# LaidBack Cyclist

ISSUE 135 | SPRING 2019


THE MAGAZINE OF THE BRITISH HUMAN POWER CLUB | WWW.BHPC.ORG.UK

- PIET'S NO TORQUE FWD
- SOUP DRAGON EPISODE 2
- HAND & FOOT BIKE REVIEW

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## 2019 RACE CALENDAR

**Races usually start at 11 am with sign on starting around 10 am**
**Please see BHPC website and forum for more details**

| | | |
|---|---|---|
| Curborough – 3rd March | Bath – 13th April | Hillingdon – 5th May |
| Preston – 1st June | Knowsley – 2nd June | York – 23rd June |
| Redbridge – 14th July | Leicester – 10th August | Darley Moor – 11th Aug |
| Gravesend – 21st Sept | Gravesend – 22nd Sept | Hillingdon – 20th Oct |

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# EDITORIAL

This is the last magazine you will receive as a 2018/19 BHPC member, so please remember to renew your membership soon. If you do not wish to renew then our Membership Secretary, Brian, would be very interested to hear your reasons. We are always looking to improve what we do so any feedback is invaluable to us.

I'm afraid the write-up of the build process for my *Vulcan* trike didn't make it into this issue. Sorry. Hopefully it will be in the next one...

In this issue, we've got lots of lovely techie stuff and a reprint of an article from Issue 100 about how the BHPC came into existence, by Mike Burrows and the late, legendary Richard Ballantine. I hope newer members will be further motivated by knowing they are part of a long historical tradition!

If you are a longstanding member, then why not think about writing a piece about the history of the club and preserve your endeavours for posterity? I'd love to publish it!


# LaidBack Cyclist

ISSUE 135 | SPRING 2019
#4 of Membership Year

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Geoff Bird

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Articles, photos, letters, etc. are always very welcome.




www.bhpc.org.uk

BHPC
THE BRITISH HUMAN POWER CLUB MAGAZINE

## WHO WE ARE

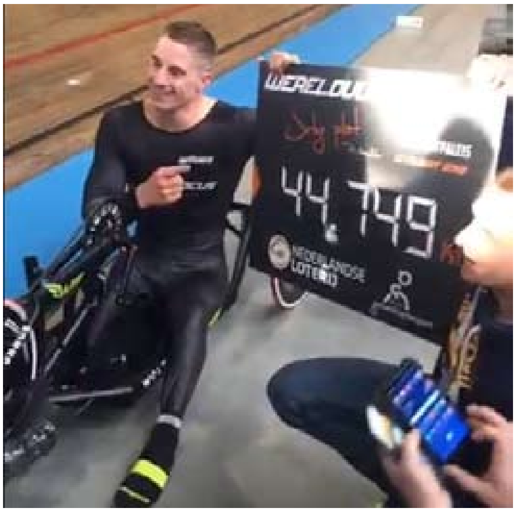
The BHPC was formed by a group of people who wanted to race their fast but funny looking bikes and trikes more than once a year.

This is mostly what we do today, but we also have a social side. And individual members will organise touring rides and other non-competitive events, many on a local basis. And as little is set in stone, new ideas are always welcome.

## FRONT COVER

Piet Kunis and his No Torque FWD *Pikuponcho*

## HANDBIKE HOUR RECORD FALLS




Jetze Plat has recently broken the Handbike World Hour Record. Jetze cycled 44.749 km's in one hour at the Sportpaleis Alkmaar (250m, indoor) on 13th March. He broke Geert Schipper's record of 42.165 km, set last year. Congratulations Jetze Plat for this amazing achievement (subject to verification by the relevant body).

### SUBMISSIONS FOR ISSUE 136

The deadline for submissions for Issue 136 of LaidBack Cyclist is **17th May 2019.**

HPV related articles and pictures, BHPC race reports etc. are very welcome. Many thanks (Ed.).

## I.C.E. ERGO – LUXURY SEAT

BY **JEFF JAMES**

The new Ice Ergo – Luxury Seat from Ice Trikes is described as the most comfortable trike seat on the market, providing unprecedented levels of comfort and back support, and is fitted as standed on all Adventure and Adventure HD trikes.

It uses Maxi Mise Airflow fabric and extra cushioning in the base and sides and it can be ajusted at the rear to suit different rider needs, also fitted as standard are side pod mounts, so no need for over the seat side pod straps, the seat is also fitted with a top weather sealed pocket for small items like keys etc, and the refective detailing on the sides will help keep the rider safer at night.

And new for 2019, there is the Ergo – Luxury Short Back Seat which has a 50mm shorter back which enhances the positioning of the neck rest making it more suitable for shorter riders, ideal for riders under 162cm tall, and at present is a fitting option on the Adventure trike, as for more details contact Ice Trikes via the website.

# EVENTS CALENDAR 2019

This is the updated events calendar although not too much to add. Please get in touch if you are taking part in an event so that other BHPC members can join you if they want. Our leader has mounted a campaign to get recumbents allowed in the Hemel Hillbuster, see below. I have added a couple of Sportives I am doing, probably on a Moulton, just to show the triangle brigade what a 100 years of cycle development looks like. The Wadworth sportive starts and finishes at a brewery, great way to rehydrate afterwards!

The Folding Society runs monthly social rides for non UCI friendly bikes and we have had folding recumbent trikes and bikes in the past, and several BHPC riders already attend some rides. The website is http://www.foldsoc.co.uk/origami/index.html for a full list, I recommend the Didcot ride in August as I organise it!

## BHPC FRIENDLY EVENTS CALENDAR FOR 2019

**Spezi** https://www.specialbikesshow.com/ 27/28 April

**Ridgeway Rouler Sportive** https://www.ukcyclingevents.co.uk/events/ridgeway-rouleur-sportive/ 27 April

**Hemel Hillbuster** https://www.dens.org.uk/events/hemel_hillbuster_e45.html 28 April

**Bespoked Handmade Bicycle Show**, Bristol http://www.bespoked.cc/ 3/4/5 May

**York Rally** http://yorkrally.org/ 22/23 June

**A Race in the Park** 29 & 30 June at Racepark Meppen, Germany.

**Wadworth Brewery Sportive** https://www.letsdothis.com/e/wadworth-brewery-sportive-39943?utm_source=google&utm_medium=cpc&utm_campaign=Event_-_Wadworth_Brewery_Sportive&gclid=EAIaIQobChMI2LDpkLq54AIVhbHtCh2tRQcxEAAYASAAEgLcUfD_BwE 30 June

**World Championships** 19th to 21st July https://www.afvelocouche.fr/world-championships-2019/

**Mildenhall Cycle Event** http://www.mildenhallfestival.bike/ 24/25/26 August

**Battle Mountain** 8th to 14th September

**Isle of Man Cycle Challenge** http://www.isleofmancc.com/ 21/22 September

**Audaxes** http://www.aukweb.net/events/ many events throughout the year

### British Pedal Car races

Wombwell Sprints 31 Mar
Bruntingthorpe 6 Hour 27 Apr
Shennington 24 Hour Race 29/30 June
Blackbushe Sprints 7 Sept
Blackbushe 100 Mile 8 Sept
Curborough 7 Hour 5 Oct

There will also be the **New Milton Pedal Car Grand Prix** on the 14th July

Researched and prepared by Stuart Glen

I t was watching the Sam Whittingham YouTube Battle Mountain video that first got me into recumbent racing in 2011, and I've been eagerly following the various Battle Mountain reports from Dave Larrington, Jun Nogami et al each year since. A competitive run down the course is something I've always wanted to do, although I always thought that the expense and time required to build a bike and get out there would be prohibitively restrictive.

### *TEST RIDE AT ROCKINGHAM (17 DAYS TO BM)*

I was hence very excited when, upon getting back from hols on a Friday night in August and thinking "I'll just check the BHPC forum for updates", there was a very intriguing post: Is anybody interested in an all-expenses paid trip to Battle Mountain? All you need to be is roughly the same size as Mike, fast and willing to ride the Soup Dragon...

Four days later I'm at Rockingham to test the bike. Mike Burrows is using the track time on Rockingham's oval to make an attempt on the UK hour record, so Andrew Sidwell is also in attendance with timing equipment, along with various other BHPC regulars, and Neil Hood in his Ristretto streamliner. Unfortunately Mike's attempt is short-lived after a first lap crash with a traffic cone, and Neil also comes off fairly soon after starting – the tricky steering of the Ristretto not helped by 20mph+ gusty winds. I complete two runs with the top off the bike, the first is a one-lap run with a top speed of 37mph, then a two lap run with a short-lived max of 45mph. The runs feel very wobbly, but the innovative single speed and landing wheel elements of the bike work well. I also have a film camera (and boom mike) in my face for the entire time, as I learn that Blue Hippo Media are making a film about Mike building the bike and taking it to the Battle Mountain event. I've not dealt with a film crew before so I try not to say anything too daft...

→

BY **RUSSELL BRIDGE**

# Soup

All Photos by **Russell Bridge**

# Dragon

## EPISODE 2

### *TRAINING*

After a chat with my friend Neil Wilkinson (ironman triathlete), we decide on a 12 day training programme of recumbent turbo runs and swimming, with a bit of weight loss hopefully thrown in. The turbo runs consist of every-other-night strength training with 8min warm up to 150bpm, followed by 4 x 4 lots of 30-sec sprint bursts, followed by a run-simulation of 120bpm to 180bpm over 7 mins, and finally a 5-min cool down to 120bpm. 40min swimming every other night. I already eat healthily, but double portions, puddings and (non-fruit) snacks are removed. In 2.5 weeks I lose 5 kilos, and power at the end of the run-simulation goes up from 300 to 350W. Not ideal training, but better than nothing given the time available. I have a good chat with Jonathon Woolrich (BM regular) over the phone re Battle Mountain tips, itinerary etc which is incredibly useful. I also head to the doctors to get some sleeping tablets – I tend to sleep poorly when away from home so hopefully the tablets will help, although I've not tried using them before. The bike has apparently been shipped via DHL 29th Aug, aiming to get to the hotel in Las Vegas by Tues 4th Sept latest.

### *THE TEAM*

Going out to Battle Mountain are myself, LSBU Mechanical Engineering lecturer Barney Townsend, LSBU Mech. Eng. tutor and ex-recumbent racer Glen Thompson, LSBU workshop technician Joe Cheney, and film crew Mike Clifford (Director) and Dave Cawley (camera). It's a good team and everyone gets on well.

### *THURSDAY 6TH SEPT*

I get a late train down to London, and stay overnight with Barney in London.

### *FRI 7TH SEPTEMBER*

We get a taxi to Gatwick airport, then a flight to Las Vegas on a Virgin jumbo, hire cars, overnight in the black pyramid-shaped Luxor hotel, and have a quick wander round the Blackpool-on-steroids gaudy sh*t-hole that is Vegas. I do not like it one bit. We grab an evening meal in a place just off the strip, then off to bed with 9hr jet lag. I get a couple of hour's kip.

News | The Observer 09.09.18 | 7

# Next stop Nevada... cyclist in 'dolphin' aims for 90mph

## British team tests limits of pedal power in world speed record attempt

**Jamie Doward**

Most cyclists tootle around town at something like 10mph. Competitive amateurs might double that, while elite professionals can exceed 30mph on the flat in events such as the Tour de France.

So spare a thought for Russell Bridge, a 41-year-old amateur cyclist and father of twins who will this week lead a British challenge to break the world record for the fastest speed achieved on a "human-powered vehicle" (HPV), which stands at a white knuckle-inducing 89.6mph (144kph).

Adding to the challenge is the fact that Bridge has barely ridden the vehicle, a recumbent bicycle housed in a super-smooth shell made out of fibreglass and Kevlar that bears a passing resemblance to a dolphin.

"We did a test day at Rockingham Speedway two weeks ago, and I've had all of about six minutes in it," Bridge said. "We got up to 37mph on the first run and 47 on the second but that was without the top bonnet on."

He admitted to feeling nervous as the Aim 93 team (the number represents the maximum miles per hour the team believe the vehicle can theoretically achieve) prepare to fly out to the International Human Powered Vehicle Association competition at Battle Mountain in Nevada.

"I'm anxious about it," he said. "I've ridden at reasonably fast speeds on recumbents before but I've bought motorcycle clothing to protect myself so if the worst happens, and we slide down the road at 70 or 80mph, I've at least got some resistance between myself and the road."

Aim 93 is a joint collaboration between two of the giants of Britain's HPV scene, Glen Thompson and Mike Burrows, long-time rivals who put aside their differences in an attempt to bag a world record for Britain.

Thompson is a senior lecturer at London South Bank University who specialises in aerodynamics and as a racer won a silver and four bronze medals at the World HPV championships. Burrows, 75, designed the revolutionary Lotus 108 bicycle on which Chris Boardman won gold at the 1992 Olympics and has built Aim 93's chassis.

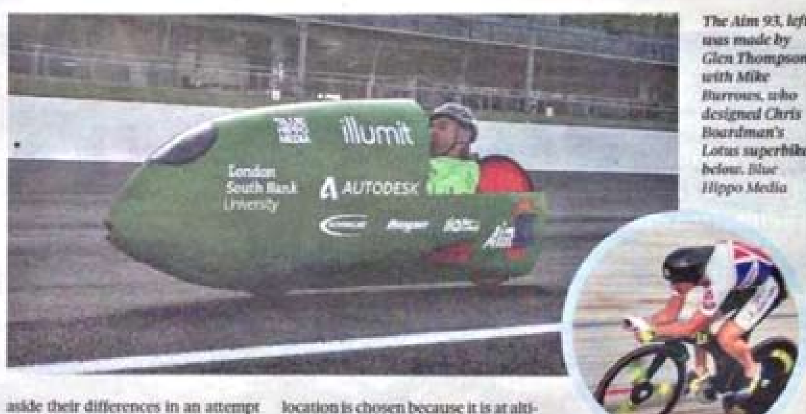
In this week's competition, riders from some 20 teams will make their record-breaking attempt on a 200-mile stretch of highway after cycling more than five miles along it to get their vehicles up to top speed. The location is chosen because it is at altitude and the air is thin.

The HPV championships, which date back almost half a century, have changed down the years, say Thompson. "It used to be people building their own things in garages but it's all got a bit more technical, and you need the resources of a university to build it. You need a lot of computer power to do the computational fluid dynamics to get the aerodynamics right."

Despite it's futuristic look, much of what was under the shell of Aim 93 was relatively simple, said Thompson. "We've gone right back to the roots of cycling to develop this thing. It's a single speed and it has a very fine chain, much thinner than a normal bicycle chain.

"We've had special tyres made and we've tried to make it as minimal as possible, whereas the other teams tend to be highly complex in terms of transmission."

Thompson said he was not expecting to break the world record. "We are going out there to gather data, do the research, and sort out what we need to do. You can't go out to Battle Mountain and do it in your first year."




*The Aim 93, left, was made by Glen Thompson with Mike Burrows, who designed Chris Boardman's Lotus superbike, below. Blue Hippo Media*

## *SAT 8TH SEPTEMBER*

Bad news – the package isn't at the hotel as promised, and after hours on the phone Barney has found out that the bike is actually still in Cincinatti customs, and they're closed for the weekend. After much discussion, we hire two cars and drive the 8hrs to Battle Mountain. Or rather we do after 4hrs faffing with film crew taking shots of Vegas, getting snacks etc. There's a rodeo in town at Battle Mountain this weekend, so our motel is full of very happy and wobbly Mexicans. After a bit of ringing around we manage to find four rooms together in the Big Chief motel instead, which turns out to be very nice, huge beds, and room in the parking area to work on the bike (should it arrive). The air is drier and hotter than I've ever experienced – 42°C in Vegas, 29°C in Battle Mountain, our noses permanently full of dry snot, eyes are stuck together in the mornings, our mouths are permanently dry. We're taking on at least 5 additional litres of water each per day.

## *SUN 9TH SEPTEMBER*

Barney is still getting no-where with DHL. I'm getting Bernadette and friends back home on social media to try anything possible – contacts high up at DHL etc. We assemble our training bike – an Optima Baron which had kindly been lent by D-Tek. It's been taken apart incorrectly to put in its flight bag, so the hydraulic brake hoses have air in the lines, and we have no bleed kit. I need to hacksaw the stem shorter, the seat is offset, we've got the incorrect cleats, but it comes together and I've got a bike to ride on at least. We take a trip to Poo Road (the road to the sewage farm) where we met the French and Liverpool teams testing. On Sunday evening all of the teams meet at the Civic Centre for the week's briefing – unfortunately we had to report our problems which isn't the best start to the week. The organisers explain how the qualifying runs work, and how this translates to get the best slots for the evening and morning runs. The wind tends to die down just before dusk, so the last slot each night is normally taken by the fastest qualifying run. After the meeting we head out to find food and end up in the Mexican restaurant together with all of the riders who've been at the Rodeo all weekend. It's all pretty lively and the food is OK.

## *MONDAY 10TH SEPTEMBER*

As we don't have a bike, we volunteer for 'chase official' duty, which gives us a great insight into the launch, chase and catch procedures. This is followed by the daily morning meeting, where the best slots in the evening runs get taken by the fastest qualifiers. Barney spends 6-hrs on hold/phone to DHL who have promised that the bike will now be re-directed to Reno, a 3-hr drive away from Battle Mountain and the nearest big town with an airport. We film a training ride in the afternoon on a quiet road (806 running North) with the film crew filming from a moving car - all very new and exciting. In the evening, we head back out to the course to watch and help at catch, then there's another meeting at the Civic Centre to report on the evening runs. Food this evening is at the Colt Casino, it's not good at all. I get a little more sleep - 3.5hrs with two sleeping pills.

## *TUESDAY 11TH SEPTEMBER*

We get word that the bike is now in transit and is now confusingly on its way to Los Angeles, which is neither Las Vegas nor Reno. The team are back out on chase duty, I head out on a training ride on the Baron. The air is very thin and I'm very aware when pushing hard of the difference. Back at the motel I make friends with Greg and Renee Cantori who've driven 4-days from Baltimore to race Greg's immaculately sorted Milan SL all-carbon fibre velomobile, with borrowed race hood.

*Late night repairs to Soup Dragon*

He very kindly offers me a run in it on the course, so at the morning meeting I bag a spot in the 2.5 mile evening run. I have 2 laps of the motel car park to make sure I can steer it, see OK etc. Thankfully I'm almost exactly the same size as Greg.

In the evening, Greg drives us out to the course, which is approx. 15miles out of Battle Mountain on a deserted stretch of road mostly used by mining trucks. I run the course in the Milan, and everything goes OK - ie I don't crash it! I clock 55.6mph through the traps, but with an illegally high side wind – I'm really chuffed with this as a first run, although I went a bit too hard too early and was spent 500m before the traps. It's very hard to judge distance on the course. In the afternoon we get a notification that the bike has now left LA on a flight to Reno, so Barney and Joe set off to overnight in Reno and collect the bike in the morning.

> *We get back to receive news from Barney that the bike has been collected but it's not pretty – it's badly damaged*

### *WED 12TH SEPTEMBER*

I do another 2.5mile run in Greg's Milan in the morning, this time a wind legal 55.3mph which earns me a shiny new 55mph hat. Again I didn't get the timing quite right – I guessed that a huge push at the ½ mile board would get me to the traps but I fell short and was spent early again. We get back to receive news from Barney that the bike has been collected but it's not pretty – it's badly damaged. Whilst the packaging could have been a lot better, it looks like it's been dropped on its nose and had something squash it from the side. Barney and Joe set off back with a 4pm eta. On getting it back we ascertain that most of the damage looks like it's to the thin fibreglass shell, and is just about repairable. Whilst the team is more than capable, I ask for help at the evening meeting and George Leone kindly offers assistance. After a little fettling, Joe and I take the rolling frame out to Poo Road and practice 15m push starts. I can just get the huge single speed going by myself, but with a push start from Joe it works very well, and the retractable wheel works well even if the operating lever is catching on my shorts and snagging another cable. I also test the steering to gauge the point where it catches – I fall at about 15mph but at least I've learned where the steering limit is (surprisingly far) - there's a shallow bend half way down Poo Road and I can easily make it around that. The chain jumps off a few times when giving it the beans, which appears to be due to the composite 150T chainring flexing – less 'torquey' starts seem to be OK though. At the evening meeting we bag the last available qualifying slot of the week – 9am tomorrow morning on the 2.5mile course. We grab food on the go – a takeaway pizza isn't the best meal prior to the most important ride of my life! I head to bed at 12ish, the team (and George) work 'till 3am getting the shell repaired. I'm awake at 3:30am after another poor night's sleep.

### THURSDAY 13TH SEPTEMBER

We're all up at 4:30am to catch breakfast at 5am, then first light at 5:30am and out to Poo Road for some practice runs in the complete shell. This is my first ever run in a fully enclosed machine. Amazingly it works – I do two practice runs with a push start, up off the wheel, up to 25mph-ish, then back onto the wheel and stop. All works OK, with me switching navigation techniques between the camera and the tiny front window. We're out at the course at 7:15am to make sure we're there before the road closures, and then get shouted at for being in the wrong place when the 5 mile runs are about to get underway.

At 9am our run is on. We have to be focused to get me in the bike, supplied with water to help with the dry mouth, taped up (50mm duct tape to cover the ill-fitting shell gaps), and ready to go. Joe pushes me off and after a nervous pause, a big cheer goes up as I go up onto two wheels and then the wheel goes up. Joe completely forgets that he's supposed to be driving the support vehicle and stands there gawping as I disappear down the road… In the bike I'm battling to work out the controls and vision all at once. The single speed is working well however and I'm up to 45mph at mile 1. I'm switching between trying to navigate using the tiny front window, which can only see a roughly 3m wide bit of flat grey tarmac about 10-15m in front of the bike, and using the camera. I do most of the course using the camera, which is OK but a bit low-res and has a definite time lag. However there's bigger issues – above 45mph the bike seems to have gained a life of its own and is making BIG involuntary movements across the road. I manage to make small speed gains, but virtually all of my effort is in keeping the bike upright. At least twice I'm bracing thinking I'm going down. On top of that the unprotected front wheel has taken on a decidedly 'grinding-wheel' like quality at speed and is eating at the inside leg of my shorts. I end up coasting through the traps at 53mph. Not to be sniffed at, but disappointing given the speed at 1mile. My mouth is unbelievably dry and I'm out of air, the decision not to install any kind of breathing tube /air intake was maybe not the best. We spend the rest of the day analysing what happened. On closer examination of the bike we find a number of issues that collectively add up to make it un-rideable and unsafe, some of which are attributable to design/build and some to transport damage: 1) the rear wheel inner bearing is loose and is causing approx. 8mm play at the top of the wheel 2) the 'loose' end of the front wheel spindle travels freely fore-aft in a slot. The slot is marginally too deep (maybe half a mm), meaning that the front wheel has approx. 8mm of play at the top of the wheel 3) whilst the rose-jointed steerer rod to the front wheel feels free of play, the thin handlebars are mounted at the top of a thin cantilevered tube, and there's a lot of flex in the bars before the desired steering effect takes place at the wheel. The three points above seem to be exacerbated at high speeds and by the side wind on the course – the lateral load from the side wind appears to be making both front and rear wheel 'float' at their respective failure points. The very flexible 'bars are then struggling to control the involuntary wheel movements. Whilst we can solve the rear wheel bearing issue, the front end issues can't be resolved in Nevada. After much contemplation, we decide that it's simply not safe to run the bike again – we'd maybe get another few mph but would likely just find out how badly it crashed. Given that Mike went through the shell and his elbow at 30mph, I wasn't keen on finding out what happened at 60+mph despite my motorbike jacket. We're all a bit low.

*Damage incurred by DHL*

### FRIDAY 14TH SEPTEMBER

We spend most of the day sat around discussing the way forwards. Everyone seems up for giving it a proper crack again next year, although Glen is retiring in a few weeks and Barney needs to battle with the university funding process & sponsorship to wangle the £20K+ required for the build and


flights/accommodation for next year. There's lots to discuss, only a small fraction of which relates to the bike design and construction. The main headings for discussion seem to be:

- Funding
- Student organisation – how to split the project up / marking goals etc
- Bike design (inc third wheel, single speed, shell construction, hatch location etc etc)
- Viewing (porthole or 2 x screens or goggles etc)
- Rider selection (inc size and effect on CdA)
- Early project completion to allow suitable testing
- Testing location in the UK (ideally 2-mile runway to allow speed testing at over 60mph)
- Bike / container transport. (Most teams seemed to be using Fed Ex, but to the airport in America only)
- Team transport (to America and then type of transport once there)
- Accommodation in Battle Mountain
- Rider training and acclimatisation (altitude and jet-lag)
- Team catering (we were wasting a lot of time finding food where-as the Delft University team had one person cooking a big pot of food each day)
- Team mechanics, repairs, spare parts etc
- Warm up on the course (we had no means to do this)
- Course strategy (when to push and how hard)

I head out to the (bike) drag races on Friday afternoon and compete on both the Optima and a surprisingly rapid Greenspeed trike. I get the 2nd fastest time of the day behind an upright bike.

## SATURDAY 15TH SEPTEMBER

We head out to see the final runs on the course in the morning, then there's a photo-shoot which we manage to miss by turning up at the organised time instead of the lets-just-do-it-now time. Very kindly the Mexican team host a barbeque in the afternoon which is good fun with great steaks, fajitas, stuffed peppers, spicy salsa etc (I like my food!). There's a wrap-up meeting in the evening, then a few drinks at the local bar.

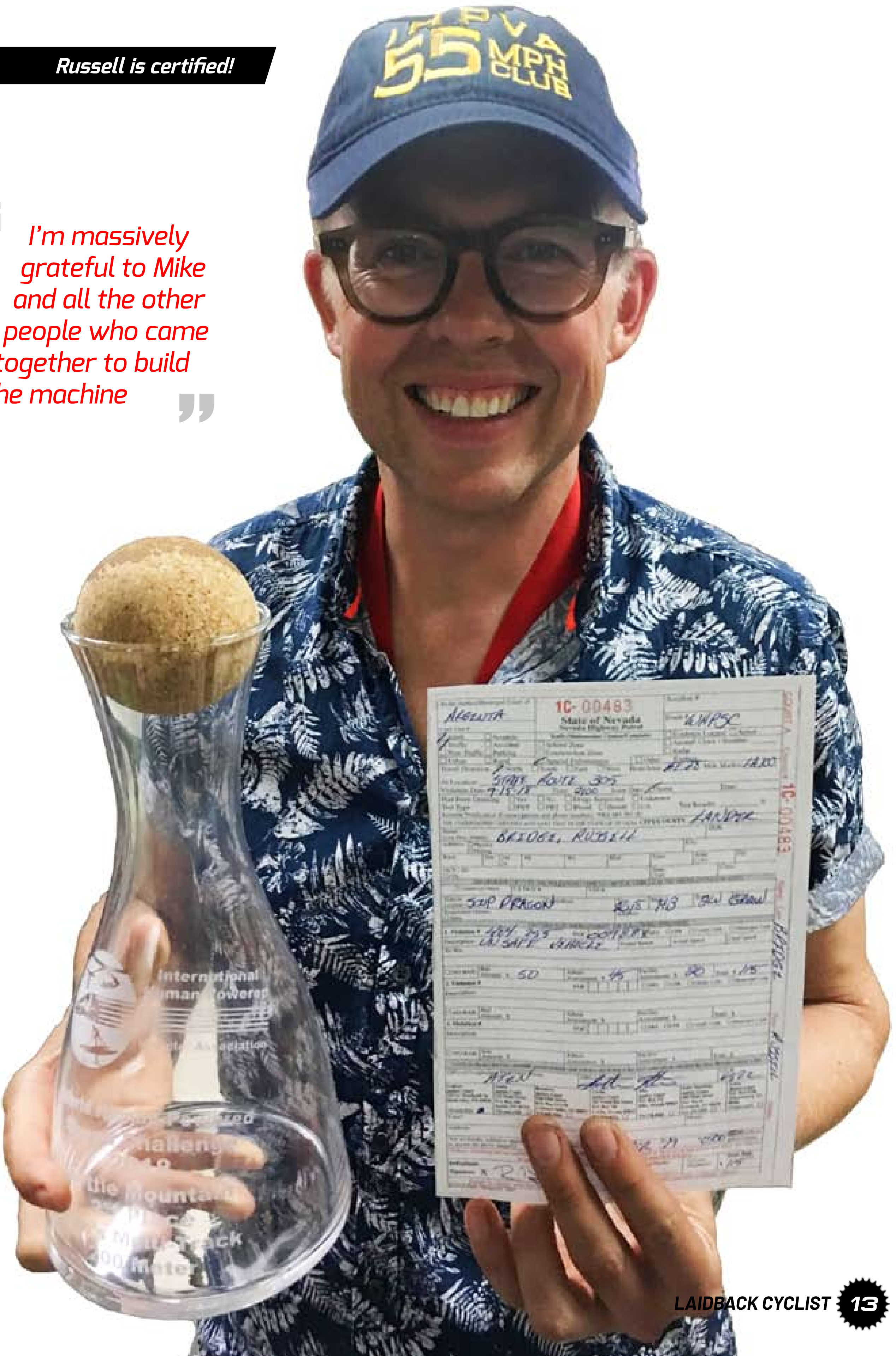
## SUNDAY / MONDAY / TUES

We head back to Vegas via one last stop at the course. We run up and down in the cars getting clear video footage and GPS data, then back to Vegas via Death Valley which is quite special, even in the dark at 9pm (and 104 degrees). To the airport on Monday, then back to London on an overnight flight, and then a train back up to Manchester.

I'm hugely grateful for the opportunity to have a proper run down the Battle Mountain course in a machine with lots of time and effort invested in it, and I'm massively grateful to Mike and all the other people who came together to build the machine. Getting the bike finished and packed ended up being a bit 'last-minute', and we were all aware before we went that there were major issues with the bike (especially rider safety), and I'm sure that there are people who thought we shouldn't have gone. However, without living and breathing the event for a week, there's no way on earth we would have gained the knowledge required to give it a (hopefully) much better go next year.

**RB**

**Russell is certified!**




> *I'm massively grateful to Mike and all the other people who came together to build the machine*

BY **RICHARD BALLANTINE**
AND **MIKE BURROWS**

**THIS ARTICLE WAS FIRST PUBLISHED IN ISSUE 100 OF THE BHPC MAGAZINE IN 2010. EDITED BY TONY HADLAND.**

# IN THE BEGINNING

## THE STORY OF HOW THE BHPC BEGAN

### GENESIS

A cycle requiring but half the effort of a regular bike — that would be a useful thing, wouldn't it? Well, therein hangs a tale.

Air has substance: 14.7 pounds per square inch, hence the importance of aerodynamics for cyclists. The energy used to propel a standard bicycle at 12mph divides equally between overcoming mechanical resistance (friction of bearings, tyres, transmission, etc) and aerodynamic resistance (displacement of air and aerodynamic drag). Double the speed to 24mph and, while mechanical resistance doubles, aerodynamic resistance increases fourfold, and the power required to overcome it rises by a factor of eight. The cyclist is now displacing well over 1,000 pounds of air per minute, a task that consumes 80% or more of a much increased effort.

One way to improve aerodynamic efficiency is to reduce frontal area. A recumbent design, with the rider in a reclining position (as in an easy chair) or supine (as in bed) improves aerodynamic efficiency by 5-20%, depending on the particular configuration.

More effective is streamlining. A part-fairing or body shell can improve aerodynamic efficiency by 25%. If the machine is a sleek, fully-faired record speed streamliner, the improvement in aerodynamic efficiency can be 80% or more. This is why fast HPVs (human powered vehicles) can do over 80mph, twice the top speed of regular bikes.

Of course, aerodynamic efficiency is more important at higher speeds. At 8-12mph an HPV has no energy advantage over a regular bike. Increase velocity, though, and there is a significant difference in rider effort. Moving a conventional bike at 20mph takes a continuous output of 200-odd Watts (about 0.26 horsepower). In comparison, for the same speed, a bare (no fairing) recumbent needs 150 watts (0.20 horsepower), or 25% less - and a full faired HPV only 100 watts (about 0.13 horsepower), or half the effort.

Did someone ask if energy-efficient cycles could be useful? Well, recumbent cycles aren't new. The upright bicycle predates the Rover Safety of 1885. But in 1896, a man named Charles Challand exhibited a recumbent bicycle at the Paris Show. And in the 1920s, some 2,000 of a recumbent model, the J-wheel, were produced in Germany.

Streamlining, too, was an early area for experimentation. In the first decades of the 20th century, starting with Etienne Bunau-Varilla, upright bicycles fitted with egg-shaped fairings set numerous speed records. But the performances which changed history came in the 1930s, when a French rider, Francis Faure, riding a recumbent bicycle called a Vélocar built by Charles Mochet, shattered speed records for the mile and kilometre. In response, the governing body of international cycle sport, the Union Cycliste Internationale (UCI),


*Left:* ***Bluebell Mk1*** **|** *Right:* ***Brighton, 1980***


ruled that to qualify for competition, a bicycle must be made from tubes, and be configured in broadly the same manner as the 1885 Rover Safety. The UCI also banned aerodynamic devices of any kind. Recumbents were outlawed and Faure was stripped of his records.

The UCI ban was enacted because cycling had become economically significant. In the 1920s, mass manufacture had made bikes available at the cost of a week's wages (instead of several months), and by the 1930s bikes were in widespread general use. Cycle sport was big business. Especially in France, home of the UCI, cycle manufacturing and cycle sport worked hand in glove, and no one wanted the financial applecart upset by technological innovations.

Despite the fact that cycle sport and the demands of the peloton have nothing to do with transport cycling, the UCI ban was effective. In subsequent years, a few builders produced recumbent designs, but not in quantity. Then came the global conflagration of World War II, which completely eclipsed cycle manufacturing and sport.

In the post-war 'Dark Age of the Cortina' everyone wanted cars; bikes were for kids and the needy. The renaissance in cycling did not begin until the 1960s in the US, and the 1970s in Europe. But when the revival came, it was a dilly. By then, the world had changed enormously … humans had landed on the moon. Technology had advanced. People looked at bikes and said: 'Nice, but how about better performance, load-carrying, and weather protection?' All over the world, designers, engineers, and tinkerers began experimenting.

In 1962 in Britain, Alex Moulton launched a small-wheel bicycle with integral suspension. The new design improved speed, load-carrying ability, and comfort. The small wheels made drafting more effective, because riders could bunch together more closely. As well, small wheels made it easier to fit aerodynamic fairings. Of course, the UCI swiftly nipped this innovation in the bud; small wheel bikes were banned in 1965. A Moulton still holds the world 200 metres speed record of 51.29mph (82.54kph) for an upright, faired bicycle.

In 1967-9 in Britain, David Gordon Wilson launched the first modern design contest for HPVs through the magazine Engineering. The brief was to improve the safety, comfort, and usefulness of the bicycle, and reduce aerodynamic drag. Most of the entries were utilitarian, but the contest led directly to the development of modern recumbent cycles, and in particular, to one of the first commercially produced long wheelbase (LWB) recumbents in the USA, the Avatar 2000.

In 1974 in California, USA, Chester Kyle built a bicycle with a fairing. Tests showed a 67% reduction in aerodynamic drag. With rider Ron Skarin, Kyle's Teledyne Titan did 40.63mph over a mile and 43.02mph over 200m. Next year, Kyle and Jack Lambie, an aerodynamics consultant, organised the first open race for modern HPVs, at Irwindale, California, USA. Kyle's streamliner did 44.69mph. Many of the entries were ill-designed or ill-prepared, and slid through the speed traps upside down or in bits and pieces. There was everything to be learned … and a whole new world to be explored! The quest for speed was on. The following year, in 1976, the US-based International Human Powered Vehicle Association (IHPVA) was formed.

Modern HPVs in Europe mark from the first Aspro Clear Speed Trial in Brighton, England, in 1980. In accord with IHPVA rules, entries were driven by human power only, with no use of energy storage devices of any kind. Otherwise, there were no limits. The whole idea was to stimulate innovation and invention in design and engineering for the

development of new cycle designs faster – lots faster – than standard bicycles.

Some of the early Aspro entries were wishful in design or execution or both, and perished at the starting gate, but others performed ably. As well, inspiration was provided by the presence of polished, technically advanced entries from the USA, such as the winning Vector. Evolution was swift; in 1982, the British HPV Bluebell was victorious in the 200m sprint at the IHPVA Championships in the USA, posting a (then) sizzling speed of 51.919mph to beat the Vector and set a world record speed for a bicycle.


Meanwhile, HPVs were being developed for use on open roads. Some were in the long wheelbase (LWB) pattern of the Velocar, such as the Avatar 2000 (used as the chassis for the first Bluebell) and the Easy Racer, both produced in the USA. Other designs such as the innovative Speedy tricycle in Britain, and the Belgian Velerique full faired bicycle, were new and original. Still, at this stage most HPVs were home-built, sometimes from scratch, more often by hacksawing two or three small-wheel bikes and rejoining bits as a recumbent.

To test the road-going mettle of HPVs, the Isle of Wight Cycling Festival of 1983 included a downhill race with tight turns, traffic bollards, and other hazards. The course rewarded handling and control, not all-out speed. Some streamliners lost it and crashed, but street-design HPVs managed the course with ease. It was only early days and a few machines, but the event was imbued with a tangible atmosphere of elation and freedom. These creations could move! And with handling and braking to match, they could be used with confidence, as well as elan.

At an evening meeting at Isle of Wight Cycling Festival, a group of HPV competitors and enthusiasts decided to form a club, and later that year, at Eastway Cycle Track in London, on 29 May 1983, Europe's first and oldest HPV club, the British Human Power Club, was founded. Dutch, German, and clubs throughout Europe followed soon thereafter.

That was genesis. Over the next decades record-attempt HPV streamliners became increasingly specialised. Sites at high altitude (thinner air) and/or with a long run-up (gravity power assist) were found to provide a significant boost to speed, and straight-line world speed records are now largely, if not entirely, limited to a single event – the annual speed challenge at Battle Mountain, USA. There, a near-five mile run-up, with a 'legal' downslope, provides fast HPVs with 200 watts or more of extra power, and performances are impressive: the 200m sprint record is now 82+mph, way faster than any of the early HPV pioneers believed possible. But speed-record HPVs are now a comparatively rare species.

Street HPVs, however, have flourished. Whereas in 1980 most were home-built, today, most are commercially produced, by both large and small manufacturers, and scores of models are available. There's everything from gently laid-back upright recumbent bikes, to fast Audax-style day-ride bikes, to ground-scraping low racers, to agile trikes, to sleek enclosed all-weather velomobiles. World championship meets, and large events such as Cycle Vision in Holland, attract thousands of visitors, and races have several hundred competitors on the track.

In the early days, much of the excitement of HPVs came from being personally involved at the cutting edge. At UCI-events, one could but marvel at the accomplishments of Olympian riders. With HPVs, one's own ideas could be put to test — and while many failed to perform as hoped, plenty were successful! HPV enthusiasts include innovators of every stripe: renowned cycle designers and skilled engineers as well as backyard tinkerers. With a common quest, there was a real sense of involvement with every success. HPVs were not just about winning; they were about progress.

*Left:* ***Windcheetah Mk1 (1981)*** | *Above:* ***Miles Kingsbury's Trout ('82)***


*Above:* ***Bicycle Magazine - May 1982***
*Below:* ***Bluebell Mk1 - 1982***


Especially in Europe, there was from the outset a sense of being involved in a movement important to the environment and society. Initially, the sense of participating in history was somewhat vague. Much is involved in taking a new design into commercial production and sustainable use and sales. No one really knew exactly how the future would arrive. But those who were there sensed they were part of a good thing. An active movement and clear success at designing and using cycles able to go faster for less effort, and with better braking, comfort, weather protection, and load-carrying ability, was clearly a fine start.

As matters worked out, there was no overnight explosion of interest in HPVs; commercially-produced street HPVs evolved and developed over time through a mixture of sport competition, limited manufacturing, and events showing what these machine could do. That's a story after Genesis, and for more — read on!

**RB**

## *EARLY DAYS*

Fans of Douglas Adams will be aware of just how significant small events can be, and not just in SF novels. It happens in real life as well.

My own particular small event involved the fitting of a gudgeon pin retaining circlip in a piston (Mk 1 Cortina), badly fitting that is, because it came loose and found its way to the side of the piston where it slowly wore a shallow groove down the wall of the cylinder. No spectacular bangs or rattles but a gradual increase in blue smoke from rear of car, which was eventually taken off the road for an extended period of time, during which I was obliged to borrow the wife's bike and cycle to work. This turned out to be quite a nice thing to do, no more being stuck in traffic jams, plus that wonderful sense of freedom that cycling gives you.

So that was that, I became a cyclist, then a racing cyclist and had even built a couple of frames when I heard about the Aspro Clear Speed Challenge, which was to be held on the sea front at Brighton in September (1980). I actually heard about it not via the media but in a local bike shop that had been given a layout drawing of the Poppy Flyer, which was being built just up the road in Cromer (and would eventually be ridden by a young Simon Sanderson).

That was thirty years ago, which means that many of you reading this would not yet have made an appearance on the planet, and many more would have grown up with the idea of laid-back cycles at least being there in the background. It was not like that in 1980. I personally do not remember where I was when JFK was shot, but when I saw those drawings of a two and a half metre wheelbase, front wheel drive, fully enclosed tricycle, with only one inch of ground clearance nothing was ever the same. The most radical thing I had seen in cycling involved a small front wheel and a sloping top tube.

It really was as if a great light had been turned on. I could now see what really mattered, and it had nothing to do with head angles, wheelbases or fag paper clearances.

It was too late to enter that first event, so a small team of us went along to Brighton as spectators. But we were already committed to building a record breaker of our own, and we had the start of an idea already sketched out. We had been discussing the idea with friends and, in particular, the difficulty of reproducing Flyer's complex hub centre steering system. "Why do you need it?" asked local trikie Fergus Muir. If you are only going in a straight line then a derailleur chain should flex that much – obvious these days, but not then.

Brighton was great – nice weather, loads of people and the media everywhere. It really was news then, and bikes and more bikes, and trikes and more trikes. There were machines like the Vectors, that you could imagine James Bond using, and others that would have suited the Keystone Cops. Every shape and size you could imagine and very, very different to the time trial scene that I was used to.

Vectors were easily the most impressive, but we felt that the Poppy Flyer layout had the most



potential for straight line speed, especially with our simplified drive train. This got simplified even more, by having only one gear of around 140-inch, and arranged by simply pivoting the axle at one end and pushing the other end back and forth, via a simple steering linkage. The original idea had been to make a classic teardrop-shaped fairing. So, to keep the cross section to a minimum, I was using a moulded bucket seat as the core structure. A 2 inch diameter ally tube ran forward to carry pedals. A pair of ally plate forks to mount the wheel were welded to this, and at the rear, regular steel tube stays were brazed to plates that could be bolted to the back of the seat. I still had an idea that two wheels would be best, and so had made a spare rear end for a single wheel, plus some bolt on stabilisers. Subsequent testing demonstrated that 84-inch wheelbase bicycles with one inch of ground clearance do not balance as such, not even at 40mph – so tricycles it was, then. But being at the back, the wheels were going to stick out just where the fairing would be curving in. Choice was either 24-inch upright wheels or regular 700c angled in at 10. Roll down tests of about a minute or so showed a loss of around 3 seconds for 24-inch and 1 second for 700c.

That left the fairing. It was suggested that a ground effect shape would give the best results, also that the bottom could be open and it would not matter if it was square from the front. (Please note: two of these ideas are wrong!) This sounded good to us, as we would not have to do any moulding as such. The fairing was built using 1mm obeche veneer and 16mm Styrofoam, and eventually covered in aluminised Mylar film (also bad ideas).

But we had an HPV of our own, and so the team, along with Andy Pegg as a power source, were set to return to Brighton in '81 as competitors.

**MB**

*Above:* ***Poppy Flyer*** **|** *Top:* ***Vector Mk1***

# No Torque FWD *Pik*


# *Cycling Ev*

# kuponcho

In 1968 Piet Kunis (a local cycling hero from North Holland) participated in a bicycle time trail over 38.5 km at the age of 22. His road bike was a Mercier with a steel frame. He won that competition in 57 minutes and 15 seconds. His average speed was 40.5 km/h. In 2018 (50 years later) at the age of 72, the same Piet Kunis with his *Pikuponcho* participated in the one-hour time trail at Cycle Vision and drove in 1 hour a distance of 41.0 km/h. It seems as if his age has no influence on Piet's performance, but if you enter the specifications of his bikes into the calculation table of Kreuzotter, you see that Piet had to deliver 345 watts in 1968 for an hour and in 2018 only 190 watts was needed for the same result.


# olution vs Age!


Piet rode in his first competition at 12 and he got his first real road bike from his father on his 14th birthday. In short, Piet loves cycling and cycling technology and has spent many years touring alongside competitions. Somewhere, around 1985 Piet saw in the monthly "Bicycle" for the first time, photos of recumbents. He was immediately very interested. He wanted one like that too.

In the following years, he dreamed of it and thought about matter. He made various sketches and drawings of front wheel driven recumbents. Because that long chain to the rear wheel, he found very illogical. No, if he started to build something, it would have to become a front wheel driver. It took until 2002 before he put together the first self-built recumbent. The result was disappointing, because the driving characteristics were dramatic. Piet found out that the combination of steering and driving on the same wheel was not that simple. Giving up was not an option, however. Many concepts would follow and luckily they got better.

> "this is the most easy-moving recumbent I have ridden"

In 2012, when Piet as a self-builder was already a member of the recumbent group, an appeal was made to the self-builders of a Jeroen Beekhuis, to work out an idea for a "torque-free front-wheel drive" and realize this in a working bike. The idea was to place the headset in such a way that it is exactly in the position, between the point where the driving chain leaves the chainring and the point where the wheel touches the ground. If that succeeds, there is no arm with respect to the steering axle and therefore no steering torque can occur. Piet picked up that idea and he first built a steel prototype and when the concept turned out to work, there followed an improved and more beautiful version with an aluminium frame. However, around that time Piet was also asked to join Wim Schermer's team to work on the realization of the Velotilt. That was so nice and interesting that his own project disappeared into the background for the time being. When the Velotilt project was recently put on a very low level for various reasons, Piet has revived his own project and after some fine grinding, there is now the carbon version; the Pikuponcho.

The reporter Willem Jan Coster from the magazine Ligfiets &, has made a test drive with the Pikuponcho and he writes in the magazine: "The bike feels stable, the steering is precise and no torque reaction can be felt through the handlebars. I make speed, this feels familiar and goes well I turn on the road by making a 180 degree bend, which is so smooth: stable at low speed, a small turning circle, no chain running and no stair reactions, conclude that this is the most easy-moving recumbent I have ridden".

Piet has made a detachable streamlined body afterwards and this one also seems to add about 5 km/h in speed gives no problems in crosswinds. After 5 versions, Piet has succeeded in building the ideal front wheel driven recumbent, with a very effective, direct drive and no torque steer. However, this concept also has its limitations; due to the concept, a low bike is not possible, variation of the chainring size is not possible and the possible length adjustment in the frame is yet to be incorporated.


# Front Suspension PART 3

BY **GEOFF BIRD**

***The last in a series of three articles Geoff wrote about 8 years ago, reprinted for new members***

**So, as promised, in this part we will be looking at springs. Firstly, some fundamental springy-type stuff.**

Imagine you are a French animator working on The Magic Roundabout in a derelict house in Paris, circa 1965. If you were to push down on Zebedee's head and then let go then he would bounce up and down. What you are unlikely to realise (animators are not very sharp, on account of spending too much time in their own company, under very bright lights) is that the number of times that Zebedee bounces up and down in a period of time will always be the same. This is called the natural frequency and is dependent purely on the strength of the spring and the mass it is supporting. The relevant formula is this:

$$f_n = 1/(2\pi) \times \sqrt{(k/M)}$$

Where $f_n$ is the natural frequency in Hz (Hertz or cycles per second), M is the mass (in kg) supported by the spring and k is the spring rate in newtons per metre. You will see from the formula that if Zebedee were to put on some weight then the natural frequency will be reduced; that is, he would bounce slower, and, if we gave him a stronger spring, he would bounce faster.

You may well be wondering what this all has to do with bicycle suspension. Well, it turns out that natural frequency is the best way of expressing how hard or soft any suspension system is, and makes it possible to compare the suspension of a mountain bike to that of a National Express coach, should you desire.

Physiological experiments show that humans fatigue very quickly when subjected to vibration frequencies in the 4-8 Hz range and ideally prefer frequencies around 1 Hz, especially for durations of over an hour or so. Lower frequencies than that cause nausea in a significant proportion of the population. So the ideal suspension system would have a natural frequency approaching 1 Hz. A saloon car would typically have a suspension frequency of around 1.5 Hz, which is a good compromise.

What do I mean by compromise? Well, let's consider a bicycle front suspension where the combined bike and rider mass is 100kg and 50% of the mass (50kg) is supported on the front wheel. We need to estimate the maximum vertical g-force the bike is likely to experience over a bumpy surface. This is quite difficult and will depend on the use the bike is intended for. For a street bike a figure of around 1.0g is probably reasonable – this would cause the rider of an unsuspended bike, with high-pressure tyres, to momentarily leave their seat. For an off-road bike it might be as much as twice this figure. So, for a street bike, we require the suspension to absorb a force of about 500N without bottoming out. If we have 50mm of bump travel, which is the distance between the suspension in its at-rest state (with the rider onboard), and its fully compressed state, then the spring must have a stiffness of 500/0.05 = 10,000 N/m or 10 kN/m or 10 N/mm.


*Typical Air Shock*

This assumes that the spring moves as much as the wheel, which is not always the case, but we will tackle that later. Plugging these numbers into the formula given earlier, we find that this gives a natural frequency of 2.25 Hz – rather more than our ideal of 1.0-1.5 Hz.

What we discover is that, if the suspension must absorb a given g-force without bottoming out, then there is a direct relationship between the necessary suspension travel and the natural frequency of the system, regardless of how much mass is supported. This is given by the formula:

$$\boxed{z = Gg/(2\pi f_n)^2}$$

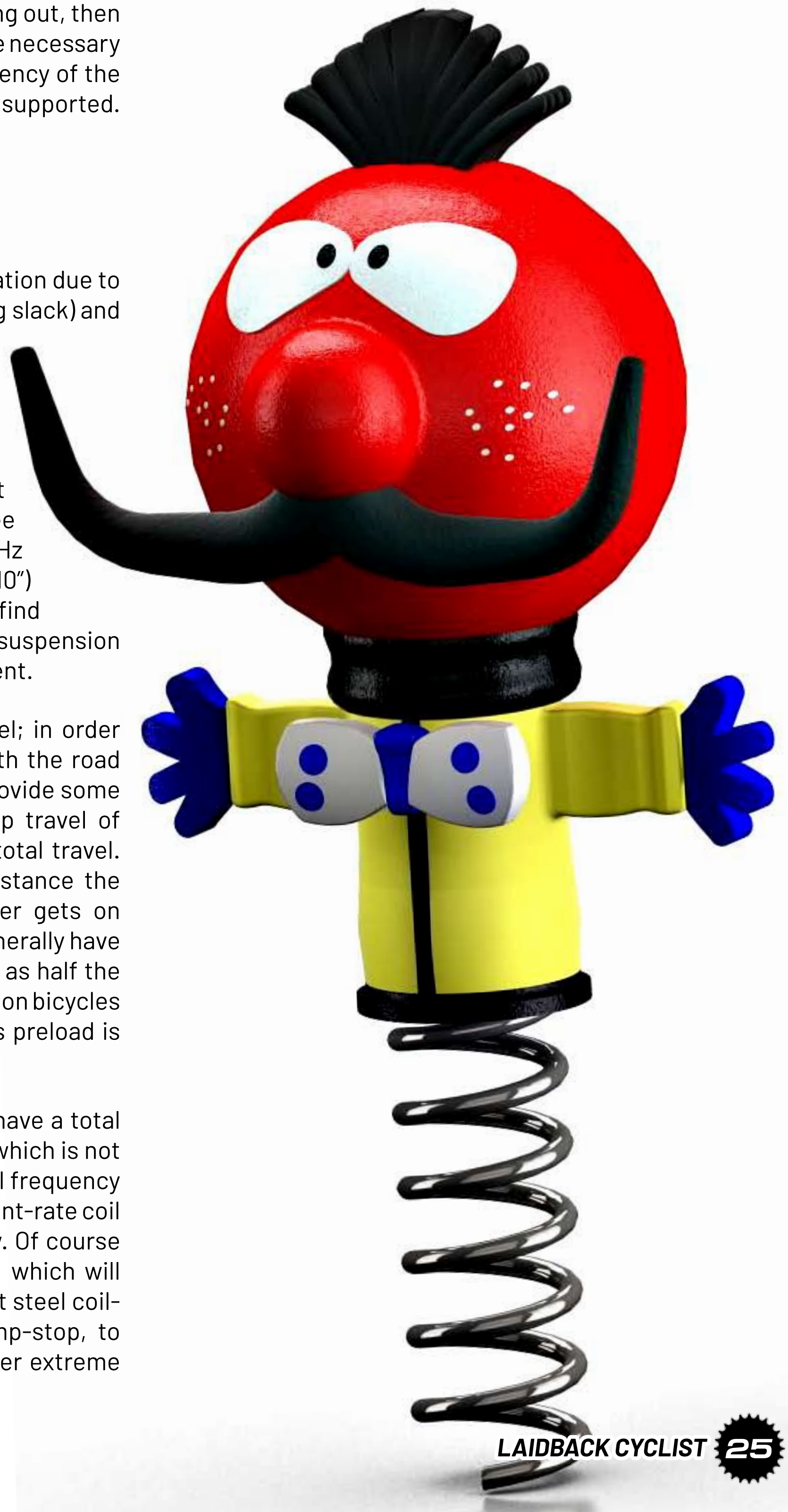
Where z is the bump travel, g is acceleration due to gravity (9.81m/s$^2$ or 10m/s$^2$ if you're being slack) and G is the maximum vertical g-force the suspension can absorb (1.0g in the above example).

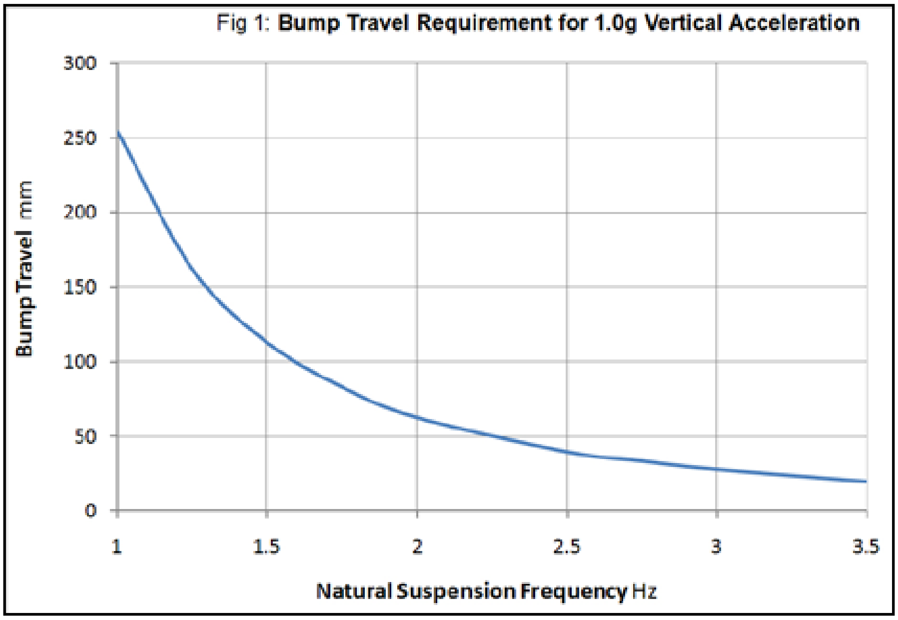
If we plot the bump travel requirement against natural frequency then we get the graph shown overleaf. You will see that to accommodate our ideal of 1.0 Hz natural frequency will require 254mm (10") of bump travel. It is very difficult to find room for anywhere near this much front suspension travel on a bicycle, especially a recumbent.

And remember this is only bump travel; in order that the tyre can remain in contact with the road as much as possible, we also need to provide some droop travel. Most bicycles have droop travel of about 25% of bump travel, or 20% of total travel. In this case the droop travel is the distance the suspension compresses when the rider gets on – this is called static deflection. Cars generally have far more droop travel – maybe as much as half the total suspension travel. The droop travel on bicycles is limited by preloading the spring. This preload is sometimes adjustable.

Most road bike front suspension forks have a total travel of between about 25 and 80mm, which is not really enough to provide as low a natural frequency as one would like with the simple, constant-rate coil spring we have considered up until now. Of course the tyre will provide some suspension, which will help. You could combine a relatively soft steel coil-spring with a progressive, rubber bump-stop, to avoid the suspension bottoming out over extreme bumps. For steel coil springs try Lee Springs, by the way.

The best way is to use a progressive spring rate. There are two methods of doing this. Either you can use a spring medium, such as rubber or






need a separate damper, you could try ACE Controls.

Natural rubber or artificial elastomers (usually polyurethane) can be used as a suspension medium in compression, tension or shear. They have the advantage of possessing a degree of self-damping, through hysteresis. The commonest way of using these materials on a bicycle is in compression, as in the rear suspension of the Trice. I have used the same spring element in one of my recent suspension designs (see below) as it combines light weight, simplicity, compactness with low cost, while hopefully giving good sensitivity over small bumps and ripples. I'll tell you for sure when I've tested it! The downside with rubber in compression is that, in order that the spring be fairly compact, it is necessary to use quite large leverage ratios, probably in the region of 5:1, resulting in large forces on the suspension components.

air, which has a natural rising-rate, or you can incorporate linkages into the system which create a progressively reduced leverage ratio as the suspension compresses. Either approach will give you a low-frequency initial spring rate, to cope with the more common, smaller bumps and a progressively harder rate to stop the suspension bottoming-out on the occasional big-hits.

Rising-rate linkages are very rare on bicycle front suspension, probably for reasons of space, complexity and weight. It is, however very easy to buy off-the-shelf air-springs for bicycles. The lightest ones use air for damping as well as for the spring, and can weigh as little as 160g. Air in compression has a lot going for it, giving a progressive spring-rate that can be easily fine-tuned using a shock-pump to vary the pressure. Unfortunately, virtually all the commercially available units for bicycles use a piston arrangement. This needs a seal to keep the air pressure in, which causes stiction, meaning there is less sensitivity to small bumps. A better arrangement is to use rubber 'bellows' – I've seen a picture of a prototype Magura unit that was like this, but I don't know what happened to it. Firestone does a range of air-springs utilising rubber bellows, the smallest of which would be suitable for bicycles, but you would need to add a damper. Julian Edgar has done just this on a series of impressive recumbent bikes and trikes (see Autospeed blog). Check out his stuff on The Net if you want to read more about suspension theory from someone with a lot more practical experience than me. Incidentally, if you

Talking of leverage ratios, I said earlier that we were assuming that the spring moves as much as the wheel. The spring rate as experienced by the wheel is known as the wheel rate, and with a telescopic

*One of Julian Edgar's machines with air-springs*

fork the spring rate and wheel rate are the same. In other systems the spring often moves less than the wheel. If the leverage ratio between the wheel and the spring is 2:1 then the spring will move half as far as the wheel. So if we want a wheel rate of 10 N/mm in this case, then what would the spring rate need to be? Well, it is tempting to think it would be 2x10=20 N/mm, and this is a mistake I've made in the past, but remember the spring not only moves half the distance but it also has to push twice as hard, so the rate would actually have to be 40 N/mm. So, you have to square the leverage ratio and multiply it by the wheel rate to get the spring rate. You can see that with rising-rate systems the maths will get horribly complicated...

You should always check the spring you want to use, whatever it is made of, is not only the right stiffness but also strong enough for the job. Manufacturers usually quote a maximum load rating.

So that concludes my triptych of articles on front suspension. If it all looks too complicated to bother with then I would urge you to think again. In my opinion suspension is well worth the effort. When I go back to a bike without suspension, it feels incredibly harsh and primitive.

Suspension protects the rider from high-frequency and high amplitude vibrations that have been proven in laboratories to increase fatigue – this can only add to efficiency, especially over long distances. It almost certainly reduces tyre wear or allows you to run lighter, higher-pressure tyres than you normally would. I've found it gives you far better control of the bike, not only on fast, bumpy descents (where your vision is also noticeably improved by the lack of vibration), but also on quite smooth surfaces, such as race tracks. Suspension also massively reduces fatigue and shock loads on the structure of the bike, meaning components can be made lighter without fear of failure. And if you implement the theory correctly then there is no reason why you can't have all these benefits without any of the potential disadvantages. The benefits of suspension dovetail particularly well with the benefits of a recumbent bicycle and I think it is likely that in the future, most HPVs will have suspension.

**GB**


Photo by ***Jon Woolrich***

# A Helping Hand?

*A review of hand-and-foot bikes by*
***Carsten Hoffmann***

A few years ago, I decided to change my one-way 24.3km daily work journey from car to bicycle. The main reason was to get some physical exercise to compensation for my predominantly sedentary job. It seemed to me a good deal to exchange the 70 minutes, I spent daily driving in stop-and-go traffic and searching for a parking space for the car, against 140 minutes of cycling in the open. Anyone who goes through a similar change knows that a previously poorly trained body needs some time to get used to the daily exercise. I often did not push hard, but dawdled a lot. While dawdling, there was a lot of time to consider whether and how to optimize the bike as a means of transportation or if there could be an alternative bicycle that would suit my needs better. From the choice of my trekking bike I knew that one has to ride/experience bicycles first hand, so I used every opportunity to test alternative bicycles and tested road bikes, recumbents bikes and trikes, Pedelecs, and many others. In addition, during my daily journeys the idea was also buzzing in my head that it does not make sense that the arms do nothing for propulsion and whether one could change that...

HF Bike race at the 2017 HPV Worlds - Varibike leads

Jon Woolrich

### THE FIRST SPARK

In April 2010, I had the opportunity to test two bicycles with additional hand drives at the special bike fair in Germersheim, Germany. I was especially fascinated by Dominik Weigel's Bionic Body Bike. Since this was not for sale, I decided to build one myself. I searched the Internet for other bicycles with an additional hand drive and contacted the respective engineers. They were very pleased with my interest and all of them were happy to let me try out their bikes, so I had the opportunity to learn the different drive concepts myself and could get a picture of the respective advantages and disadvantages.

### A NEW TYPE OF BICYCLE DEVELOPS

Since I now knew most of the builders personally and I was very sad that such bicycles on the general bike market had a shadowy existence, I thought it would be a good idea to pool energies and potentials, to complete the circle and bring the builders together.

In April 2013 around 20 builders from Germany, France, the Netherlands and Switzerland met in Germersheim in the shadow of the special bike fair. And since the common product still had no name, the first step was to find a common term for "bicycles with additional hand drive". After numerous proposals and discussions, the term "HF-Bikes" (hand-and-foot bikes, hand-and-foot bicycles) was established for this type of bicycle. The term "Full-body-bike", which was also discussed, not only appeared to be less specific, but also proved to be the trade name of a British manufacturer.

### MOTIVATION

As a new type of bicycle, the question is: Why? What added value does this concept have compared to the established bicycle types? On my regular ride, I tested different types of bicycles. Normal pedelecs were out of the question for me, because after some training the speed gain was only marginal compared to my trekking bike and the training effect was reduced by the additional electric power. I also rode an S-pedelec (faster), a few times on my way to work, but I felt like I was driving half a scooter, half a bike and I did not get the feeling that I had achieved much on arrival at my destination. The training effect was limited.

I also tested recumbent bicycles and tricycles. I felt the seat position with both was very pleasant, but for me, the main disadvantage was the limited view in heavy traffic. In addition, it is much more difficult with recumbent bicycles and especially recumbent tricycles to nip through somewhere or to switch spontaneously between cycle track and road. Racing bicycles and triathlon bikes allow quicker progress than with the trekking bike, but you have to ride in a low crouch. The position makes it necessary to train the back muscles, so that it can be maintained over a long period of time (70 minutes in this case). In order to be able to ride the route daily with the road bike in a low crouch, I would have had to plan additional exercises and training for my back muscles, which ran counter to my original motivation: I did not want to do 2 × 70 minutes a day cycling and then to strengthen the back muscles in a gym, but to improve my physical fitness by cycling, so the training for upper body, back and arm musculature should also take place during cycling.

The benefit of Hand and Foot (HF) bikes against other bike types is to enable the rider to train the whole body, not just the leg muscles and if a speed increase is achieved, this is a welcome side effect.

## *THE TEST – OVERVIEW OF TABLE*

The following table shows the HF bikes I have tested so far. In the horizontal lines of the table, different characteristics of the respective HF bikes are listed, which I would like to explain below. In the vertical columns of the table, the respective HF bikes are mentioned - for each bike, a brief description is given below.

Unfortunately, I have not been able to test all known HF bikes yet. For example, the "Korbike" by David Price (USA), the "Full Body Bike" from Stanford University (USA), the round-rowing bike by Uli Siegel (D), the "Nykarus" by Luc Bortels (B), modifications of the "Berkelbike" by Rik Berkelmans (NL) and the HF-Bike by a mysterious "Mr. T." from Spain. Also very recent developments like the Cardigo and the TwiCycle could not be tested until now.

## *TECHNICAL EXPLANATIONS OF THE TABLE*

### Hand driven wheel

The foot drive force is applied to the rear wheel for all indicated HF bikes. This indicates whether the hand driving force is applied to the front wheel or to the rear wheel. In isolation, this parameter does not involve any advantages or disadvantages, the overall concept is more important.

### Steering

This shows if the bike can be steered normally or if the rider must steer by shifting body weight or tilting the entire mechanism to one side. Riding HF bikes, which cannot be steered normally, is more difficult to learn and could be somewhat dangerous in urban traffic.

### Use of the hand drive

The use of the hand drive can be optional or obligatory. If an optional hand drive is used, the hand drive movement can be stopped at any time. In the case of alternate hand positions, the whole upper body weight is placed on one arm when the hand drive is not in use. In case of obligatory use, the hand drive must always be used – the hand drive therefore moves along with each movement of the bicycle. For some HF bikes, there are additional handlebars for when not using of the hand drive. For beginners, a chance to pause use of the hand drive is very helpful, as the appropriate muscles are not yet adequately trained.  Also, it can be useful to be able to stop the hand cranking movement in difficult situations. In my opinion an optional hand drive is best, since in dangerous situations it is not even necessary to transfer to an additional handlebar.

#### Hand drive motion

The hand drive motion is defined by whether the hands move together (synchronised) or if the movement is the same as for normal foot drives (alternating). In the case of the Exycle, the hands move toward each other (mirrored).

Furthermore, the direction of movement differs: It could be a rotation (as with the normal foot drive), a vertical up-and-down movement, a lateral movement (along the handlebar), or a proximal movement, which means moving towards the body, similar to rowing.

Alternating rotating motions are very good to put the power on the street, but they are more difficult to

| Bike | 4strikebike | AIEx Amboss | AIEx Exycle | AIEx Harmony | Bionic Body Bikes | Dopo-bike | Excycle | Gildasfire | Novosport Moveo |
|---|---|---|---|---|---|---|---|---|---|
| Website | www.4strikebike.com | www.alex-bikes.de | www.alex-bikes.de | www.alex-bikes.de | | www.dopobike.de | www.exycle.de | www.gildasfire.com | www.novosport.de |
| Constructor | Lex van Stekelenburg | Carsten Hoffmann | Carsten Hoffmann | Carsten Hoffmann | Dominik Weigel | Joachim Berger | Bernd Monno | Gildas Failler | Ulrich Albert |
| Hand drive wheel | rear | rear | rear | front | front | rear | front | rear | rear |
| steering | Normal and by weight displacement | normal | normal | normal | normal | normal | normal | normal | normal |
| Use of the hand drive | Optional (offset hand positions) | optional | optional | optional | optional | mandatory | optional | optional | mandatory |
| Hand drive movement | Alternating rotating | Synchronous vertical | Mirrored lateral | Synchronous rotating | Synchronous rotating | Alternating vertical | Mirrored lateral | Alternating vertical | Synchronous proximal (rowing) |
| Transmission of the hand drive | Via foot drive | Via foot drive | Via foot drive | Separate drive | Separate drive | Via foot drive | none | Via foot drive | Via foot drive |
| Hand drive in relation to foot drive | Variable synchronous | Variable synchronous | Variable synchronous | Variable synchronous | Switchable asynchronous | Fixed synchronous | Asynchronous | Variable synchronous | Fixed synchronous |

learn and have a certain potential danger since the hand driving force pulls in the direction of steering. With synchronous rotating movements, the driving force can be obtained from the arms (synchronous stable) or the back (synchronous dynamic). In the case of synchronously rotating movements, the upward movement may be more difficult, the downward movement correspondingly easier. The synchronously proximal movement corresponds to the motion of rowing. The best movement depends on individual preference.

### Gear change for of the hand drive

The frequency of the hand movement can be adapted to the speed of travel by means of gears. If this occurs together with the frequency of the foot drive (cadence) the hand and foot drive must normally move in synchronism - unless there is an additional gear change for the hand drive as in the case of the Ruderrad. With separate gears for the hand drive, there is the difficulty of adjusting this to the foot drive. An exception here is AIEx Harmony with the Nuvinci N360 Harmony, which makes this automatic and stepless.

## HAND DRIVE POWER IN RELATION TO THE FOOT DRIVE

This parameter indicates how the arms must move in relation to the foot drive cadence. This determines how well the hand drive and foot drive are matched. If it is fixed synchronous the arms must move in the same rhythm as the rotary movement of the feet. For example, in the case of the Raxibo, the rider must move in a natural alternating manner. The disadvantage is that for stopping hand cranking, the hand must transfer to a second steering bar. Variable synchronisation

| | | | | |
|---|---|---|---|---|
| Raxibo | Rowingbike Thys 222 | Ruderrad | Tetrad | Varibike |
| www.raxibo.ch | rowingbike.com/en | | | www.varibike.com |
| Lothar Dickenscheid | Derk Thijs | Klaus Schorn | Veit Lehmann | Martin Kraiß |
| rear | rear | rear | front | rear |
| By weight shifting and tilting handlebar | By weight shifting and tilting handlebar | normal | normal | By weight displacement |
| Optional (secondary steering) | mandatory | optional | Optional (offset hand positions) | Optional (offset hand positions and second handlebars) |
| Alternating rotating | Synchronous proximal (rowing) | Synchronous proximal (rowing) | Alternating vertically | Synchronously or alternately rotating |
| Via foot drive | Via foot drive | Separate drive | Separate drive | Via foot drive |
| Fixed synchronous | Fixed synchronous | Variable synchronous | Switchable asynchronous | Variable synchronous |

gives the rider more choice, but also requires more practice, to find a movement sequence that is both comfortable and uses the hand power effectively. With the asynchronous drives, the movements of the hand drive and the foot drive are completely independent of each other. In my opinion, the

*4strikebike*

variable synchronous and the asynchronous drives are best, as there the driver is very flexible in the use of the hand drive.

All photos of this article are from the manufacturer(s).

## *THE INDIVIDUAL HF BIKES*

### 4strikebike

During the development of the 4strikebike, the Dutch physician Lex van Stekelenburg was very concerned about a physically useful movement. In spite of the alternately rotating hand drive movement, which normally requires more practice, riding the 4strikebike can be learned quickly. This is made possible by a steering damper (centerer) and a special mounting for the handlebars, which also allows steering movements when the hand drive is used. The 4strikebike is well suited for reaching high speeds on the flat. What is striking is the sitting position of the rider, like on a road bike or a triathlon bike, which promotes higher speeds, but also stresses the arm force by additional support of the upper body weight.

### AIEx Amboss

In this prototype by the author, the hand driving force is introduced synchronously vertically only with the downward movement - the handlebars do not rotate in the crank bearing in the front, but are backpedalled for the upward movement. This is made possible by a freewheel on the left foot crank. The aim of this concept is to minimize the additional load on the cardiovascular system by using the gravitational force of the upper body for propulsion. Similar to some ("synchro-dynamic", see above) handbikes, the additional drive force is largely derived from the back muscles. This makes it comparatively easy to reach comparatively high speeds. On the pictures you can see the AIEx Amboss 2.0. With this bike the author of this article participated on the Human Powered Vehicles (HPV) World Championship 2017 in Mannheim, Germany. The name AIEx stands for All extremities

**AIEx Exycle**

In this new prototype the author of this article used the retrofit kit of the Exycle of Bernd Monno (see below) to put the hand drive force to the backwheel of the bicycle. That way the power of the hand movement goes through the derailleur gears of the bike. In comparison to the Exycle, it is possible to remain at a more constant speed with the hand drive, but there are some more frictional losses. As the hand drive can be paused at any time, even beginners can ride this bike very easily.

**AIEx Harmony**

The highlights of this prototype are two Nuvinci N360 harmony drives, which are installed in the front and rear wheels. These automatic hub drives allow hand and foot drive forces to be matched automatically at any speed. But these hub gears also have considerable disadvantages in practice: The high weight of the two hub gears, the loss of efficiency caused by especially these hub gears and last but not least the need to supply the hub gears with battery power.

**Bionic Body Bike**

The Bionic Body Bike by Dominik Weigel was the first HF bike, which sparked my enthusiasm for this type of bike. The optional hand drive and the synchronous rotating foot drive enable rapid learning and a noticeable increase in power, especially when accelerating. It is good that the handlebar can be fixed in any position. This increases the everyday comfort of the Bionic Body Bikes even more. In spite of the separate gearing of the hand drive, it is not easy in practice to find a suitable gear ratio for both the hand and the foot drive.

**Dopo-Bike**

In the case of the Dopo-Bike the rider must use the hand movement all the time, since the handlebars move up and down alternately and at the rhythm of the cadence. Nevertheless, the Dopo-Bike is surprisingly easy to ride and to manoeuvre safely. You immediately get a very good feeling that the additional hand driving force is also effective on the road - the reason for this is, among other things, the engineer Joachim Berger's redirecting mechanism, designed with a lot of detail and great safety reserves. The obligatory hand drive needs getting used to. It requires some training in order to travel longer distances. When turning and in difficult situations you cannot crank and the handlebars are not straight. Overall, a great bike that invites you to new speed records and which is quite addictive: Once you get used to it, it feels odd to ride a normal bike again, with the handlebars fixed.

### Exycle

The Exycle is the most successful bicycle development by the engineer Bernd Monno. As the hand grips move laterally apart, anyone can ride it immediately. The hand drive can be stopped at any time, with the hand grips at the end of the bars or at their closest position. My first test trip included an 80-km-tour through the Oberhavel (close to Berlin). It is a feature that the Exycle hand drive can be mounted on various bikes as a retrofit kit. The only downside is the lack of a gear change in the hand drive: At higher speeds, you have to move the arms very fast to get the extra power to the road.

### Gildasfire

The Frenchman Gildas Failler developed the chic Gildasfire, in order to be able to move better on the beaches in Brittany. The movement sequence (rocking bars) corresponds to that of the Dopo-Bike, but with the difference that the hand drive does not necessarily have to be used here. There is even a latching function. However, the other side of the coin is that the rider must find a suitable rhythm. Overall, a convincing concept, which does not shy away from off-road use.

### Novosport Moveo

With the Moveo the foot cranks can be mounted either alternately or synchronously. Developer Ulrich Albert of Novosport recommends synchronous, which allows a smooth movement sequence similar to that of rowing. This takes about 15 minutes to learn, then the full-suspension bike glides along the street - until you are exhausted. Your arm and belly muscles may be unused to this motion and need training. If you want to increase the strength of arm and stomach musculature, you can do both on this bike with the convenience of a recumbent and a pleasant overall movement.

### Raxibo

The Raxibo was developed in Switzerland and is therefore ideally suited for climbing in the mountains. But builder Lothar Dickenscheid also makes multi-day tours through the lowlands with it and produces the bike in several colours. Among the HF bikes, the Raxibo is one of the bicycles that requires more practice in order to be able to ride it with confidence. The second handlebar helps in learning as well as in tricky situations. A tip: Going uphill, the movement can be learned more easily. The movement is similar to the 4strikebike, modelled on the natural human alternation.

### Rowingbike THYS 222

The Rowingbike THYS 222 has some special features compared to the other HF bikes in this comparison: the foot drive of the recumbent does not take place by means of rotating cranks, and the power transmission is carried out by Dyneema ropes for the hand and foot drive. For the change of ratio, the Dutch designer Derk Thijs has developed a special spiral, which the rope acts on. The movement, which is very similar to rowing, and the steering by tilting the handlebar, needs learning, which is more difficult because of the need to use click pedals. Once you get the knack, this bike can move very quickly with a very even whole body movement. There are even special rowing bike championships. The bike, which is also available with a carbon frame, is ideally suited for competitions and training. However, when using the bike in everyday life, the disadvantages of limited manoeuvrability and a reduced view of traffic are important to note.

### Ruderrad (Rowingbike)

The very shallow seat tube angle means that the rider sits very upright on the Ruderrad, like on a Dutch bike. As a result, the arms and hands do not need to support any weight. Since the hand drive is optional, you can cruise, and then just start pushing with your hands during the journey. The steering is safe and easy even when hand cranking. Some practice is required as the hand drive is not fixedly connected to the foot drive: It must be timed so that it does not get stuck at the dead point of the action. The hand drive has its own additional transmission, but the optimal timing of it with the foot drive is not easy. With the Ruderrad the Cologne-based Klaus Schorn has developed a full-suspension HF bike that can easily meet all requirements in the everyday life of a large city. It is also available as an e-bike and as a tandem.

### Tetrad

The Tetrad, by the late engineer Veit Lehmann, can be seen in the bicycle museum Pedalwelt in Heimbuchenthal, where the collector Ulrich Teige exhibits one of the last examples. Thankfully the author was allowed to take a test ride with the museum piece. The hand drive is effected by means of upward and downward moving bar halves, from which the hand drive force is transmitted to the front wheel via a dérailleur gear. Learning the movement takes about 15 minutes, the first time you are almost frightened by the change of the hands. Since the weight of the upper body can also be added here, and the hand drive has a separate gear, a lot of power can be used efficiently, which is manifested in a significant increase in speed and significantly more exhaustion. The steering when using the hand drive must be learned, but is ultimately without problems, since the hand drive can be stopped at any time. Overall, a very well thought-out concept, but unfortunately no longer available.

**Varibike (picture – page 30)**

With the Varibike by Martin Kraiß, the hand drive cranks with their ergonomically shaped grips can be used either synchronously or alternately. With the small additional handlebar this allows a variety of different postures and drive variations. The steering, principally by shifting the weight, requires practice, though this is helped by the large fork trail and the steering damper (centerer). The beginner can hold on to the extra handlebars, which are also used in emergency situations and for braking and shifting. The red anodized hand and foot cranks and the Shimano-XT group make the Varibike a perfectly designed training machine for the whole body. There is also a Varibike Trike and an Indoor Varibike available.

## *CONCLUSION*

"And what is the best HF bike?" the curious reader will ask. Counter question: "Is there the best bike?" No, there is not, because which bicycle is "the best" depends, of course, on the respective purpose and also on the individual preferences of the rider. Although the bikes presented here naturally have the connecting commonality that they all have both a foot drive and hand drive, there is a wider range than one would normally find in a comparison. A comparison of racing bikes with mountain bikes is finally a comparison of apples with pears. Because such comparisons make little sense, there cannot be a best HF-bike.

Therefore, the tested HF bikes can only be roughly classified here for different applications, HF racing bikes, HF mountain bikes, HF recumbents, HF everyday bicycles, etc. If mainly speed is important for you, test the 4strikebike, the AlEx Amboss, the Dopo bike, the THYS 222 or the Varibike. If you do not want to miss out on terrain, or if you travel a lot in the mountains, you might be happy with the Gildasfire or the Raxibo. If you are planning to make longer tours as an inexperienced rider, you could try the AlEx Amboss, the AlEx Exycle, the Bionic Body Bike, the Exycle, the Raxibo and the Ruderrad. Best suited for the heavy traffic in a big city are the AlEx Amboss, the AlEx Exycle, the AlEx Harmony, the Bionic Body Bike, the Exycle and the Ruderrad . You should also remember the purpose of HF bikes, which is to allow the use of all muscle groups during cycling. This purpose overrules this differentiation of the existing HF bikes. Due to the distinctive element of the additional hand drive, individual preferences regarding the hand drive and also the respective overall concept are generally more important than the classification of the respective HF bikes. For example, for a rowing movement, try the Moveo, the THYS 222 or the Ruderrad. If you want a movement with normal human alternation, this can best be achieved with the 4strikebike, the Dopo bike and the Raxibo. With the Gildasfire, the Tetrad and the Varibike, this is also the case, but you have to find the rhythm yourself – therefore you can interrupt the hand drive at any time.

It is not possible to answer the question of which movement, drive and overall concept best suits in a theoretical article. The bicycles must be ridden. This is all the more true for HF bikes so that you can develop a feeling for the different drive concepts as a rider and individually decide which HF bike best suits your needs. An excellent opportunity to experience the different HF bikes live is each year at the last weekend in April at the special bike fair in Germersheim.

## *THANKS*

My sincere thanks go to all of the above-mentioned builders, who have not only allowed me to ride the various HF bikes in the best HF biker solidarity but have also provided photo material for this article.

For the English version I have to thank very much Jonathan Woolrich, who did not get tired to correct the manuscripts over and over.

Carsten Hoffmann is a psychotherapist, a bicycle developer and an everyday and touring cyclist from Cologne. With two friends he is rounding Germany along the course of the border. Contact: alex-bikes@arcor.de

## *LEGAL NOTICE*



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**CH**

***More pictures on the back cover!***

# BHPC ACCOUNTS TO 31ST DEC '18

**Opening balance, 1 January 2018: £5050.25**

**INCOME**

| | |
|---|---|
| Magazines & postage | £90.06 |
| SYWTB | £113.00 |
| Books & postage | £761.00 |
| Race fees | £1566.00 |
| Prepay race fees | £495.00 |
| Membership | £2092.00 |
| Stickers and postcards | £64.00 |
| Deposit interest | £6.00 |
| Website tests | £0.21 |
| Donations | £71.10 |
| Derby velodrome | £575.00 |
| Camping Darley Moor | £55.00 |
| | |
| | |
| **WC2018** | £8807.30 |
| | |
| **Total** | **£14695.67** |

**EXPENDITURE**

| | |
|---|---|
| Printing (3 magazines) | £770.05 |
| Postage and stationery (3) | £634.55 |
| Track hire (incl. Derby deposit) | £2017.25 |
| Insurance | £254.57 |
| Timing system (tags) | £28.98 |
| Website security cert. | £35.94 |
| Software & site hosting | £274.8 |
| Domain name | £12.59 |
| PayPal refunds | £43.00 |
| Paypal fees | £141.45 |
| Camping Darley Moor | £50.00 |
| Books | £385.00 |
| | |
| **WC2018** | £8297.09 |
| | |
| **Total** | **£12945.27** |
| | |

**Closing balance, 31 December 2018: £6800.65**

*These summarised accounts show a surplus over the year of £1750.40, comprising £1240.19 surplus from the overall account and £510.21 surplus from WC2018. (see below for summary of the WC2018 accounts).*

*BUT….. we have taken £575 income for Derby Velodrome and paid a deposit of £150 contributing £425 to the surplus which will be paid out in 2019. Also, we have paid for the printing and postage of only 3 magazines in the year. This is due to the membership/magazine year not being the same as the financial year we use but it usually evens out with 4 in each. This year it hasn't and that should be another £350 ish out of the overall surplus.*
*For this year (2019) we will have the added expenditure of replacing the kit that was stolen. This will probably be about £1000 and that, together with the Derby payments and more printing, would mop up the £1750 surplus from this year. This means we are still breaking even and, in my opinion, we are in a healthy financial state.*

**WC2018 ACCOUNTS**

| **INCOME** | |
|---|---|
| **ITEM** | **AMOUNT** |
| Registration fees | £6,311.00 |
| T-shirts | £125.30 |
| Camping | £2,351.00 |
| donation | £20.00 |
| | |
| ***DONATIONS IN KIND*** | ***SOURCE*** |
| *Diesel for generator* | *Neil Hood* |
| *600 gels* | *High5* |
| *Carrier bags & catalogues* | *Schwalbe* |
| *Water bottles* | *ICE* |
| *Tyre levers* | *ICE* |
| *Workshop facilities* | *ICE* |
| *Local information* | *Deal Tourist Information* |
| *Caps for the winners* | *ICE* |
| *Sprint timing kit* | *Jonathan Woolrich* |
| | |
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| | |
| | |
| **TOTAL INCOME** | **£8,807.30** |
| | |

| **EXPENDITURE** | |
|---|---|
| **ITEM** | **AMOUNT** |
| Track hire | £750.00 |
| t-shirts | £945.40 |
| camping | £2,160.00 |
| Parking charges for campers | £690.00 |
| extra toilets | £669.60 |
| hire of Tee Pees | £150.00 |
| security | £1,008.00 |
| cancellation insurance | £90.92 |
| prizes - wire models | £205.70 |
| prizes - pottery | £200.00 |
| stationery, labels and ink | £114.80 |
| Timing | £118.80 |
| Race organisation | £120.53 |
| programmes, leaflets | £119.98 |
| gels and bags | £14.98 |
| 2 advertising banners for Mike's bikes | £113.88 |
| Contribution to van hire and fuel for Mike's bikes | £100.00 |
| postage | £25.50 |
| PayPal fees | £307.77 |
| refunds via PayPal | £391.23 |
| | |
| **TOTAL EXPENDITURE** | **£8,297.09** |
| **Balance** | **£510.21** |

*If you have any questions please contact treasurer@bhpc.org.uk*

*Heather Fortnum*

*BHPC Treasurer*

*Russ's first run in the MIlan - BM 2018*

BHPC
BRITISH HUMAN POWER CLUB

Above: **Varibike** **|** Below Left: **Dopo-bike** **|** Below Right: **Pikuponcho steering detail**