Geoffrey Owen, founder, owner and senior design engineer writes about the Orion tone arm

The trouble with being an engineer is that one is born with a natural tendency to look at the world through critical eyes and consider how differently you might have designed the things around you had been have been given the job.

But then, if ever you feel inclined to prompt such a discussion, most engineers are usually happy to explain the constraints placed on them as they've worked on their pet projects. Engineering is more than a profession, it's an obsession, a state of mind, and one that comes with an inbuilt affliction - we just can't leave a design alone.

No sooner do we get half way through building a prototype than we usually think of even better ways of doing things and want to modify the design.

I came to tonearms having already passed through the loudspeaker and turntable phase.

The earliest effort I've kept records for was a parallel tracking arm in which ceramic balls ran in the vee of two optically flat glass plates bonded together. The fixed rail had a steel rod underneath the glass, whilst the sliding arm was fitting with weak magnets that 'sucked' the two parts together.

Though I had eliminated tracking error and need for bias correction, I created the problem that the cartridge's cantilever suspension bore the entire stress of pulling the inertial mass of the cartridge and sliding arm structure along with it. As the tiny (and very delicate) parts that connect the cantilever to the external mechanics within the cartridge are the only thing that provides any anchoring, the coils would always to be biased as it pulls the arm inwards. A second problem in trying to design an (ostensibly) frictionless movement was the it had to be absolutely horizontal – lest it should 'fall' inwards or outwards under gravity. Given also that most 1970's turntables had very soft suspension (as did cartridge suspension), it would have been a disaster as a product.

Commercially, I came to manufacturing tonearms by accident – Tangent Acoustics, my last formal employer, went broke and I had to do something to pay the mortgage. Arms were small, didn't take up much space and (in the early '80's) were less contentious than trying to compete against the all dominating Linn turntable.

Beogram and Gale turntables

What also attracted me to tonearm design technologically was that it seemed one area of hi-fi that had languished in the simplicity of the 1940's. With turntables like the Gale and Beogram 6000 appearing on the market, I was soon smitten by the idea of playing technological catch-up.

Having only just emerged from my student days, my head was buzzing with ideas and I'd retained the ability to play with complex equations – I also had an aptitude for seeing glaring design inadequacies in tonearms.

It seemed to me that 1980's products were blighted with resonances, fitted with pretty-standard ball-race bearings (or wobbly unipivots) and suffered a complete disregard for dynamic balancing. Moreover, aligning the cartridge was a gamble and internal wires were anything that could be bought from RS Components.

Tonearms were little more than metal sticks with a transducer at one end and a counterbalance at the other.

What annoyed me most was the focus individual designers had for specific areas of design. '*Buy my product because it has the lowest friction'* – *'buy my product because it has the lowest effective mass'*....etc.

It didn't seem to occur to anyone that products should optimise not just one parameter, but all of them. It's a bit like fitting a modern Lamborghini V12 into a 1960's mini – great noise, fabulous engine but hopeless in every other way....start by substituting the passenger seat for a fuel tank.

But for me there was another caveat – when you are setting out in a new business and have limited resources, your ambitions are constrained by finances. You also have to accept that life (especially in engineering) is a continual learning exercise driven by the appearance of new materials, software and new manufacturing techniques (like 3D metal printing) ...like I say, we engineers don't stand still for long.

And thus it came to pass ….

that, armed with four years of engineering and physics (sprinkled liberally with that mysterious substance called arrogance and lubricated with a few drops of entrepreneurial aspiration), I started Helius.

I started with the intention of addressing three specific areas of tonearm design – dynamics, bearing design and tracking geometry.

So, we now come to the fun stuff – how to set about revolutionising an important but seemingly forgotten component in the Hi-Fi chain.

The 1983 Orion arm was a world game-changer – it ***really*** was a revolution in tonearm design.

My starting point was to look at a simple children's toy that had intrigued me for months - a small plastic bird with its wings outstretched and whose pointy beak happily perched on the tip of my finger.

No matter how much it wobbled, it was always securely fixed to my finger and best news of all, it was physically impossible for that beak to chatter no matter how much the bird rocked (at its natural resonance frequency). The inertial mass of its wings were effective in damping high frequency vibration (more so in the context of amplitudes generated by the cartridge) – This led to a future idea of damping by differential masses. Proper damping wings now appear on the new Phaedra arm, but that’s material for a future article.

Applying this idea to tonearm design, the central bearing (beak) represents a focal point through which reactive energy generated by the cartridge could leave the system with almost perfect efficiency. It was a point free from vibration – or, as I called it when I first designed the Orion tonearm – a point of zero potential.

Anyone who has an Orion can look into the heart of the arm and will see a bearing close to the centre of gravity of the main structure.

As you can see from these 2 images, the main bearing structure of the Orion is balanced around the equivalent point of the bird’s beak.

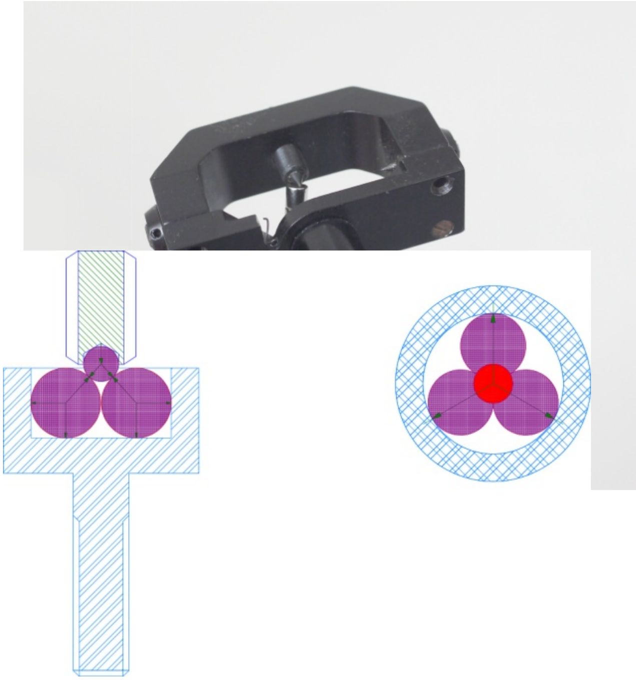
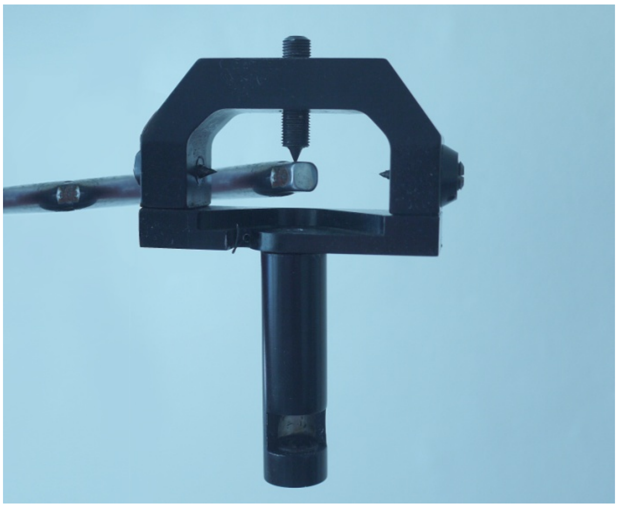
Unlike the bird, the Orion’s bearings are fully captured, so this point of focus achieves perfect efficiency in the transmission of wave energy from the tube structure, to the outside world.

The next question was how to build on this idea.

It next struck me that there were no tonearms that optimised their design of bearing. As far as I am aware (to this day) no other manufacturer has put any effort into the rotating components.

All the manufacturers I know of use off-the-shelf bearings (complete with cages and an array of moving balls.) Those who use unipivots tend to fit either a single point jewel or have cones that sit in a ring of balls. Some try to stabilise their designs using magnets – but none of these ideas have been perfected for tonearms.

My ambition was to build on the centroid principal and create a bearing specifically for tonearms. The engineering parameters were minimal friction, ultra-fine adjustability, chatter-free and self-aligning.

Recently, I have come to use materials that transmitted the widest frequency bandwidth – ceramics, ruby, silicon nitride etc. By this, I mean choosing sphere materials that ensure whatever the frequency of the energy coming down the arm tube, it is passed efficiently from one part of the moving structure, to the next.

There is only one geometric configuration that offers both a captured design and minimal friction – and that is the tetrahedral bearing.

In this scenario, you place three spheres in a close triad formation (as close as possible without actually touching) then place a smaller sphere in the centre.

In each Euclidean plain the balls make only 3 points of contact – the central ball pushes the other three outwards and makes only three points of contact with the main spheres. Because the surfaces are spherical, they also self-align.

As for adjustability, an M5 metric fine thread has a thread pitch of 0.5mm. Given that (with a little practice) ones can make adjustments down to about 5 degrees, consider that if 360 degrees of rotation corresponds to 0.5mm of axial adjustment, then 5 degrees gives 7 microns of movement. Given this is split between the left and right bearings, its tantamount to adjusting 3.5 microns per side with every 5 degree adjustment....well within the thermal expansion tolerances of the surrounding metal.

This figure shows how axial adjustment of the small central ball exerts both an axial thrust and lateral force. The larger balls are pressing against the peripheral wall of the bearing cup and the axial position is governed by the basic assembly – the balls can't sink lower into the assembly because the cup restrains them.

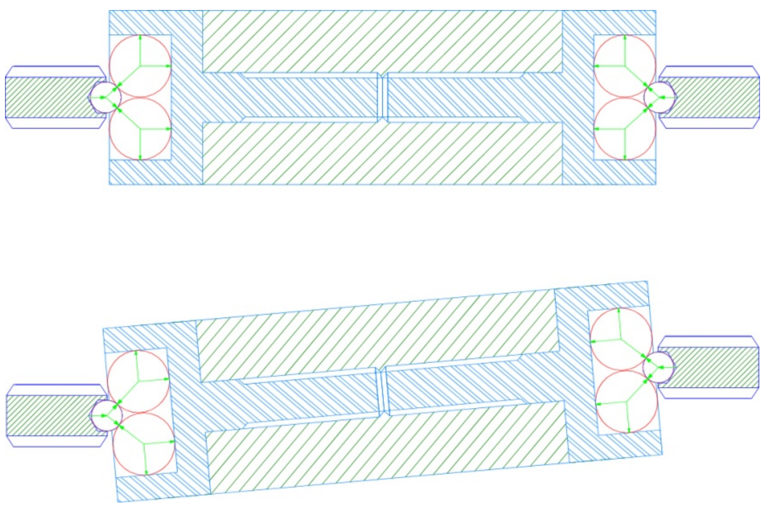
There are only 4 moving parts in total – each of the 4 balls experiences only three points of contact; this constitutes the configuration of minimal friction...it cannot be bettered in a constrained bearing system.

Next we consider how machining tolerances are accommodated. With the best will in the world, we can drill tap holes within margins of microns, but this is not perfect. Threads always require a working clearance that allow screws to turn.

The beauty of using spherical surfaces is that they

self -align – like a rose joint bearings.

In the example drawn here, the misalignment is a full 5 degrees where we normally machine to tolerances of 0.10 degrees.



As the inner grooves present more challenging conditions (in the context of tracking error and radial velocity), I have always been prepared to compromise on the outer Z.E point by an inaudible modicum rather than sacrifice the audible quality of performance in the inner grooves where you ***can*** such issues.

In designing my equations, I used surface area-per-track as my starting point. Six minutes of play time on the outer grooves will correspond to a radial increment of about 8mm. (depending variables like groove modulation levels, feed rate etc.)

In contrast, six minutes of play time on the inner grooves is more likely to be double the radial difference. (16mm depending on those same parameters)

My aim was to compromise the classical geometry and argue that the inner tracks deserve to sound just as good as the outer ones.

What happened next was (mathematically) interesting.

Unlike the approach of simply optimising classical geometry, my starting point was to develop a set of differential equations in which the two points of zero error were treated as constants that I could nominate at the start of an iteration. I then set a maximum error of one degree for the outer groves and set about plotting loads of iterations) I basically 'played' with the geometry until the computer read off really small numbers (for tracking error) across the entire surface.

This gave me an idea of where to place the arm in respect of platter.

After a couple of days I got really bored and decided to modify the algorithm to become 'self-seeking'. If the tracking error got worse the program 'unwound' itself – effectively going backwards. I eventually developed a program that 'spiralled' around possible mounting points; in effect, the program 'homed-in' on the optimal position....after a day or two (using very old and primitive computers from the 1980's !!) the results were perfected...and proved very interesting.

You see, I also made the arm length a variable in the maths.

In the early 1980's - 99.99% of all tonearms were 9"...except for a small handful of professional units that were 12".

Now, I'm not about to divulge the maths as it took me a long time to develop these equations, but the results for the optimised 12" arm geometry are thus.

Helius 12" tracking error results.

Record Radius.	Angle to perpendicular.	Tracking Error.
145mm	**89.0**	**1.0 deg (stylus set-down. Outer groove - start of play)**
140mm	**89.6**	**0.4**
131mm	**90.0**	**0.0**
120mm	**90.**2	0.2
110mm	90.4	0.4
103mm	90.7	0.7
90mm	90.2	0.2
74mm	90.0	0.0
70mm	89.5	0.5
61mm	88.4	1.6 (run-out groove)

If you look at these results, you'll notice I started by accepting a one-degree maximum error limit on the outer groove. (when you first put the stylus down and you get that initial crackly sound.)

By the time the music starts playing, the tracking error is less than half a degree and you get all the way to the run-out groove before the error rises to a degree. In fact, if you look, you'll notice the last track is played with less than half a degree of error – and I promise you can't align a cartridge that accurately...and even if you could, the stylus bounces around in the groove more than this.

I have often reconsidered the idea of making a parallel tracker – but I continually asked myself what is the point of adding all complexity when the error is so low?

I still reckon the 1970's Beogram 4000/6000 turntable represent the best technology if you want to go down this route.

As you can tell, I've long lusted after doing a parallel tracker using lasers, modern aspheric optics, encoded drives etc – but would it sound any better? .....I dunno...the jury's out until I try. I could certainly do it as I have international patents in laser optics....and yet I waver when I ask myself about the benefits. It'll certainly cost three times as much and if you consider the ratio of musical improvement to cost, you quickly confront the law of diminishing returns.

Anyway – getting back to arm geometry, I knew that (for the 12" arm) improvement in tracking error came at the cost of significant increases in inertia. The stylus had to 'drag around' the arm – which was OK if the cartridge compliance was very low – but not so good for a high compliant cartridge.

I worked on the 10" version and found I could achieve 97% of the 12" tracking error performance in a design that had little more inertia than a 9".....perfecto !!

And thus it came to pass that the Helius 10" was born – significant improvements in tracking error with little cost on inertia.

Thus also, we must come to an end of this article. In the Cyalene I came to address the question of having what looks like a very heavy arm but one that actually has a very low Effective Mass.

Other features of the Cyalene were its enhanced use of differential masses, tapered-tri-metallic tubes, line contact bearings, fixed counterweights, elastomer bias threads etc.

Cyalene remains one of the rarest Helius arms on the second hand market, I haven't seen one come up for years.

Auf Wiedersehen – until we meet again.

Tel. (0044) 1386 830083:

contact@heliusdesigns.co.uk