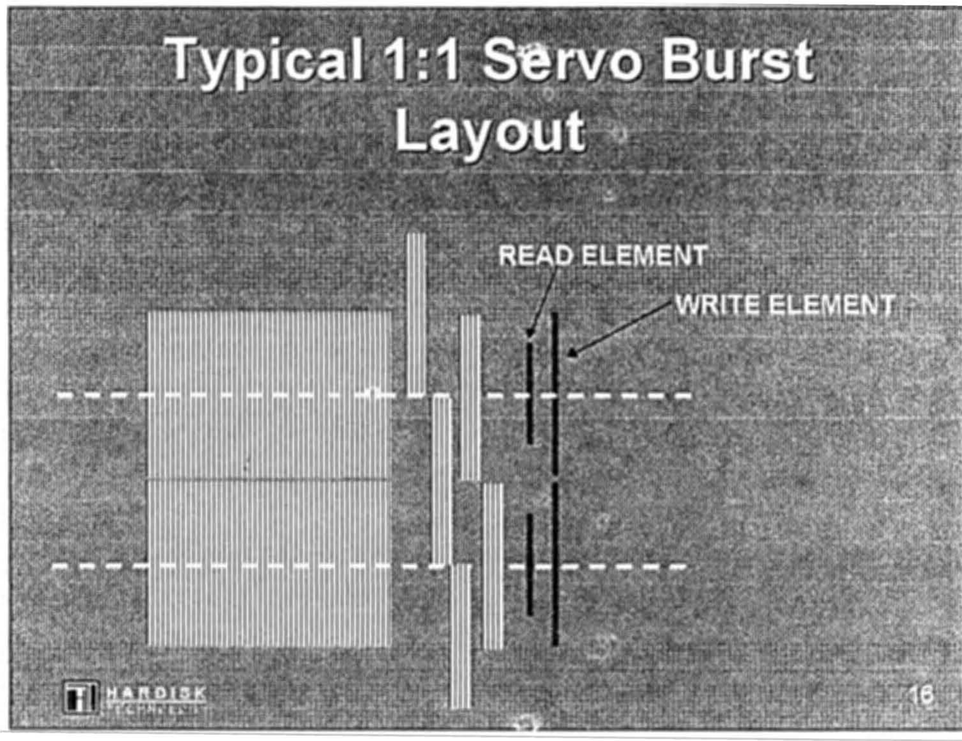
• Capital equipment, engineering talent and operating budgets are freed up for more rewarding drive development.

• Since every drive can servo write itself, manufacturing can better adapt to changing market demand. Servo writers will never again cause lost revenue.

• With more rigid mechanics and no HDA invasion , yields will increase.

• And... With a wealth of technical information on each drive produced, not just those audited or failed, quality will improve.

•"CHECKERBOARD" Self Servo Writing Technology eliminates classical servo writers and will allow you to servo write the future drives you desire to produce.

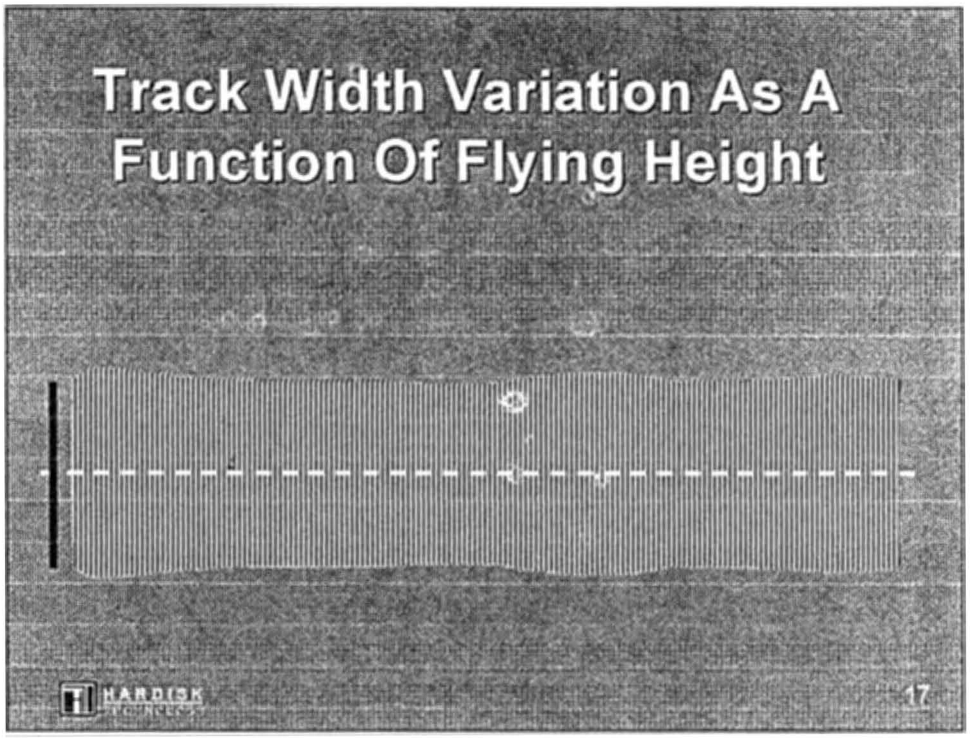


lap or shingling
• write over prev track w/ absolute servo ref

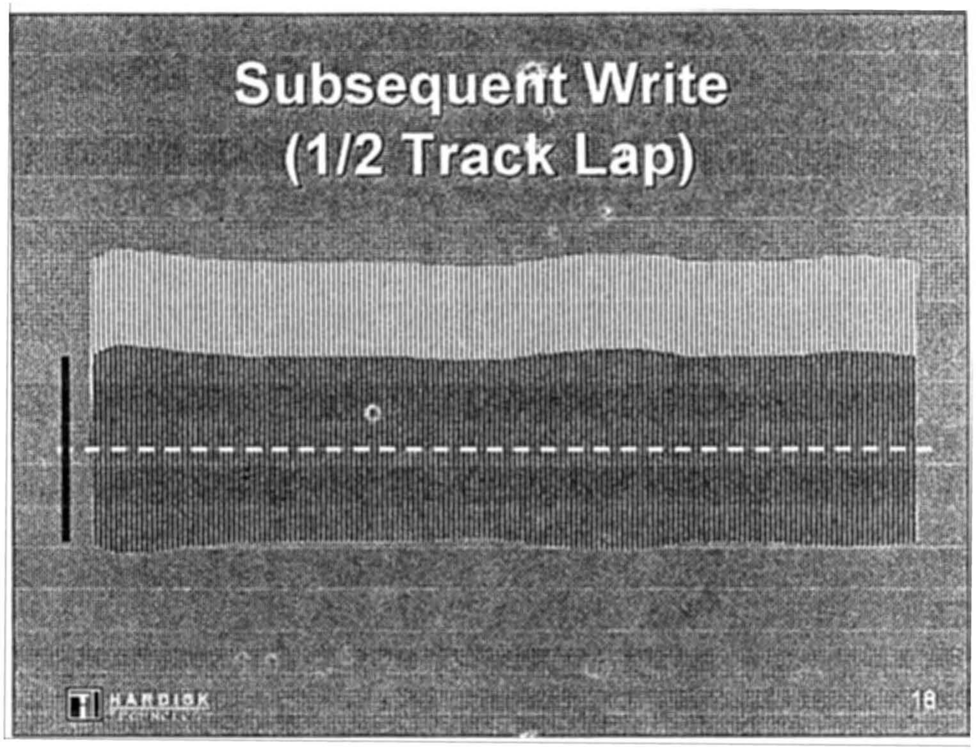
The typical 1:1 servo burst layout writes servo burst the same width as the track pitch. Since the write core is narrower than the track pitch, the bursts are often written using a half track overlap method (Shingling); wherein the inside end of one burst is trim erased while the outside end of the other burst of a given pair is being written. If written from O.D. to I.D., the intersection of any given burst pair is defined only by the outside (trailing) edge of the write core.

This pattern can be written without overlapping writes, however, the amount of gap between the two burst will vary because the effective written track width varies throughout a given revolution. This varying gap will reflect in varying servo gain at each wedge. Additionally, since two different writes on two different revolutions define the burst null point, the opportunity exists for larger written in position errors.

This pattern will generates flat spots in the position signal because the bursts are wider than the read element

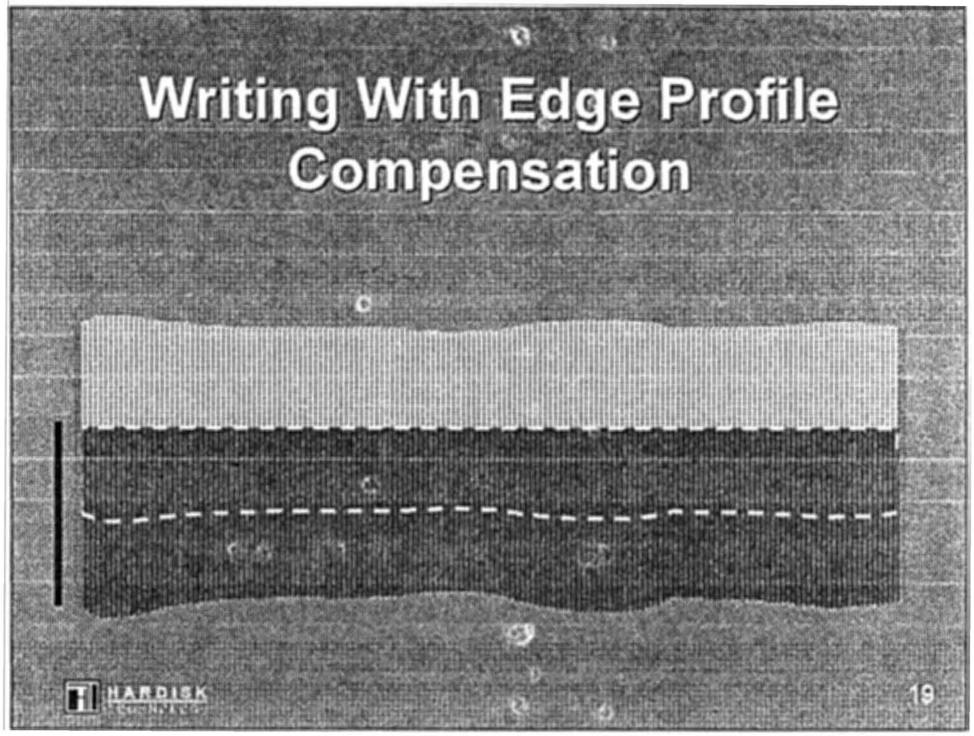


Although the centerline of the head may describe a perfect circle or a “least energy path”, the edge of the written track will vary from the centerline because the track width varies throughout the revolution. The major cause of track width variation is due to varied fringing at the ends of the write element as a result of flying height variations. The largest component is often a once around at the fundamental spindle rotation rate.



As subsequent overlapping servo writes are performed, the upper edge of the write element trim erases bursts written during the previous half track write, matching bursts are written and other servo information is overlap written.

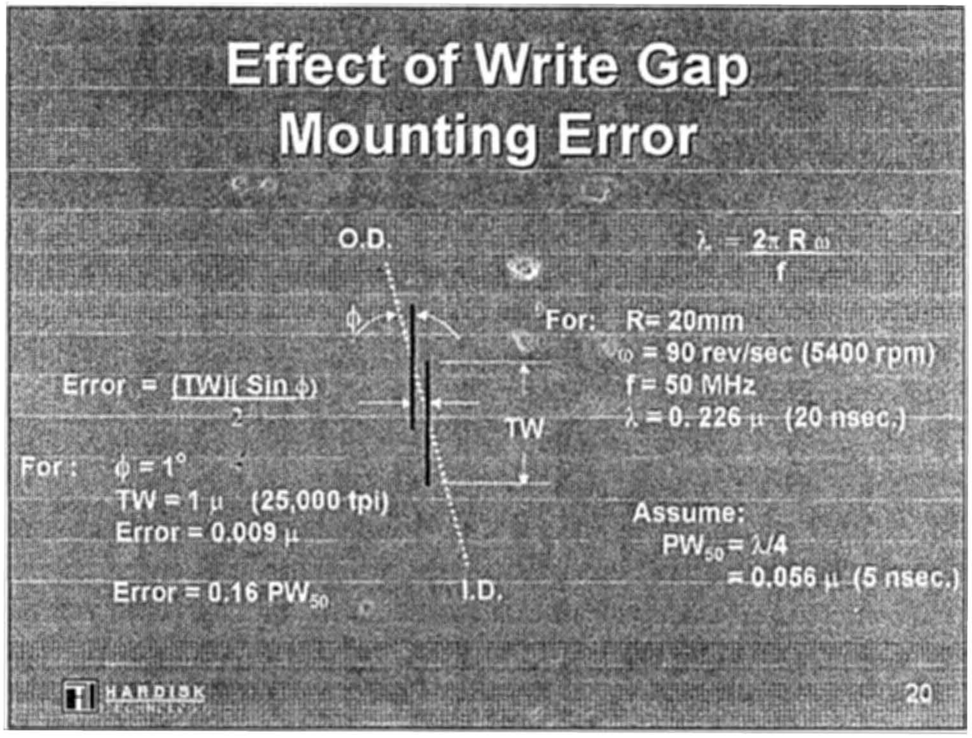
The resulting servo pattern will appear as if the center of rotation changes after servo write. After the fact, feed forward, correction can compensate for much of this type of repetitive error, but must be applied on a head by head basis.



By characterizing the edge profile of a each head at each servo track, it is possible to provide a feed forward correction to the actuator during the servo write revolution such that the trailing edge, not the centerline, of the write element defines a circle or a least energy path. Of course the leading edge of the write element will define a track edge with twice as much error, but remember that it is the trailing edge of the write element that defines servo wedge burst balance points.

PES info in checkerboard
1st pass: 5-7 revs/ Servo surf.
2nd pass: 2 revs/ Servo surf.

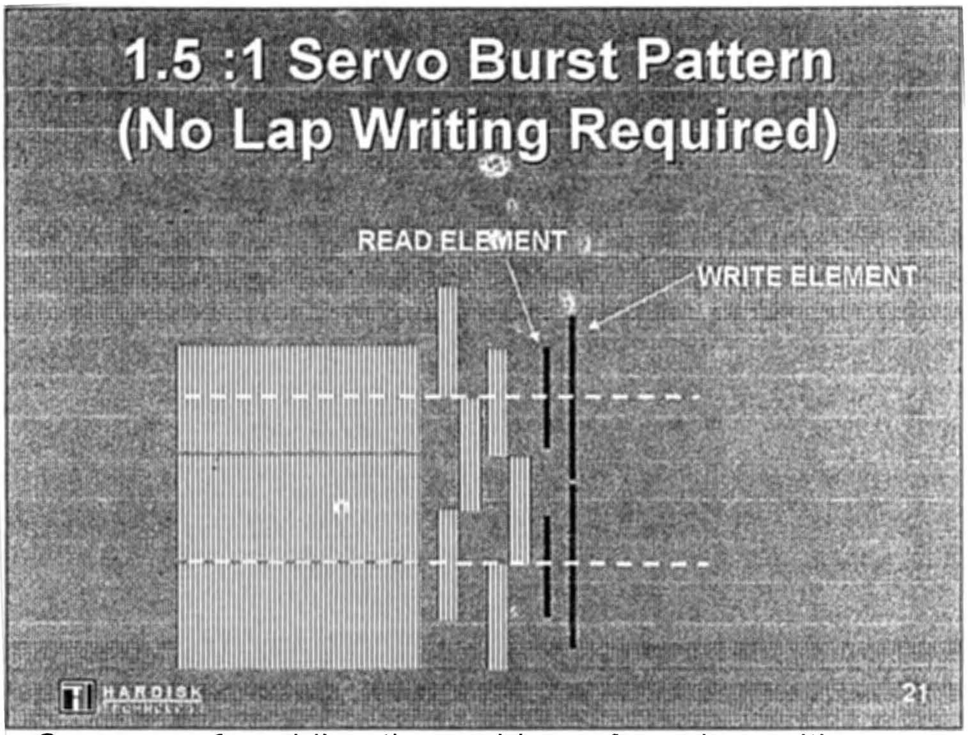
Although taking additional time, this technique results in a far superior servo pattern. The additional time to write becomes less objectionable when selfservo writing is performed within the drive as opposed servo writing on expensive conventional capital equipment servo writers.



The task of matching adjacent track servo information and shingle writing has become much more difficult as servo frequencies and thus bit densities have continued to increase. With servo frequencies equal to or exceeding 50 MHz and the PW_{50} less than 5 nanoseconds, it becomes necessary to maintain timing to sub-nanosecond tolerances.

Additionally, any mounting error that places the write element on anything other than an arc about the pivot of the actuator will result in incoherent shingling and track- to- track misalignment of Grey Code information.

Selfservo writing affords better control over track-to-track timing and permits correction of write element mounting errors on a head by head basis. Such corrections on a conventional servo writer would be far too time consuming.



write 1/2 as as my servo tracks

One way of avoiding the problem of overlap writing, or shingling of the servo information is to write data the width of the write element and to trim erase so as to leave information that is the width of the read element. Since the read element is typically about two thirds the width of the write element, a very workable layout results from advancing the actuator one third instead of one half track pitch between servo writes.

This approach does not require shingling, generates no flat spots in position signal and together with edge profile correction results in a far superior servo pattern. It does take additional time to write so is best applied in a selfservo solution.

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