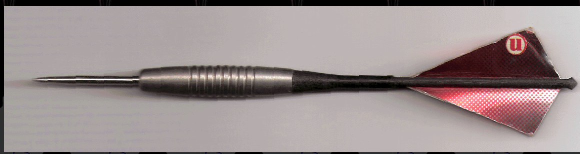
Accur8



Accuracy-Optimised Dart Prototype (c.1986)

Welcome to the last in my 8-blog refresher course on dart flight dynamics. The preceding seven were the build up, this is the big finish, the 170. Its aim is to show, at unapologetically extensive length (oxymoronically sorry about that!), the reason why a serious dart player might care about yaw wavelengths, static margins, moments of inertia, and all the other aeroballistic esoterica I've been trying to explain. That reason is because an understanding of them can be employed to produce or "tune" a dart to be aerodynamically more accurate. Not convinced? Read on!

I think most players would concede that a dart with a bent shaft is likely to be less accurate, as may be one with over-small flights that wobbles about on the way to the board and lands at odd angles. However, I also think it's generally believed that, providing a dart flies fairly true and lands straight, aerodynamics has done its job and accuracy is then down purely to skill.

Well, to a certain extent that's true. Darts is above all a game of skill and, as stated in the very first blog of this course, *Still Geeky After All These Years*, if you throw a dart in the wrong direction "no amount of clever aerodynamics short of a guidance system can help". But that blog also explains how that's not the end of the story as aerodynamics can still make a dart thrown in the right direction miss by some millimetres due to aerodynamic perturbations from the trajectory of its centre of gravity as well as the offset of the point at the moment of board impact.

Continuing with a quick course recap, the second blog, *Wait Lift*, mentioned that the last factor above can often be mitigated simply by fitting larger flights, a measure that seems increasingly popular with top pros and one that indeed may often lead to more consistent board impact angles. The mechanism by which flights, large or small, stabilise a dart mainly through the aerodynamic lift force they generate was then explained in *3 Degrees of Incidence* and the phenomenon whereby that lift force becomes less well-behaved at much larger angles described in *4 Stalling*.

5 Go Mad on Cycles introduced the concept of "yaw wavelength", a characteristic distance, not dependent on throw speed or angular amplitude (below the stall angle), that a dart takes to "pendulum" one way and then the other in flight. The sixth blog, *6 Degrees of Freedom*, introduced some of the basic ideas behind "6DOF" trajectory modelling and went on to cover how the yaw wavelength thus becomes a function of a dart's "Overturning Moment", a product of the "Normal Force" (mainly comprised of the lift force from the flights) and the "Static Margin", the distance between a dart's centre of gravity and the point where the Normal Force acts.

7 Moments to Ponder then looked at the effect of a dart's Moment of Inertia (MI) on the yaw wavelength and how fitting longer shafts can sometimes increase the MI so much that it negates much of the benefit of the greater Static Margin that results. The concept of dynamic stability was also introduced whereby the yawing motion of a dart damps out over sufficient distance.

OK, enough recap. Now let's see how all that fits into producing a more accurate dart.

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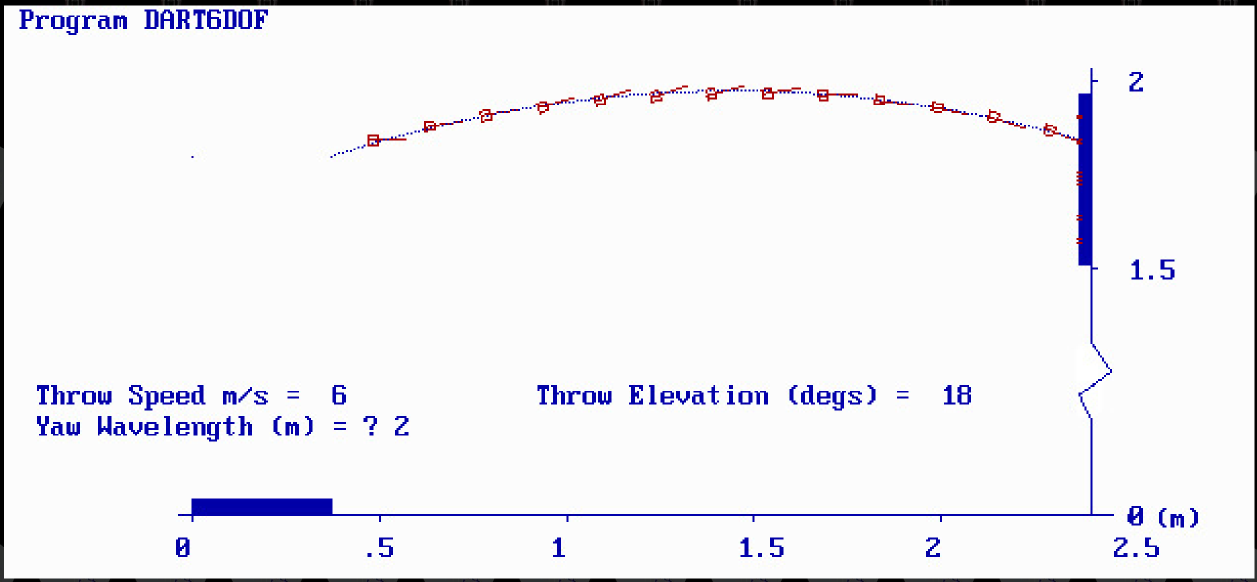
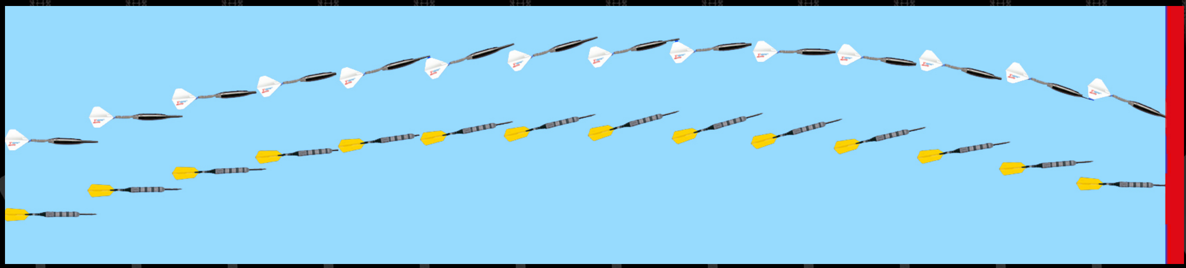
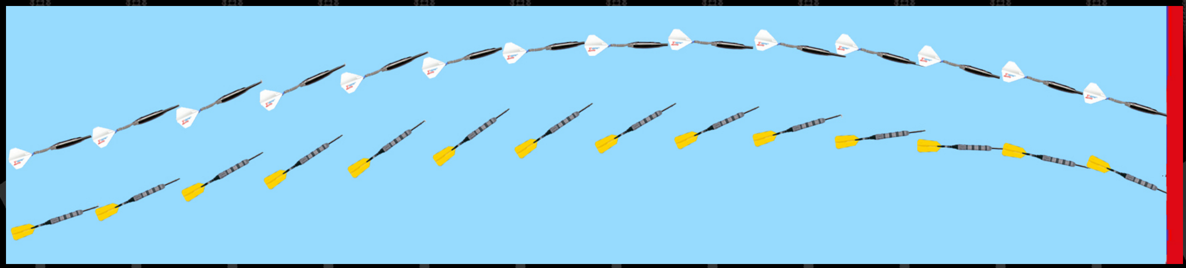
Below is a graphic of the output from a 6DOF program (remember?) for a very high-stability steel-tip dart (yaw wavelength 2m) thrown at 6m/s upwards 18degs (to hit T20 from a reasonable release height) but pointing horizontally with no angular rate, a not uncommon mode of release. The dart thus has 18 degs of downward initial yaw. With a normal stance the throwing distance to the board from a 2.37m oche is around 2m, so the dart has time to yaw up and then down again in flight, hitting the board with a "damped" 6 degs of downward yaw and around 21 degs below horizontal. (Quick reminder here; "yaw", more fully "complex yaw", for near-axisymmetric projectiles like darts refers to the incidence angle in both horizontal and vertical planes).



Reckon that graphic is a bit, erm, 1980s? You're right! It's from the very program that was used during the development of the prototype accuracy-optimised dart shown at the start of this blog. Let's update the imagery but not the maths by showing a repeat of the above trajectory compared with another below for a less stable dart (yaw wavelength 3.5m) thrown in exactly the same way.



Some players, however, release their darts pointing upward along the line of the trajectory but with a small upward angular rate. Here's what that might look like for the same two darts:



Those graphics illustrate a couple of interesting points. Firstly, although most steel-tip players will probably find a less stable dart will land flatter in the board, as shown in the first graphic, the second reveals this is by no means a hard-and-fast rule. Secondly, the consequences of using a long yaw wavelength dart in terms of how much it can “wobble about” is clear, especially if, as in the second graphic, you’re the type of player who throws so their darts have an initial yawing rate.

When that “wobbling about” is large enough to cause the dart to stall, the increased drag will cause it to hit the board low by a few millimetres and the chaotic nature of stalling means the exact amount it does so is less predictable, as, more importantly still, is the angle at which it lands. For these reasons, players who impart significant initial yawing rates, which includes some pros as well as most novices, are likely to be most accurate with short yaw wavelength darts.

The comparatively low MI (Moment of Inertia) of some torpedo-shaped barrels helps them, especially when fitted with light shafts and anti-stall flights, to have a short yaw wavelength and thus minimise inaccuracy due to high initial yawing rates. I call this type of barrel stability-optimised and left is a classic example and one that partly inspired the design of the more recent Sigma One on the right.

Even more important to accuracy than aerodynamics, though, is that a dart suits the player’s grip, which in many cases means a fairly long (50mm or so) roughly pencil-shaped barrel is preferred. As shown in blog 7, the length of such a barrel (see example below) generally results in the dart having high MI, even when fitted with a light shaft. This means it needs lots of lift from big flights to keep the yaw wavelength down to reasonable levels. So a Catch-22 situation can arise – for players who use high MI darts big flights are need to keep yaw down and reduce inaccuracy due to drag and point offset, but at a given yaw angle big flights will have more drag anyway.

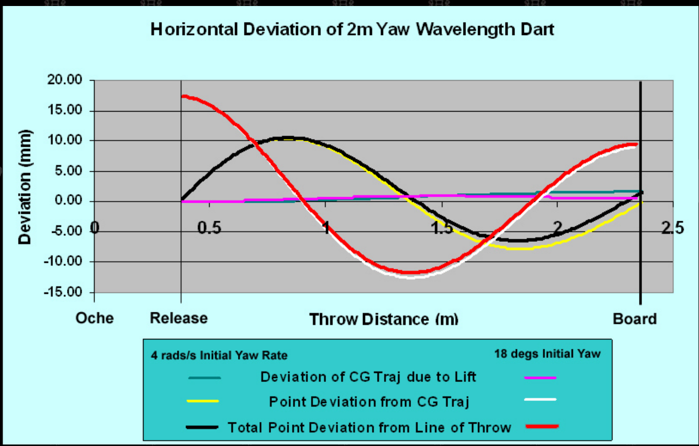
Unicorn John Lowe
90% Tungsten (c.1985)

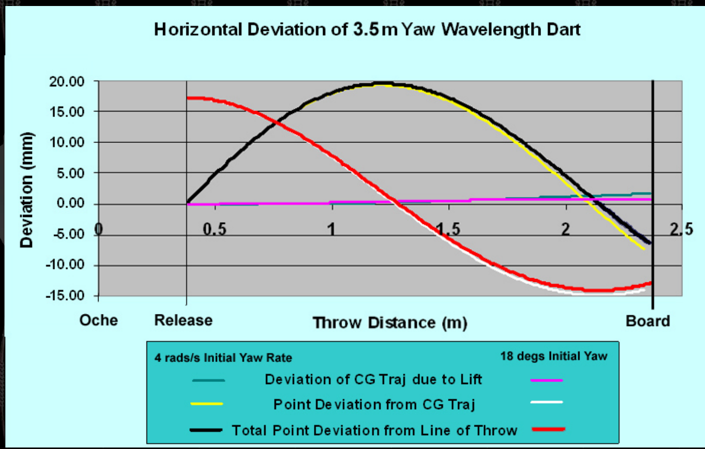
Unicorn Sigma 970 One
97% Tungsten (c.2008)

Gary Anderson 2019 Edition Barrel with Gripper 3 Two-Tone Shaft and Big Wing Flights

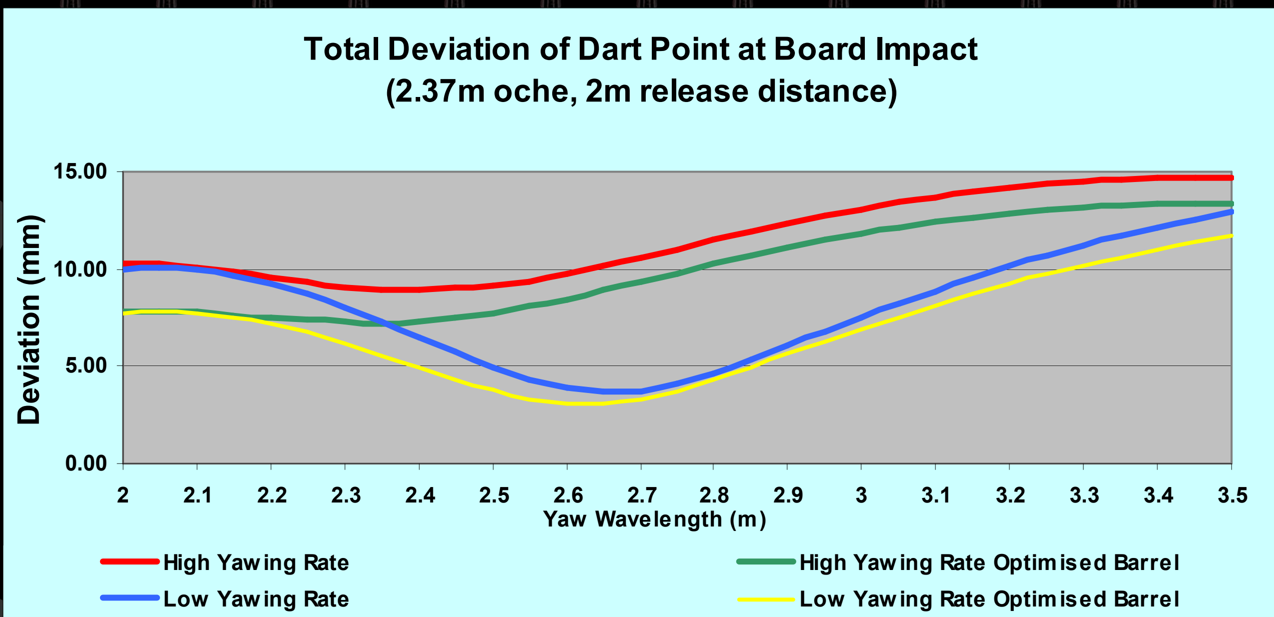
So far we have been focussing on accuracy in the vertical plane, but horizontal accuracy is important too, even when aiming at letter-box shaped treble 20. In the horizontal plane there may be errors in the line of the throw, but drag and even variations in throw speed are not much of an issue. Thus aerodynamic accuracy is down to two effects, deviation due to aerodynamic lift caused by in-flight yaw and the offset of the point from the trajectory of the dart's CG at board impact.

Below are two graphs showing the horizontal deviation due to these parameters, separately and combined, for the same initial conditions and dart yaw wavelengths as in the earlier graphics.





The deviation trends shown in these graphs also apply to the vertical plane, although with the added complication of the effect of drag. They can thus be combined with that drag effect to provide a single figure for the total deviation in both planes of the dart's point from the trajectory of its centre of gravity at board impact. The below graph does this using the release conditions already specified plus a lower level of initial yawing rate (1 rad/sec), for both representative conventional and stability-optimised barrels and yaw wavelengths between 2m and 3.5m.



With that graph we at last approach the denouement of this epistle. The graph illustrates why players who have a pronounced "flick" to their throw (as do many of we less skilled exponents of the sport!) are likely to be more accurate with low yaw wavelength high-stability darts. Meanwhile players with a smoother release, like a certain Mr G Anderson, may do better with a dart of a wavelength in the 2.7m region. Guess what dart we saw just now fits that criterion?

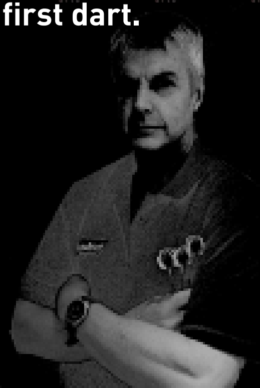
All this relates to throwing from a normal stance and a 2.37m oche, giving a trajectory length around 2m. A dart with around a 2.7m yaw wavelength then has time to go through about three-quarters of a yaw cycle, which, as I explained in my March 2008 blog "The Adventure of the Three-Quarter" (qv Sherlock Holmes!), means the lift effect will be in the opposite direction to the offset of the point at board impact, reducing the total deviation, especially for lower yawing initial rates.

As yaw wavelength is pretty much unaffected by throw speed, so is the c.2.7m optimum, although throw speed does affect trajectory length, as does release position. However it's a fairly "flat" optimum, so only a very non-standard release position or oche length would change it much.

The deviation graph also shows the potential advantage in pure aerodynamic accuracy terms of the type of stability-optimised barrel already discussed. Such a barrel, combined with a light shaft and flights with sufficient lift to provide a yaw wavelength in the 2 to 2.4m region, provides a "stability-optimised dart" such as the Sigma 970 One. The same barrel combined with a set-up that yields a yaw wavelength around 2.7m provides what I call an "accuracy-optimised" dart such as the Sigma 970 Pro, which has been sneakily hiding in the background to this blog.

All that said, though, if three darts that are exactly the same are thrown in exactly the same way under exactly the same conditions the point will obviously land in exactly the same place, irrespective of aerodynamics (and Werner Heisenberg). This is why "muscle-memory" throwers (step forward Michael Smith et al) would get lots of 180s with pretty much any adequately stable dart providing it had a barrel that suited their grip. Most players, though, will have more throw-to-throw variation than such players. Moreover, even muscle-memory specialists will often need to hit a target, especially a target not as well-practiced as treble 20, with their first dart.

As I said, darts is first and foremost a game of skill, but that's no reason not to get that little extra bit of help from your equipment! On that note, I reckon it's more than time to say.....



That's all Folks!