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GOALS, RULES AND TECHNOLOGICAL INNOVATION

By Paul B. MacCready

(Presented at the 1986 World Congress on the Medical and Scientific Aspects of Cycling, Colorado Springs, Colorado) September 2, 1986.

ABSTRACT

Competitive events have a strong influence on the development of a sport, even on non-competitive aspects. Paradoxically, while competitions stimulate technological innovation, rules tend to inhibit innovation, and yet competitions must have rules to promote safety and fairness. Clues about the possible future course of cycling technology come from exploring cycling's past and from the development of other sports that are also based on technology involving structures and aerodynamics, such as sailplaning, hang gliding, and sailboating. For high-speed-cycling competitions, the definition of a bicycle now presents a major dilemma: specifically, what aerodynamic improvements are to be permitted (related to the question of whether racing success is to be based on human prowess or technological advantages)? Specifying a minimum drag at a high speed rather than specifying design details is a possible way out of the dilemma, but the concept has problems in measurement and in public acceptance. Industry, educational and research institutions, and sports organizations will continually be linked with inventors and cyclists seeking the best compromise on the rules that serve to coordinate and stimulate cycling. The goal of simple, fair, unchanging rules must be sought even if it proves unattainable.

INTRODUCTION

The technology of cycling can include not only the vehicle but also the rider who powers and guides the vehicle, the rider's training, the use of the vehicle for recreation or competition, and the underlying research, development and manufacturing. We will focus here on the vehicle, while still considering the users and suppliers. Our aim is to explore factors related to stimulating cycling, especially through technological innovation. (We implicitly assume cycling's growth is a worthy cause). The exploration includes considering what cycling is, how rules determine technology and how they can either invigorate or stultify innovation, and how several other sports have handled compromises of rules. We then contemplate what all this means with respect to cycling, and suggest some recommendations and conclusions.

Motivation is, of course, the primary drive for technological innovation and arises from both psychological and economic factors. For cycling, motivation includes the ego drives of competitors, the enthusiasms of researchers, economic goals of manufacturers, recreation enjoyment for the sporting participant, convenience for commuters, and the innate characteristic of humans to brag about equipment.

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In This Issue...

EDITORIAL COMMENTS

By David Gordon Wilson

"If it looks right, it will work right" is the ungrammatical advice young designers are often given. But "looking right" implies a long period of often subconscious education. And every now and then we encounter something new that re-educates us. HPVs in general are, we believe, educating the public into a new concept of what is "right". I have tended to be wary of composites, but just trying to bend an astonishingly lightweight carbon-fiber assembly educated my outlook dramatically.

These musings are prompted by the drives on the MIT Daedalus HPAs. They are all shafts with gears. Now that may not seem as astonishing to you as it does to me. At the turn of the century there was a craze for shaft-drive bicycles. The shaft was generally enclosed within the right-side rear-wheel fork. Two pairs of right-angle bevel gears connected the shaft to cranks and to the rearwheel. The whole set up looked neat.

I had always believed that these drives were abandoned because they were heavy and had high losses, and possibly also because the very high overload torque that a rider can produce in extremis is difficult to handle with gears in a lightweight housing. But in an aircraft attempting to fly far further under human power than has ever been achieved before, high efficiency, light weight and reliability are essentials.

The long wire-and-nylon chains that have been used on most previous HPAs have often given trouble, and were heavy despite the light weight of the Berg chains used. The new geared-shaft drive was designed and machined by Bob Parkes, using off-the-shelf Arrow case-hardened gears giving a three-to-one step-up at the cranks and a one-to-one at the prop-shaft. He removed a great deal of metal from the gear hubs and webs. Bob said that an added advantage of the gear drive over the chain was the absolute quiet, allowing the pilot to listen to other messages from the plane's structure.

Most recumbents drive the rear wheel from cranks way up forward, and the chain is long, heavy, and dirty. But having experimented with several other transmissions I thought that the chain was still supreme. I'm being re-educated. Isn't that what the IHPVA is all about?

ABOUT LETTERS

Perhaps I should apologize for publishing favorable letters. But since Spring, 1984, when I became editor of *HUMAN POWER*, we've never had a negative letter. I hope that represents true reader satisfaction, but more likely it indicates good-feeling and restraint among people too well-mannered to criticize volunteers. We can take some criticism! It helps to ensure that we are going in a direction you want. And the contributors always like feedback on their ideas, as you will see from Jim Roberts' comments.

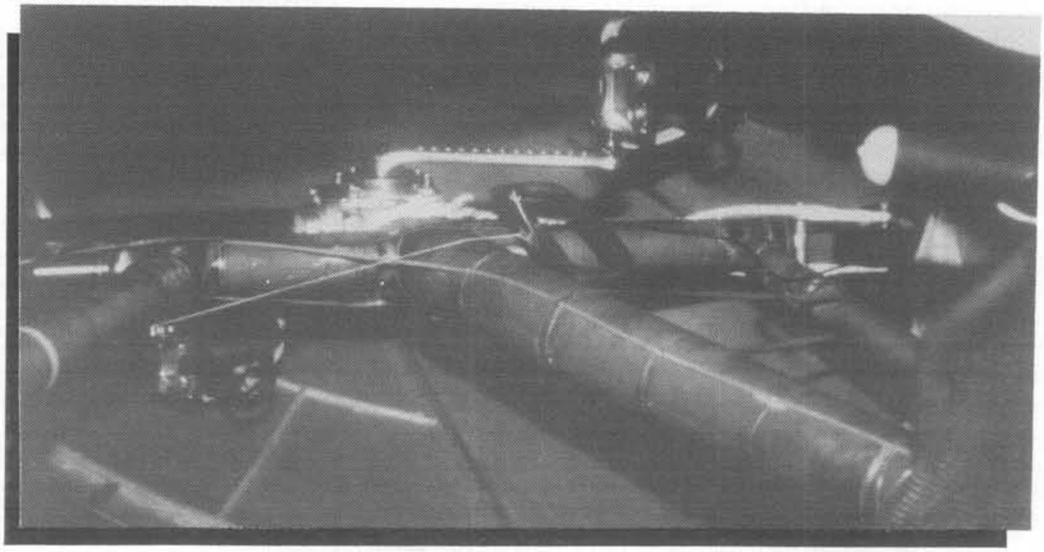

FIG. 1: Gear Drive of the MIT Human Powered Aircraft Eagle. *PHOTO BY Peggy Scott*

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LETTERS

ROBERTS SEEKS COMMENTS

My pieces on 'Recumbents on Dirt Roads (*HP* Vol.5, Summer 1986) provoked only one response. I've had correspondence with Charles Brown on the virtues and presumed liabilities of frame/drive flexibility.

I had really hoped to stir up someone involved with ergonomics. After all, the dialogue still goes on in conventional bike design concerning structural rigidity. We are getting some good exposition in other technical areas. Why the (for me heavy) silence on the issues raised in my piece? It feels like dismissal. Or perhaps those with some involvement have proprietary interest that preclude sharing.

Since the *Slingshot* mountain bike is obviously a development closely associated with my own work, I thought it might build a fire under readers interested in the topic if I reviewed this design. Mark Groendal, *Slingshot* designer, selected the basic geometry of the mountain bike, removed the front down tube, put a Kevlar flexing spring plate between the top tube and seat post, then triangulated with cables and coil springs. The two sets of springs obviously have different 'rates' and are pre-loaded.

With a geometry that pivots at the seat post, maximum deflection occurs along the vertical axis of the crank.

Gene Sloane, author of *All-Terrain Bicycles* and *The All New Complete Book of Bicycling*, wrote a glowing report to David Strong of Strong Mountain Cyclery, 5/27/'86 and I quote: "... On fast downhill runs on rough, bumpy, rock-strewn mountain trials, I find the Slingshot to be measurably easier to control. I don't bounce around as much as on a conventional All-Terrain bike. The bike is extremely forgiving. The frame absorbs downhill rough-road shock very well, and so I find myself feeling a lot more secure on these speedy descents. The bike really comes into its own, though, on fast cornering, where it sticks to the trail and road surfaces like glue. On steep hill climbs, where I am applying a lot of torque and pressure on the pedals, I find the bike seems to me to help itself up the hill. That is, I note that when I press downward say from the 1:00 o'clock pedal position, the frame absorbs some of this energy. A I reach the bottom of the stroke with one pedal and begin another downward power stroke with the other pedal, energy stored from the previous stoke actually comes back and helps push the pedal downward, like an invisible leg. I liken this effect to the "body english" one uses on a trampoline. If you time your strokes just right (and in a short while this becomes automatic) you find hitting at just the right moment to press down as the bike springs back at you, just as the jumper times his leap downward to hit the trampoline as its tensioned surface is at maximum spring-back."

It would seem that many of us believe we are at a plateau (or cul-de-sac) in HPV design. My work in flexible systems suggest that there are a lot of sound ideas to be explored in the future.

I'd like to provoke a response by claiming that both *Gold Rush* (DuPont prize-winning recumbent bicycle) and the *Light Eagle* (MIT record-breaking HP aircraft) owe their success - at least in small part - to drive system "winding".

Jim Roberts
The Wave Project
Box 408
Chimayo, NM 87522 USA

HYDROFOIL UPDATE

Congratulations on [the winter, 1986, vol. 5/4] issue of *HUMAN POWER*! It is the biggest and most substantive to date. Steve Bussolari's paper is among the best we have had in *HP*...

The response to the *SCIENTIFIC AMERICAN* article has been terriffic! There are now hydrofoil projects at a half-dozen unversities, and several commercial projects as well. Allan and I may joining up with one of the commercial ventures to actually get a hydrofoil into production.

Alec N. Brooks
1536 N. Altadena Drive
PASADENA, CA 91107 USA

LOVE LETTER

I want to tell you how much I enjoy reading *HUMAN POWER*. It's really interesting to find out the latest inventions and technology. I hope to get started building my own HPV this summer.

Catharine L. Humphrey
P.O. Box 623
MINDEN, ME 89423 USA

HPA UPDATE

The Daedalus group is managing and handling everything very well, and the *Light Eagle* is excellently built. It's impressive to see this huge HPA. I think that they will do it [*i.e. fly from Crete to Greece - ed*]...

Prof. Akiro Naito (1620 Dai Kamakara, Japan) informed me that they have started a new HP helicopter project.

Ernst Schoberl
Ossiacher Str. 42,
D-8500
Nurnberg 50, FR Germany

[*Ernst Schoberl also sent information about a beautiful solar-powered model plane he and others are building - ed*].

Kristin & Kurt Wold's tandem stands tall.

A HUMAN POWERED FOOT IN THE DOOR

by E. P. (Peter) Ernst

After the establishment of stunning records by air, land and water vehicles, HPV builders may turn to more practical goals which would, by definition, whet the appetite of commuters worldwide.

Indeed, a great many are prepared to acquire benign and efficient alternative vehicles, provided they offer a modicum of weather protection for daily use. The vicious circle of 'high price tags, hence no buyers' can be broken, although manufacturing quantities will be modest initially. If there exist acceptance problems, they can not generally be solved by home craftsmanship, but require highly professional solutions.

Top-end approach

UCI rules and other inhibiting factors have made the bicycle industry the least receptive partner for innovation. For instance, among the ten Swiss manufacturers, so far only one was willing to venture into modest batch production of alternatives. The resulting VILLIGER *'VILOSTAR'* (fig. 1) is a pleasing semirecumbent, longwheel-base bicycle, protected by a partial FRP - fairing with ample (rear pannier) carrying capacity and a lockable oddment compartment up front. The price of Swfr 2,000 ($1,400 - US) is high, but there are buyers willing to pay a financial premium to break with 100-year-old traditions.

Potential but intractable alternative manufacturers are the carmakers. Regrettably so, since the auto industry has balked at offering sensible alternatives to commuters and it is precisely the massive presence of motorcars that frightens people away from using something lighter for short trips.

Indeed, from a commuter's point of view one may question the much-vaunted progress of a century of automobile development, if one compares the two-up lightweight (260 kg (570 lbm) of Carl Benz of 1885 and the 1.3 ton deadweight of today carrying an average of 1.3 passengers. For many generations, car users have failed to pay the ecological and social costs of their activities. More and more automated comfort features were added to the car. Today's squandermania calls for three dozen "keep-happy" non-essentials, which by themselves command more energy than human beings actually need for nimble urban locomotion(1).

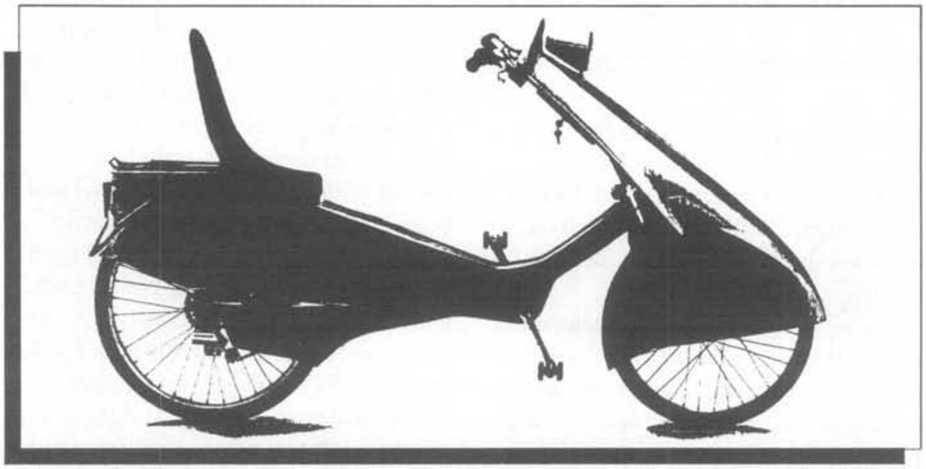

FIG. 1 The Vilostar is the only semi-recumbent in limited production in Switzerland.

If between 20-100 kw are nonchalantly consumed for car travel, versus a requirement for HPVs of between 100-500 W, the energy ratio is 200:1. However, such gargantuan difference should not lull technocrats into professional blindness. History has its whims. In the 60s the first wave of subcompact-car imports reached the American shores. US automakers chuckled, predicting their early demise. Today the roles are reversed: the buyers displayed unsuspected energy, environmental and economic awareness and cut the US dinosaurs down to size.

The day may come when thinkers in Detroit have to read IHPVA publications with possible afterthoughts of venturing into hybrid commuter vehicles of hyper-efficiency, as advocated by our members Malewicki *et al* (2) in the USA, or Grundbacher (3) in Switzerland.

Grass-roots approach

Our hopes for early results might better be pinned on very special and restricted markets, possessing nevertheless broad public appeal.

Practical, improved HPVs might find open arms among the handicapped, for whom the commuting problem remains to be solved, in spite of efforts by insurance companies and rehabilitation laboratories.

Wheelchair users still have a severely restricted commuting range, due to early depletion of either muscle or battery power.

This challenge can be met by the IHPVA, if we broaden our horizons to encompass all possible muscle/hybrid drive options. Handicapped mobility will benefit from:

- extremely lightweight construction, using composite materials;
- better weather protection; and
- muscular extension via solar power and the use of better gearing.

At present, many muscle-powered wheelchair trips into the countryside end after a half mile of roughing it, or may be cut short by inclement weather. A possible improvement might look like the HPV in fig. 2, which is basically a revised wheelchair with classical rear wheels with hand-rims, plus front wheel drive. The above goals can be reached by careful integration of a lightweight detachable/pivoting solar roof. Amorphous thinfilm solar cells add little extra weight to a composite material weather top able to provide the vehicle itself, or, when stationary, at home. Capacities are limited to daily commuting range at the most. And a permanent magnet DC motor draws minimal amperage, thanks to constant-torque stepless drive, as an improvement also to overall battery cycling efficiency.

A suitable drive system is being perfected by Reswick (4) (see *HUMAN POWER* No. 4 Winter 86/87) and may play an appreciable role in other HPV applications, if expected overall efficiency reaches 90-95%. The simultaneous effect of human plus auxiliary power would reduce the motor requirement. Ideally, components of the novel vehicle would be multifunctional in order to attain the envisaged savings in weight.

Electronics will play an equal part in keeping hardware small in optimal energy management and full user information, similar to the instrumentation of the SINCLAIR C-5 threewheeler.

Price sensitivity in this market should not be critical and the widespread need for

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such vehicles will allow for sizable production batches.

For the first time a thoroughly engineered mass-produced vehicle could demonstrate our philosophy effectively:

1. Technical feasibility and soundness of combining/integrating human power with other tractive means, and
2. Economic viability of such advanced HPVs, with corresponding encouragement for industry to push beyond this special case of benign commuting.

Widespread acceptance of HPVs by modern society has yet to come. However, cities around the world have by now completed their practical experiments with "soft" modes of transportation. There is no doubt that the benefits of human-based transportation to environment and health are immense and internationally recognized. Yet, fiscal discouragement of dinosaur use for daily short-distance routines can bite only when adequate public transit facilities get supplimented by widespread HPV acceptance.

Let us hope that pioneering efforts by communities such as Davis, California (5) will soon be matched by equally courageous industrial forays into alternative vehicle techniques, so that our mutual concern may get a strong foot in society's door to a more liveable future.

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FUTURE BIKE CH Moser St. 15
CH-2503 Biel, Switzerland

(4) J. B. Reswick
"Design Considerations for an Electric Vehicle Automatic Transmission"
RESNA 9th Annual Conference
via J.B.R. 1003 Dead Run Dr.
McLean,VA 22101, USA

(5) David B. Pelz
"Bicycle Programs"
Public Works Dept.
226 F Street
City of Davis, CA 95616

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Switzerland

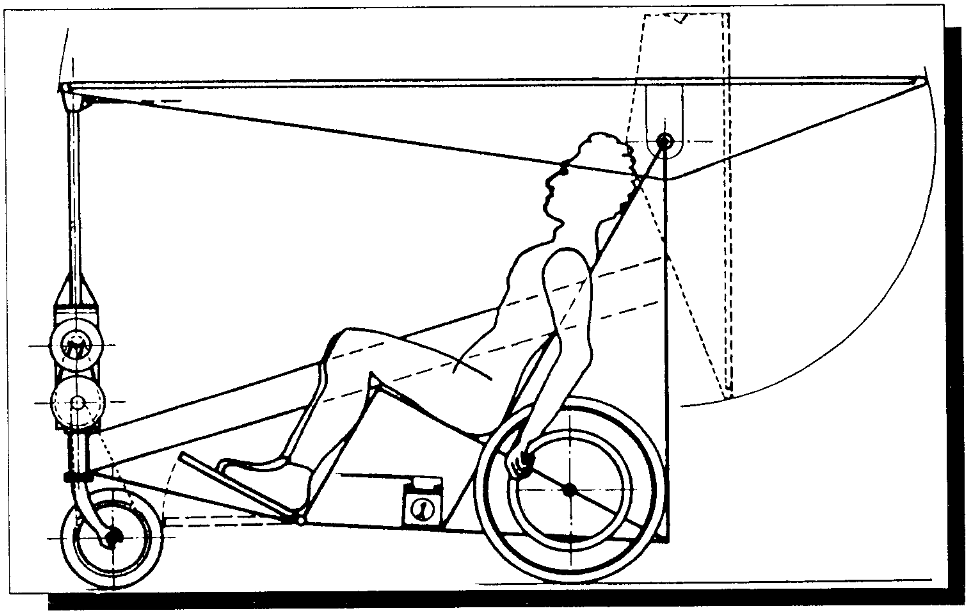

FIG. 2: Parasol *Project could produce useful transportation for physically disabled.*

VENTILATION OF STREAMLINED HPVs

by John Nobile

When making ventilation holes in the fairing of an HPV, a certain amount of drag will be induced due to the disruption of external air flow and the initiation of internal airflow. This increase in drag may be substantially reduced through the use of a diffuser.

A diffuser is a device that reduces the velocity of air while increasing the pressure. If properly designed, an efficiency of about 65% can be expected with respect to conservation of energy. A nozzle can also be used to reaccelerate the exiting air from the interior of the vehicle. Because this set-up allows the minimum amount of air to pass through the vehicle at a low velocity, the drag caused by this air is very small. Also, the air enters and exits at near free-stream velocity, which minimizes the disturbance to external airflow.

In order to design a diffuser of correct size and shape, the minimum velocity at which it must provide adequate ventilation must be decided. It is desirable to have an additional closable vent for very-low-speed operation (hill climbs) so that the diffuser will not be oversized for efficient ventilation at normal speeds.

A minimum effective speed of 15 m/s (33 mph) is chosen, and an air-flow requirement of 2 liters/sec. is considered adequate. By choosing the ratio of diffuser outlet-to-inlet areas to be four, the velocity of incoming air will be reduced by a factor of four before it enters the interior. There is a corresponding pressure increase associated with this velocity reduction, which is where the kinetic energy of the air is stored until the air is reaccelerated out of the vehicle.

To determine the inlet area required, the volume flow rate is divided by the free-steam velocity.

$$\text{inlet area} = \frac{2\ \text{liters/sec}}{15\ \text{m/sec}} = 1.33\ \text{cm2}$$

The free-stream velocity is equal to the rate of the vehicle if the inlet is located at the nose of the vehicle. This is the logical place since the relative velocity of the air is minimal. The value for the inlet area should be increased by about 12% to compensate for viscous forces. (1) This gives an inlet area of 1.5 cm^2, yielding an exit area of four times that, or 6 cm^2. The only thing left to determine is the divergence angle, or slenderness ratio, which can be determined from a diffuser performance map once the geometry is known (2). The diffuser efficiency is dependent on this angle.

For a flat-walled diffuser with a square inlet, a length-to-inlet width ratio of 14 will give an efficiency of 65%. Using a conical diffuser with a length-to-inlet diameter ratio of 14 gives about the same efficiency, which is near maximum.

As can be seen from this analysis, a properly designed vent opening will be

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small, and the drag induced by it will be small. In theory, if the vehicle were sealed, a nozzle should be placed at the tail to reaccelerate the air that is being expelled.

The nozzle may not be necessary in all cases, since in reality there are openings in the fairing for wheels, which will draw out the air.

By the use of properly designed diffusers, fully faired human-powered vehicles can be more efficient and practical for longer rides and for everyday use.

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(2) Ibid

John Nobile
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71 Wildwood Road
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(203) 374-4389

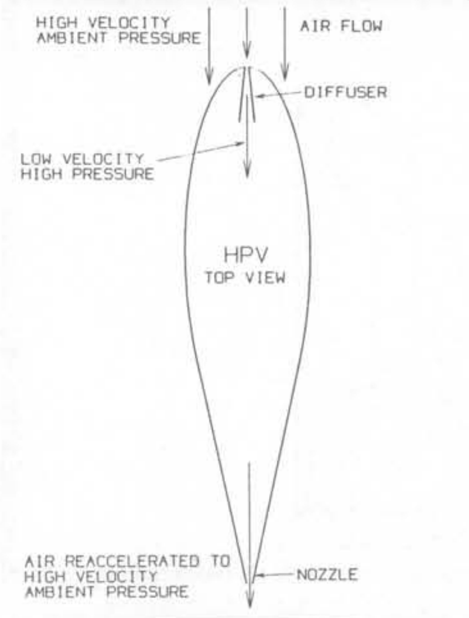

FIG 1: Optimized ventilating system.
DIAGRAM BY JOHN NOBILE

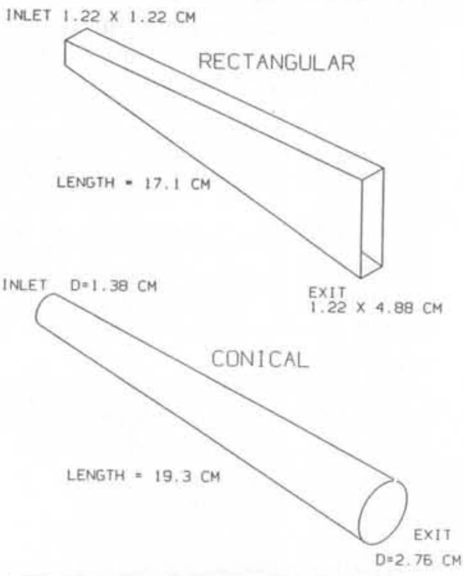

FIG 2: Diffuser Geometry. Area Ratio = 4; Efficiency = .65
DIAGRAM BY JOHN NOBILE

DEVELOPMENT OF AN AERODYNAMIC BICYCLE FAIRING

By James Donahue

RESULTS

The partial fairing which I have designed and built allows approximately a 3-4 mph (1.5 m/s) advantage over the unfaired bike. Speeds mentioned in this article were recorded in miles per hour by a Cateyemate cycle computer and were converted to meters per second and rounded off. I rode the bike myself for these test runs, although I do not race professionally. On level ground I have never exceeded 30 mph (13.4 m/s) with the unfaired bike. I have gone 31 mph (13.6 m/s) with only the spoke cover on the rear wheel. On the morning of July 16, I achieved 34 mph (15.2 m/s) on level roadway with about the same level of effort as a 30 mph (13.4 m/s) sprint. Previous unpowered coastdown testing has been suspended due to the fact that the hill was too steep. The brakes had to be applied to keep the vehicle under 37 mph (16.5 m/s) in order to negotiate the curves safely. The unfaired bike averaged under 35 mph (15.6 m/s) on those tests. These tests are somewhat subjective, and I will do more testing. I plan to be at the next IHPSC in Washington DC this September where the official timing tests will be more objective.

I have applied for a Design Patent on this Aerodynamic Bicycle Fairing.

Author with partial fairing

CONSTRUCTION

The fairing is the third prototype. The first prototype was built of aluminum in October 1985. The incentive to build such a device came from the technical data in the article by Gross, Kyle and Malewicki in the December, 1983 *Scientific American*. The second prototype was a modification of the first, with sides being extended down to fair the lower portion of the bike and rider. The second prototype was noisy due to vibrations. The first fiberglass mold was made from the second aluminum prototype.

The mold was then filled in with more fiberglass to round off the sharp corners inside the mold. I've developed a good mold-release mixture which consists of silicone-rubber caulk thinned to brush-on consistency with epoxy/lacquer thinner (toluene, methanol and methyltrimethoxysilane pose certain health hazards. Wear rubber gloves and a respirator if you decide to experiment with this stuff. Get the Material Safety Data Sheets from the manufacturer of any resin you may use. It may be of interest, for example, to know how much epoxy resin it takes to kill laboratory animals). The third prototype was made of fiberglass/ epoxy from the mold. An extra plug has also been made of fiberglass/polyester resin from the mold as I am not satisfied with the surface of the mold. I plan to make a really smooth mold from the plug after it is smoothed out. Kevlar will be used for the fourth prototype when the second mold is ready. The windshield is acrylic plastic which I heat-formed over an electric barbecue grill while wearing a respirator and heavy gloves.

The windshield is held in place with nylon screws and nuts, and is sealed with silicone caulk. The heads of the screws are covered with ductape.

An interesting safety feature is the 20-watt sealed-beam quartz-halogen headlight, which is covered with acrylic

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CAFE RACER, AN UNUSUAL APPROACH

by Marten Gerritsen and
Marinus Meijers

(Both authors are former chairs of the NVHPV; Marten was also a founder and a former secretary of the club. He is an automotive engineer in the school of management studies at Twente University of Technology, and Marinus Meijers is a mathematician working in industry - ed.)

FIG. 1: Café Racer - one of the new breed of European streamliners (shown without roof panels.)

Introduction

Compared with the situation in the United States - that is if *HPV-News* gives us a balanced impression - sprint machines have never really caught on in Europe. The few machines we do have over here are usually *Vector*-copies, although there are of course some (usually British) exceptions, the most notable being *Bluebell*, *Poppy Flier* and *the Bean*. Practical machines are the norm, not surprisingly if one considers the difficulties of trying to find a suitable test track for a proper sprint machine. Dutch roads are windy, narrow and busy, and above all difficult to close off legally.

Of course these small matters will not deter determined constructors, especially once they have agreed to build streamliner in a fortnight. (Yes, it was late, but no, we hadn't been drinking so yes, we're probably slightly mad). We had several reasons to build a sprint vehicle:

- we thought it would be nice to put an interesting sprint machine on the "Tweewieler RAI", our national bi-annular cycle-show;
- at that time the DuPont prize was still on offer and we were not adverse at having a go. However, like everybody else in Europe, we were just another loser as soon as the US teams went for high altitudes; and
- we have a somewhat different view on what will make a fast vehicle, and building a machine is the most practical way of finding out whether these views can be justified. As we feel that our present results support our approach we hope the following will be of interest.

Design philosophy

Nearly all sprint machines we have seen will not travel in a straight line. This is of course wasteful as:

- it will reduce the rider's level of confidence;
- it will represent an energy loss; and
- it will disrupt the flow over the body.

The rider is probably the most important factor here. A top-class athlete is hard enough to come by without expecting him to put up with an extensive familiarization period to adapt to the vehicle's deficiencies.

Our main object therefore was to build a dynamically stable vehicle and leave the aerodynamics until later. We also thought a prospective rider would feel more comfortable in a three-wheeler than in a single-track vehicle (with all its inherent sidewind problems) although in a crash a two-wheeler could well be safer. The near-circular section of most three-

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plastic in the same manner as the windshield for aerodynamics. Bicycle Lighting Systems (see the Source Directory for address) is a good source for these lights. I feel that a bright headlight should be incorporated into any HPV used on the roads open to traffic. My 34 mph (15 m/s) ride was done before dawn to avoid traffic. The battery is kept in the bag under the seat. A Berec red tailight with HPR-52 halogen bulb and a Belt Beacon are attached to the bag. Reflective tape appears on the fairing, bike frame, and rear aero spoke cover.

Full-Fairing Potential

I have considered building a tail fairing to be used in conjunction with the front fairing. With stretchable fabric attached over the sides to cover the gap between the front and the rear, the vehicle would qualify as "fully faired".

More Tech Data

The third prototype fairing weighs 7.5 lbm or 3.5 kg. The whole bike weighs 41 lbm or 19 kg. BMX brake levers are attached to the ends of the drop handlebars with handles pointing forward. ATB finger shifters are attached where brake levers usually go. Tires are 27 x 1-1/8. Avocet smooth-tread clinchers at 105 psi or 724 kPa. High gear is 54 x 13 or 112 gear inches.

Please feel free to write if you have any specific question(s), but do enclose a stamped, self-addressed envelope.

James Donohue
87 Plymouth Drive North
Glen Head, New York 11545
USA

wheelers makes them much more prone to a "barrel-roll", while the popular canopies reduce the strength of the shell considerably.

However, because for production reasons our shell would have to have a flat bottom, we settled for a three-wheeler. A rear-wheel-steered vehicle will never feel as safe as a front-steered one (at least we have never built/ridden one which comes close), so from a psychological point of view it would have to be a front steerer. Low rolling resistance is of course another necessity, and here we decided a single front wheel would be superior as it bypasses all toe-in/toe-out problems of a steered axle. A reclining seating position gives more power than a prone position and would be more familiar to the prospective riders (car-like). (A normal cycling position is of course even better, but offers too big a profile and the C.G. would be way out.)

Nothing good has ever come of a chain-drive with lots of pulleys and lots of free lengths whipping around (ask Moser) so we would have to have front-wheel drive as well.

In fact, this all is starting to sound much like an *Allegro* or *Poppy Flier*, but we were not too impressed by them. For instance, how can you expect *Allegro's* three crankshaft bearings to stay in line in what must be a flexible body-shell? And we certainly were not going to spend massive amounts of time and money (our budget was only $200) on a mould for a body shell (which the first time invariably turns out to be too short, narrow or whatever).

But then, of course, we had to come up with something different in order to stay within our meagre budget and our self-imposed time-limit.

Driveline

The design brief for the driveline held quite a few requirements:

- Front-wheel drive
- Front-wheel steering with sufficient lock to steer the vehicle even when on two wheels (rather useful at over 22 m/s (50 mph) when you encounter heavy crosswinds; we run a narrow track)
- Good dynamic handling qualities and adjustable geometry
- Gears in the 7-11m range (87"-145") for a design speed of 20m/s (45 mph).
- 24" front wheel
- High efficiency
- Compact build
- No machining operations more complicated than milling, turning or brazing.
- Easy to service and to set up.

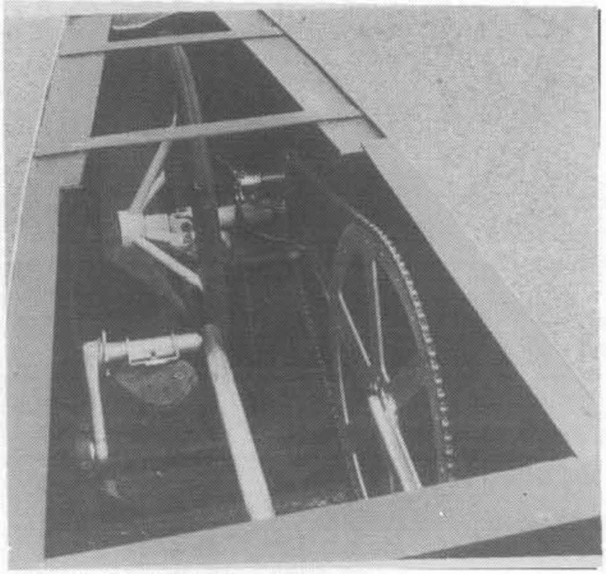

FIG. 2. Final driveline design.

For the drawing board we felt this could be translated into a steering-axis in the plane of the wheel, adjustable trail and derailleur gears. To clear the front wheel on full lock the chainline has to be moved over to the right and this either means an asymmetric weight distribution or a "sidewinder" setup. We opted for the latter solution and therefore we had to build a crankshaft as a layshaft was, of course, not acceptable.

The final design is shown in the illustrations.(Fig. 2)

The crankset consists of a centertube (ovalized downtube) with two high-carbon axles brazed in welded-in sockets. The pedal tubes run on needle bearings with bronze thrust washers taking up sideslack. Two standard cranks are bolted on the tapered ends (we use the cranks the "wrong" way up) and two self-aligning bearings are fixed to the pedal threads. The right-hand bearing stub also locates the 100-teeth chain ring while a hose clip tranfers the drive torque. The whole assembly is mounted in a thin-walled steel subframe which also takes the front-hub assembly.

The hub-bearing assembly is a fabricated item with a steering offset of 50 mm (2"). This means that some sideways movement of the drive shaft has to be accomodated. The drive shaft-cum-U-joint is built up from a thin-walled tube with end pieces brazed on.

The home-made U-joint runs on ball bearings and a tapered axle-end transmits the drive torque to the road wheel. The caster angle is adjustable by rotating the hub-assembly in its mounting, but obviously this also affects the ride height. The steering arm is as long as possible to diminish problems which could arise from play in the joints or flex in the push-pull steering rod.

The front wheel features a plywood rim connected to the alloy hub by four spokes made out of 16-mm (5/8") conduit bolted and glued in place.

The drive shaft is free to move sideways. This is accomplished by mounting the end bearing (again of the self-aligning type for obvious reasons) on a swing arm which also mounts the derailleur.

The gear-changer is modified to take the cage on the outside. The body therefore does not protrude outside the chainline.

The 20" rear wheels (wired-on tyres) use hubs with location pins. The axle tube was made in a lathe so alignment problems were kept to a minimum. Two triangles of light tubing connect the back axle to the body. Lateral stifness in the truss is provided by two lengths of welding rod brazed in place. The rear frame also provides the mounting points for the two sidepull-brakes. Access to the rear wheels and brakes is extremely good (the cardboard belly-pan is only taped in place) so it is easy to adjust the brakes so that they will not drag.

The body

The body of *Café Racer* is constructed out of 3-mm (1/8") plywood. 2-mm plywood would perhaps have been more appropriate but it is much more expensive. The sheets are joined by a method known in boat-building circles as "stitch and glue". A Tornado-class catamaran is a nice example of the art. The 3-D shapes that can be obtained are surprising, but as this was to be our first attempt we have been rather conservative and as a result the vehicle is far too angular to expect good aerodynamics. A flat bottom was used as it greatly simplifies construction by providing a convenient measuring plane. In a borrowed living room, the carpet

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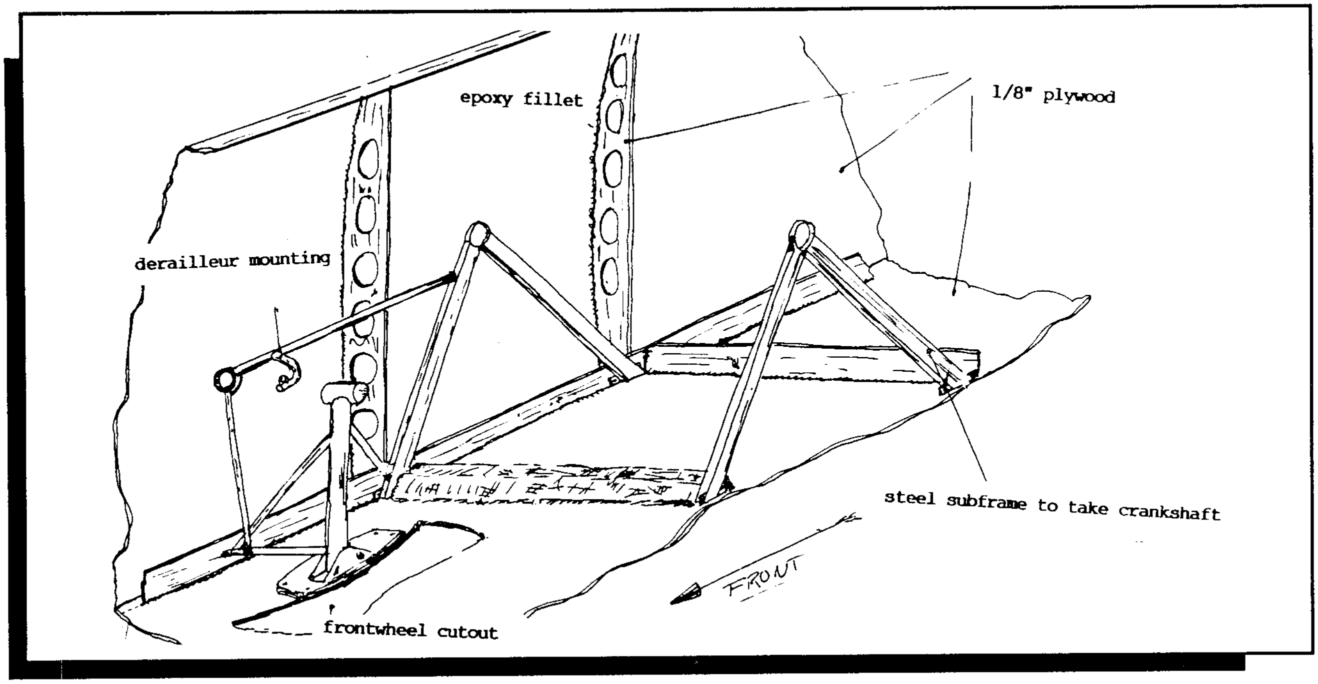


FIG. 3: Cutaway shows details of steel subframe, derailleur mounting and fairing construction.

was rolled back and a couple of wood joists were nailed to the floor to provide a working surface. The floor pan was temporarily tacked in place and the bulkheads were cut and positioned. The next step was rough-cutting the sides and stitching them into position. Instead of thread and needle we used a power drill and plastic-coated copper-wire. The plastic coating is essential as it will not stick to the epoxy we used to glue it all together and so we were later able to remove the wire.

Depending on the expected loads we used either E-glass tape and epoxy or only a fillet of resin and microballoons smeared along the joint. (*Fig. 3*) When cured all staples and bits of wire were removed (much better for all planing and sanding operations) and foam blocks for the trickiest shapes were cemented in place. The roof of the vehicle is also made out of "Roofmate" and it was shaped with an electric plane (the actual shaping taking only minutes in sharp contrast to the vacuum cleaning required afterwards). The foam particles wind up with an electrical charge and will stick to anything, including windows, to the chagrin of curious neighbours.)

As mastering the art of vacuum forming great expanses of Plexiglass was deemed to be to time- and cash-consuming we opted for flat windows. Nowadays, the windows are not only taped but bolted in place as well; at first we kept losing them when transporting the vehicle on a car roof. Entry is by removing the center roof panel.

Performance

Vehicle weight is a rather disappointing 40 kg but we have an excellent professional paint job (courtesy of EBAG-trucks) which surely weighs 5 kg!

And although low weight is very handy when storing or transporting the vehicle our computer simulation points out that minimal weight is not all that important.

Handling wise, our vehicle turned out to be a disappointment. From day one it handled so well that we had to shelve our envisaged development program.

At the European Championships we finished second with a totally untested vehicle and a mediocre rider. Upcoming heavy sidewinds spoiled our last runs and finally finding top-gear means little when you lift a wheel in the traps. So in the end we managed only 82.16 kph (51.625 mph) against the experienced Gerhard Scheller's 92 kph (57.5 mph) in the Gronen *Vector.*

Subsequent testing at the Oldenburg University (W. Germany) by Falk Riess and Rainer Pivit revealed a stunning CDA factor of 0.110 + 0.016 (m2), which translates into a drag factor of around 0.27.

The rolling resistance was rather better with .0446 + .0024, especially when one considers the mediocre quality of the wheels involved.

Our drag-factor (measured by averaging 10 decelerations in the corridors of the university) is in marked contrast to claims made by everybody else, Gronen for instance claiming 0.07. In our opinion this justifies our conclusion that to go fast, you first of all need a good-handling vehicle. It also probably means that some claims are perhaps slightly optimistic.

Notes

Café Racer was originally built with two 28" wheels in the rear with a upwards-sloping tunnel in between, so in fact the vehicle appeared to have two tails. This proved to be an aerodynamic mess and the wheels probably never tracked. We managed only 60 kph (37.5 mph) and with tufts and video we found a large mass of stagnant air around the tail. So, two days before the European Championships we converted to two 20" wheels and a normal tail configuration.

With our construction this involved little more than cutting through the glass tape, bending the panels in the required shape and making a new bulkhead and gluing on another block of foam.

We didn't even have to disturb the paint job, some small touching up on the morning before the race being all that was needed. It did, however, impose some logistic problems as it meant that we had to go racing with two trikes and a two-wheeler, and only six wheels to share between them!

Bolting the shoes to the pedals was another bad idea which turned out to be very tiring when waiting. We soon converted to the system as used in the Elgar Clip track pedal. Our version is however three times as big.

DESIGN AND TEST OF A HPB PROPELLER

By David Gordon Wilson

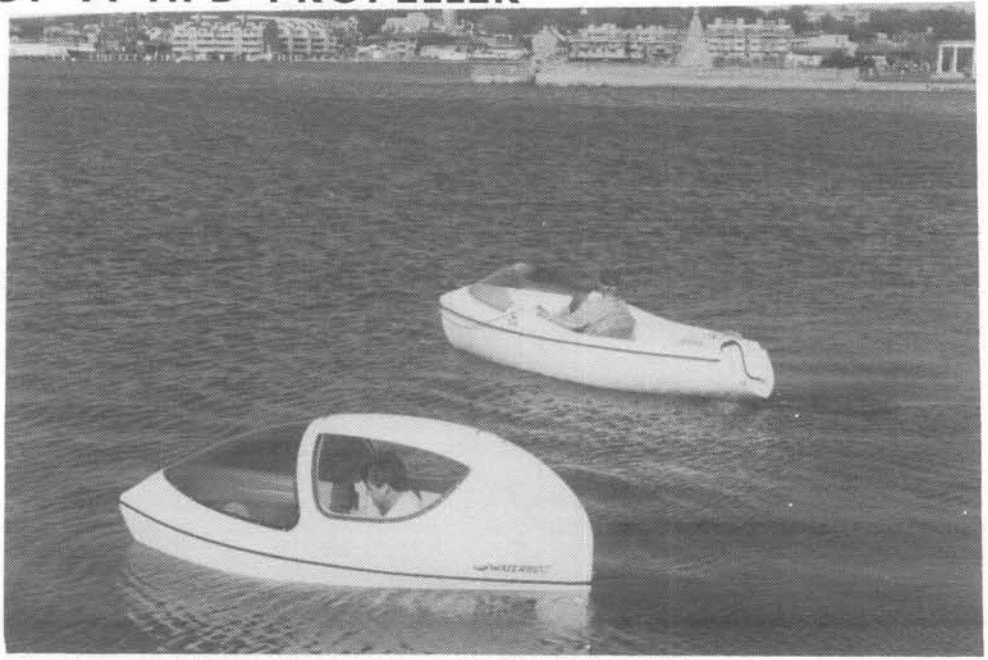
SUMMARY

A two-bladed small-chord propeller was designed using an advanced code based on Larrabee's minimum-induced-drag procedure, and was tested on a Hoyt-Laser "Mallard" against a conventional three-bladed large-chord propeller. It showed an approximately ten-percent improvement in acceleration time.

BACKGROUND

Garry Hoyt, whose designs have been seen in *HP* vol. 5 no. 4 (in a book review) and vol. 3 no. 4 (a news item about his "*Waterbug*"), wished to have a high-efficiency propeller designed for his new HPB, the "*Mallard*". He commissioned a new design from someone highly skilled in designing aircraft propellers, and the resulting three-bladed design looked very like something from an aircraft. Unfortunately, it seemed to run completely stalled until nearly up to full speed, giving a very slow acceleration. Pedalling the boat from a standing staft was like churning wool. In order to get the *Mallard* into the water, Garry modified a traditional boat propeller (three blades and very large chord - *i.e.* width), and it gave good all-around performance from a dead-in-the-water start.

He came to me to ask if a higher-efficiency unit could be designed, preferably with two blades so that the boat would be more attractive as a yacht dinghy. (Having two blades means that one is in the lee of the keel, reducing drag when the dinghy is towed behind the yacht). I added the project to my thesis list at MIT, and Kent Piland chose it for his senior thesis, and Don Chan worked on it as an undergraduate-research project.



Waterbug and Mallard in Newport Harbor. PHOTO BY: Dave Wilson

Kent Piland with new design propeller
PHOTO BY: Dave Wilson

PROPELLER DESIGN

The work fell into two parts: the propeller design and the test. The design part was relatively easy. We went to Mark Drela, principal aerodynamicist for the MIT HPAs and on the Aero-Astro faculty, and he was kind enough to let us use his MicroVax and his "ROTOR" propeller-design program. It has a long pedigree, through at least Betz and Larrabee (see *HP* vol. 3 no. 2), and Mark has added his own improvements and made the propeller extremely user-friendly. The design specifications were simple: the diameter must not exceed 400 mm and the boat design speed was about 2.25 m/s. We used a hub diameter of 60 mm from one of the existing designs. Kent and I chose to use a pedalling rpm of just over 60 and the existing four-to-one step-up gear, giving a prop speed of 250 rpm. With Mark's input we chose a tip lift coefficient at stall of 1.3.

Other aspects of the propeller design are given in Kent's BSME thesis (*Tables 1-3 and Figures 1 & 2 were taken from his thesis*). Garry Hoyt turned these data over to Aero-Prop, of Meaker, OK, which produced a handsome-looking prototype in laminated-and-varnished wood (*See below*)

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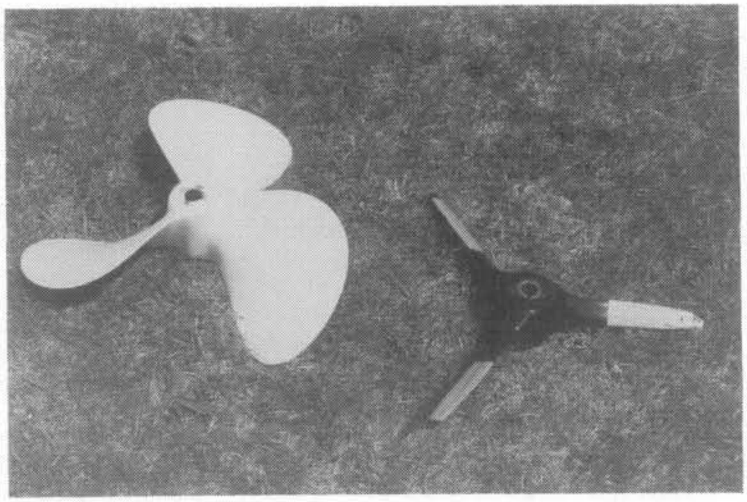


TABLE I: FINAL DESIGN OPERATING CHARACTERISTICS

speed (m/s)	tip lift	hub lift	thrust (N)	eff (%)	power (W)	rpm	torque (N*m)
2.2	0.4	0.4	49.0	83	129.75	250	4.95
1.0	0.95	1.36	65.83	65	100.0	192	5.0
0.5	1.29	1.5	63.62	34	91.19	174	5.0

TABLE 2: BLADE DIMENSION

station no.	radius (m)	chord (cm)	angle (deg)
1	0.04	8.34	62.04
2	0.06	8.94	52.55
3	0.08	9.10	44.71
4	0.10	8.74	38.33
5	0.12	8.00	33.18
6	0.14	6.98	28.98
7	0.16	5.69	25.53
8	0.18	4.04	22.67
9	0.19	2.93	21.42
10	0.20	1.00	20.25

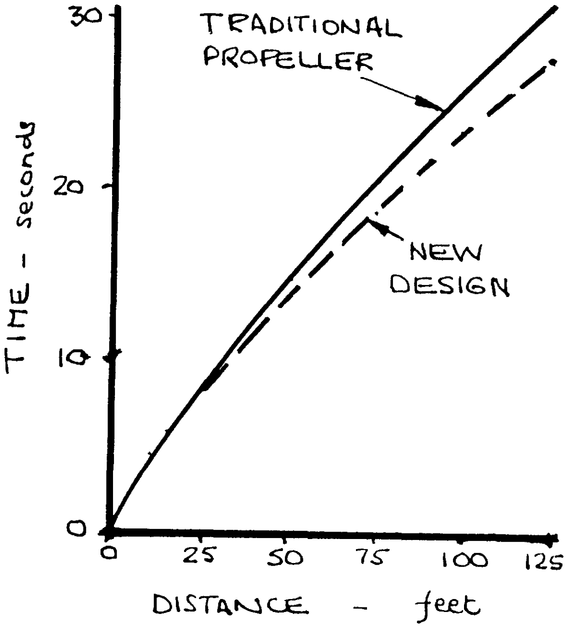


TABLE 4: TEST RESULTS

TABLE 3: FOIL-SELECTION THICKNESS COEFFICIENTS

NR	X/T	YU/T	YU/T
1	1.00000	.00000	.00000
2	.99893	.00016	.00004
3	.99572	.00065	.00016
4	.99039	.00153	.00027
5	.98296	.00288	.00033
6	.97347	.00471	.00030
7	.96194	.00697	.00019
8	.94844	.00958	.00002
9	.93301	.01247	-.00017
10	.91573	.01563	-.00036
11	.89668	.01895	-.00057
12	.87592	.02254	-.00081
13	.85355	.02635	-.00110
14	.82967	.03039	-.00148
15	.80438	.03462	-.00193
16	.77779	.03901	-.00247
17	.75000	.04355	-.00309
18	.72114	.04818	-.00391
19	.69134	.05285	-.00461
20	.66072	.05753	-.00549
21	.62941	.06215	-.00647
22	.59755	.06664	-.00752
23	.56526	.07093	-.00864
24	.53270	.07480	-.00983
25	.50000	.07821	-.01106
26	.46730	.08100	-.01233
27	.43474	.08310	-.01362
28	.40245	.08445	-.01491
29	.37059	.08500	-.01618
30	.33928	.08475	-.01740
31	.30866	.08369	-.01856
32	.27986	.08187	-.01962
33	.25000	.07938	-.02056
34	.22221	.07631	-.02135
35	.19562	.07270	-.02196
36	.17033	.06861	-.02236
37	.14645	.06408	-.02255
38	.12408	.05918	-.02240
39	.10332	.05393	-.02208
40	.08427	.04837	-.02145
41	.06699	.04264	-.02045
42	.05156	.03670	-.01901
43	.03806	.03039	-.01753
44	.02653	.02462	-.01569
45	.01704	.01871	-.01277
46	.00961	.01210	-.01024
47	.00428	.00660	-.00750
48	.00107	.00330	-.00442
49	.00000	.00000	.00000

TESTS

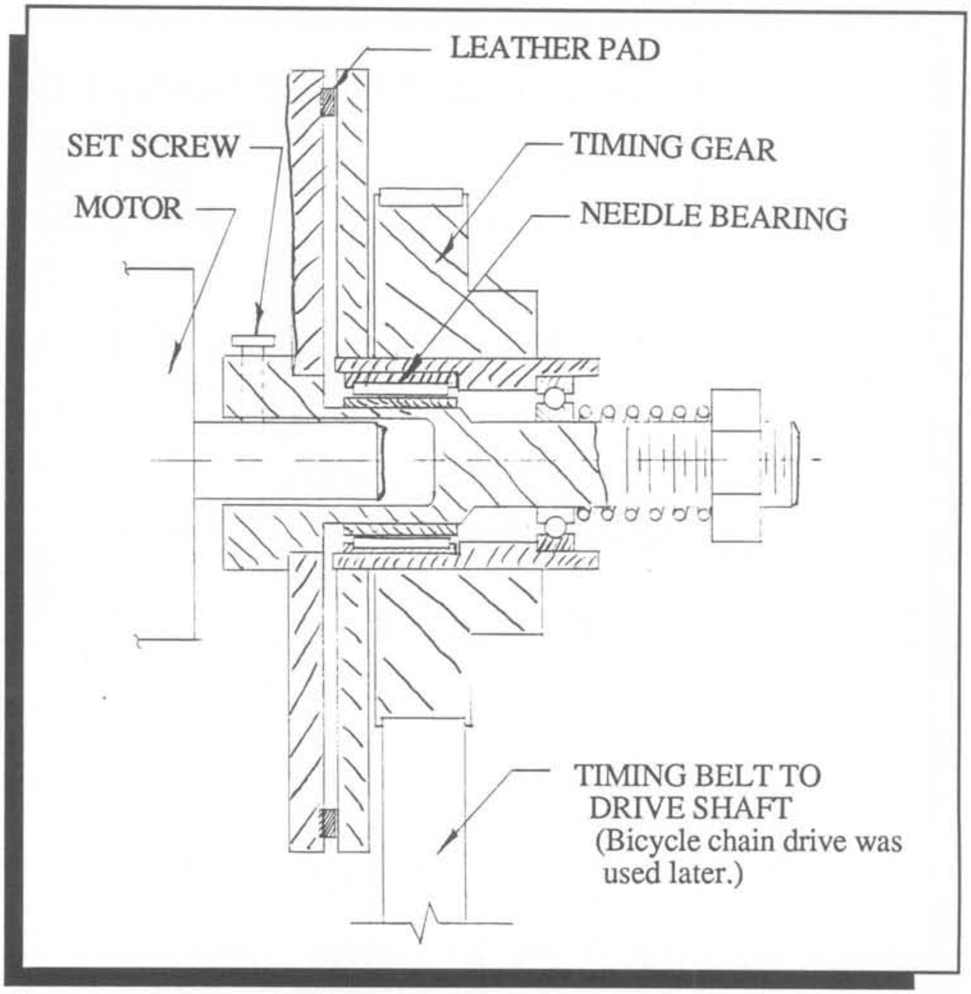
It would have been pleasing to have reported that we tested the propeller in some high-tech facility at MIT. However, the principal propeller tunnel was fully booked 24-hours a day, and if we had found an open hour it would have cost us several hundred dollars. After reviewing many unattractive alternatives we decided on an on-boat comparative test against the existing propellers. (Because of shortage of time we tested only the new and the traditional propeller). We tried to devise ways of measuring the power input accurately, and then hit on the idea of supplying simply a known torque. All we had to do was to build a slipping clutch (*FIGS. 3 & 4*). So long as we turned the input to the clutch faster than the output, the torque output would (presumably) be absolutely steady and constant. We also bought a surplus 48-volt DC motor, Garry bought four auto batteries, and Kent, Don and I drove down to Newport, RI on the last possible Saturday of the summer term.

Our modification of the Mallard drive system to take the motor, clutch and chain gear reduction was not something to advertise too widely, but it worked very well. We ran the tests as follows. We marked off the harbor wall with various distances from a starting point. One of us sat on the four auto batteries in the boat and manouvered the *Mallard* until it was level with the starting line, stopped. On the "go" signal the motor switch was thrown on, and two others in the team ran along the harbor wall, timing the arrival of the prow of the boat to the various marks. After a succession of runs we switched the propellers and repeated the tests *(Table 4)*

The new design shows a significant improvement in performance at constant torque. This was quite satisfying, because the new design seemed so much less substantial to look at. It would certainly give far less drag when being towed.

We assumed that it would also have a higher efficiency. These simple tests could not prove that. If we could have recorded the shaft speed of each propeller as a function of boat speed we would have had better performance comparisons. A possible (and less favorable) explanation of the improved performance of the new propeller could be that it was turning at a higher speed than the old design, and was therefore absorbing more power. However, we don't think that that was the case.

At least Garry Hoyt, who is a very courteous person and most enjoyable to work with, professed himself very happy with the result.



▲ *FIG. 3 Cross-section of slipping clutch.*

▼ *FIG. 4 DC Drive motor and constant-torque slipping clutch. PHOTO BY: Dave Wilson*

WHAT IS CYCLING?

Human power can be used for moving a person on land or water with or without a vehicle. Cycling is a special case of a vehicle having wheels and moving over the ground. It is useful to consider human-powered locomotion from a larger framework so that the cycling portion can be better illuminated and defined.

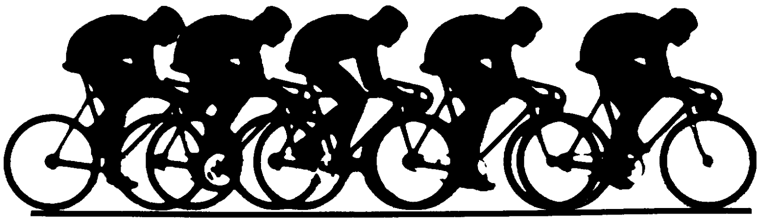
A person swims in water, but can move faster with the aid of swim fins, webbed gloves, and certain wing-like devices operated by the legs. More complex devices eventually constitute vehicles. Some rare boats are propelled by legs, but most involve arm-operated paddles or oars: paddleboards, surfboards, kayaks, racing shells, and rowboats (and to be complete, even 300-man oared boats from several thousand years ago).

As for land, there are skis and snowshoes for snow, and skates for ice, while for ordinary surfaces there are bare feet, "human-powered shoes" in great variety, stilts, pogo sticks, skateboards, scooters, and cycles with 1-,2-,3-, or 4-wheels (mostly leg-driven, but some, such as wheelchairs, using arms). One can even add somersaulting and walling on one's hands and note the application of human power to mountain climbing.

Human-powered flight requires a vehicle. The vehicles at present are all large, light-weight, propeller-driven devices.

To complete the picture, note that animals other than man provide power for vehicles, usually to move man or some load of interest to man. Sometimes muscle power is augmented, as with electric motors, or gasoline engines. Small fossil-fuel engines can generate tens and even a hundred times as much power as a person and can permit a vehicle to have better performance, and be heavy, rugged, and safe. Battery power is more limited but still packs much more wallop than muscles and has the added potential of regeneration from braking or charging from on-board photovoltaic cells. Sometimes wind or wave motion is harnessed to help propel a vehicle that also uses human power.

Finally, we need to note that gravity, through non-horizontal terrain, plays a significant role in cycling. Climbing uphill takes extra power at the rate of weight times vertical ascent speed. Moving slowly on foot, the extra power is considerable; moving fast on a bicycle, the ascent speed can be large and the extra power requirement huge.



Thus there is a whole spectrum of power sources for apparatus and vehicles that transport people, from relying 100% on human muscles to 0%. Here we focus on bicycles powered solely by muscle, while recognizing that some interesting technological innovations may arise from a bit of augmentation by electricity, fossil fuel, or wind. If the augmentation dominates, the we end up with a car or motorcycle, which may be practical but which eliminates the exercise benefits and challenges of cycling.

Man is inefficient as a runner. With efficient mechanisms (bicycle, ice skates) he can move about twice as fast as running, to a sped where air drag starts to dominate. Then, with a streamline fairing, the speed can be doubled again. The inefficiency in running is due to the loss of potential energy with each step as the center of gravity is raised and lowered without effective energy storage and recapture, and poor recapture of the kinetic energy of moving limbs.

The bicycle is an extremely efficient mechanical device for deriving power from the rider. The constant center-of-gravity position eliminates the potential energy loss each cycle, while the pedal-chain-wheel-inertia system avoids the kinetic-energy loss. The bicycle, with its large diameter low-drag wheels, is also extremely efficient as a device for moving over a smooth, hard surface. No shoes, scooter, skateboard, roller skates, or pogo stick offers the combined effectiveness of a bicycle in power extraction and motion efficiency. Vehicles with other than two wheels have special features: the unicycle emphasizes fun with great demands in skill: three and four-wheel cycles emphasize stability for less agile cyclists and in some cases a great load-carrying capability which is used commercially, especially in other countries.

The bicycle readily reaches a high enough speed that the standard vehicle is fun to ride, useful for sport, touring, commuting, and exciting competitions. It is a wonderful device to lure people into healthy exercise. In races, however, the speeds are such that aerodynamic drag becomes a dominant factor. Thus vehicle design looms large, and the troublesome challenge for rule-makers is to provide definitions and limits for vehicles so that winning cyclists are fairly selected.

Design evolution and the IHPVA: analogy to natural evolution

Given enough time to for development, entities evolve, within the constraints of physical law, to fit a desirable opportunity. There is a close analogy between the way goals (rules, motivation) stimulate or inhibit technical developments and the way the characteristics of a particular ecological niche in nature (the coal limits, opportunities, and competition), serve to design the creatures that fill the niche.

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Evolution of creatures, devices, or ideas works on the simple basis that things which leave descendents are those which work well enough to survive the competitive pressures and leave descendants. There is no right or wrong and no perfection, just the criterion of relative success. Whether the law of the jungle or the law of manufacturers' economic competition is involved, what succeeds In nature, the ecological niche establishes the rules; any solution can enter the fray and will be scored versus competitors. In man's technology, with development staking place thousands or millions of times faster than in nature, the economics of large-scale manufacturing is a strong forcing function and this market depends on standardized demand and hence on the existence of rules and advertising.

Almost a century ago, after several decades of design innovations, the conventional "safety bicycle" emerged with its two equal-size tangent-tension-spoke wheels, pneumatic tires, and chain-driven rear wheel. The standard bicycle of today differs from this ancestor only in detail; except for the gear shift, the changes would scarcely be detectable to the casual observer. One reason the 1986 and 1886 bicycles are similar is that the 1886 version was so good, being efficient, safe, easy to ride, easy to store, and simple and inexpensive to build. But another reason is that bicycle competitions,which tend to set technological standards even if only a small percentage of cyclists competed, dictated that the vehicle be standardized (Therefore not be improved) so no rider would have an unfair advantage. Like a species of animal, the multitude of these satisfactory bicycles fitted well their broadly based and economically driven "ecological niche" and the design evolved only very slowly and in minor ways as the decades went by.

One modern view of natural evolution has a new species sometimes evolving out of a stable, established species via a major, rapid, adaptive change labeled "punctuated equilibrium". In a suggested scenario a small group of animals somehow has to operate in isolation from the main group, in a circumstance where different ecological pressures are found to be especially favorable to certain inheritable genetic aberrations or traits. The genes (the carriers of the creature's design to the next generation) of the odd superior individual in the large population get submerged in a massive gene pool and have little effect. But in a new, small, isolated ecological niche, the superior individual's superiority can be relatively more important for survival, the individual's genes will be less diluted in the small population, and in relatively few generations a new species can evolve. Eventually the new species may even spill over into the large original ecological niche, prove competitively superior there, and completely supplant the original species.

In 1975, the IHPVA was formed to stimulate the development of fast human-powered vehicles without the inhibiting effects of rules. The sole criterion of success was "going fast",with no concern about the mechanism or configuration. The resulting evolution of new designs was rapid, as a small number of inventors (initially in Southern California) found what worked in this new isolated "ecological niche". Fantastic speds are now being achieved (65 mph, 105 kmh); equilibrium was "punctuated".

After a few years of strictly speed competitions, IHPVA added competitions for "practical" vehicles. The definition of "practical" is still in a state of flux,as are the criteria for judging the vehicles, but the overall aim is clear: a human-powered vehicle that offers safety, speed,versatility, comfort, and economy, and that would be attractive both to commuters and long-distance riders. A new"species" only can evolve from this competition if a design emerges that is so satisfactory it becomes widely manufactured; no such design has yet been demonstrated.

For half a century there have occasionally been isolated pioneers showing that streamlined fairings permit high speeds or that unusual configurations show promise for meeting a specific customer's desires, but such aberrations had negligible impact on conventional bicycles. Serious developments of mainstream touring, sporting, and racing bicycles were economically driven and tended to be ones that could be comfortably assimilated into the mainstream, such as the ten-speed derailleur and improved brakes. The major trends that kept cycling healthy over the last few decades have been popularization of variations on the theme of the conventional two-wheel bicycles with standard seating position. The economy and versatility of the ten-speed gearshift brought many customers into the field; BMX bikes for competition and rough use around town have created a substantial new market; and mountain bikes are a recent success story.

IHPVA has popularized an enthusiasm for generating significant change and, with its competitions, media interactions, newsletters and technical symposia, has stimulated inventors,cyclists, manufacturers, and universities to explore technologies for the future. The international publicity accorded early IHPVA records no doubt helped stimulate the aerodynamic innovations for standard bicycles which began in 1976. By 1978, aerodynamics, tubing, clothing,and helmets were commonly contributing to higher speeds. Dr. C.R. Kyle, co-founder of IHPVA, has been a significant contributor to the technology that in 1984 produced the U.S. Olympic bicycles.

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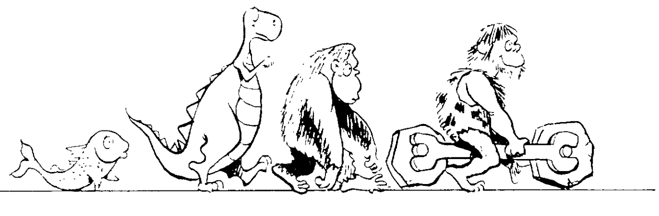

RULES AND THEIR EFFECTS

In 1938, the Union Cyclist International established rules against recumbents and streamlined fairings in racing. After the 1976 developments cited above, in 1978 the UCI "loosened the tourniquet" on the prohibition of aerodynamic features. In 1984, an aerodynamic rule milestone (or millstone, depending on your point of view) was achieved when Moser was permitted to set an official one-hour record at Mexico City with a bike that had been tailored in a wind tunnel and featured solid wheels, and subsequently similar Olympic bikes were accepted. The door for innovations via aerodynamic modification has certainly been opened a significant amount, but at the cost of some controversy about the past decisions and questions where this all leads, about what rules will best serve the purposes of cycling.

There is also the question of the criteria for competition. In a team sport, such as soccer, the winner is a team, not an individual. In a 100m freestyle swimming race, the winner is clearly th the individual. For a faired bicycle/tricycle speed event or a human-powered airplane challenge, the vehicle is a major part and the prize or honor is usually shared by the rider and the vehicle developer. In the Tour de France, an individual wins, but aided by his team. In international sailplane competitions, radio communications permit the several competitors from one country to coordinate thermal hunting and give an improved chance to each of them and a still larger chance to a particular one. Such coordinating communications complicate the issue of whether the winner is an individual or a team. This coordination is done by some countries with well-disciplined teams; with other countries where discipline is less characteristics and where the competition is clearly considered as selecting an individual winner, the radio is not used for "collusion" purposes (and a competitor may even use it to mislead his competition while also gleaning from it whatever useful information he can).

It seems logical to adopt the general principle that the official winner(s) of a competition is the individual or group whose efforts were dominant in determining the winning. For solo events where no apparatus is required, such as swimming and running, or where the apparatus offers no special advantage, such as tennis, bowling or chess, the principle is straightforward to apply: the winner is the winner. For team events, the team is clearly the winner. In every case, a coach/trainer may have made a significant contribution, even masterminding a football triumph, but the competitor(s) gets the official reward. Where the apparatus makes a unique contribution to winning, the designer/developer (or sometimes the sponsor) gets some or most of the plaudits.

Categories promote competitors reasonably. The hare races the tortoise only in myth. Categories based on size or weight or age or sex are easily defined. Categories based on experience or ability are generally harder to define, and there is continuing controversy about amateur vs. professional. Categorization is brought to a high level in BMX racing: age groups, subdivided into novice, intermediate, and expert classes based on the number of top finishes in a lower class.

Where the rules must also consider apparatus, categorization can get sticky (except where the competition is about apparatus, as with the IHPVA speed event). Sailboat races between Hobi 16s or Cal 40s or Star Class boats should be fair, but questions do arise. One competitor may have better sails or a wider choice of sails. The rules committee has to decide what is permitted. For the Star Class, small improvements in design have been authorized that help keep the class technically up to date and that allow manufacturers to sell new models without wiping out the class.

Sailplane competitions have provided a strong stimulus for that sport since the first glider competitions in 1920 in Germany. Through the 20s and 30s, and then after WWII, both contests and record attempts produced developments and performances that could not even have been dreamed of by the first pioneers. As the gliders became more efficient, the pilots learned how to locate and exploit upcurrents, first to stay aloft longer, then to fly further. The need for speed as well as efficiency drove the designs to higher wing loadings and to advanced structural concepts to provide safety even in the severe weather wherein the best lift was found. Regulations arose for safety reasons, in the form of certification for both the vehicles and the pilots. Before about 1950, contests considered duration, distance and altitude; thereafter, the focus was on distance, which in effect combine all three. As distances got greater with improving vehicles, instrumentation, piloting strategy, and meteorological understanding, speed events were added, especially closed-course speeds that kept the sailplanes from venturing inconveniently far from the contest airport. There were no one-design competitions because there were so few vehicles of one type until the Schweizer 1-26 became ubiquitous. Competition categories did arise in the 1950s. There has always been the open class. Now there has been added a "standard" class (15m span, no flaps) and a "15m class" (like open class, but span limited to 15 m). Also there are now some initial competitions with self-launched (auxiliary-powered) sailplanes. In addition to the stimulus of sailplane competition, there are awards for achieving certain distances, durations, or altitudes (the Gold C, Diamond, etc.). Sailplaning is just a hobby, but the forces for innovation have been so strong that the technological advances have been huge. Modern openclass sailplanes, with 22m wingspans, glide as flat as 60:1 and, using thermals, complete triangle courses of hundreds of kilometers at average speeds exceeding the 130km/hr. The vehicles can cost more than $50,000, even

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before the instrumentation (including a flight-optimization computer) and radios and navigation gear and oxygen equipment are added.

The growth of hang gliding was rapid throughout the 1970s. The first contests were more the equivalent of picnics or get-togethers, but they served to fire the imaginations of everyone present. The only scoring was for spot landings and later bomb drops with bags of flour. The real goal was safe and pleasant flights with hang gliders having beautiful, individualistic appearances. By the mid-70s the sport had matured to where the manufacturers combined voluntarily and established the certification of safe vehicles, while clubs supported a national organization to certify pilots. The safety record improved. Contests began focusing on aerial maneuvers, duration, and distance. Vehicle performance improved markedly. A small number of contest participants kept pushing manufacturers to better performance limits, but the larger number of sport pilots pushed manufacturers on a different course focused on control and comfort. In the U.S., the field has been getting smaller since its heyday in the late 70s. Liability problems contributed to the decline, and also many pilots diverted into powered ultralight aircraft, sailplaning, and regular lightplanes. For hang gliding, the main benefit from rules was the improvement in safety.

THE HEART OF THE DILEMMA IN CYCLING

The simmering pot of aerodynamic improvements boiled over in 1984 when the UCI made a controversial decision and accepted a record made with a disk wheel. The rules permitted design changes for structural reasons but not aerodynamic reasons. (General rule 49 state, "..the use of protective shields, wind brakes, bodywork or other devices on any part of the bicycle ... for the purpose of reducing wind resistance shall be prohibited.") By omitting spokes,and making the outer shell structural, the disk wheel was made "legitimate." Its significant aerodynamic benefits were achieved, allegedly within the constraints of the rules. A spoked wheel covered with non-structural lids, essentially identical in structural function and aerodynamic function, would be illegal. Who knows what the regulatory body would decide in the future about a spoked wheel with sturdy lids adding significantly to the structure. Designers and manufacturers now need to invest resources based on guesses about the rules interpretations of the future. The same goes for streamlined handlebars: supposedly built with an airfoil cross section for structural reasons, actually made that way for aerodynamic reasons (and apparently with little concern about the danger from the sharp trailing edge in an accident).

If you asked 100 cycling officials, competitors, and manufacturers the question, "Are disk wheels and streamlined handlebars made because of structural benefits?" you would get 100 "nos"; if you asked, "Are they made because of their aerodynamic drag benefits?" you would get 100 "yeses." If you asked whether the disk wheels and streamlined handlbars fit either the intent or the letter of the UCI rules, there would be some differences of opinion (the rules are somewhat ambiguous, and so various interpretations are possible). If you asked whether they are good for the sport, there would also be differences.

The year when a structural change was made for obvious aerodynamic reasons, yet accepted as within the rules, was 1984. A philosopher, examining the implication of the decision which in effect ignores the contradiction in "Aerodynamics is structure," would probably note the connection with another "1984": George Orwell's classic book. Orwell introduced us to "doublethink," with Big Brother coaxing/coercing us to see no contradiction in phrases such as "War is peace" and "Ignorance is strength."

Increasing speeds, records, new heros, and new technology all help vitalize a field, lure in participants, and fuel manufacturing. The new aerodynamic bicycles and clothing/helmets provide such benefits, but there is a question about where all this leads. Track meets, marathons, and jogging are all part of a field which has grown healthily, without controversy about equipment. Tennis is another sport where equipment is not expensive, and skill, not technology, determines the winner. Does cycling need aerodynamic improvements? A big stimulus to U.S. cycling this year was Greg Le Mond's Tour de France victory. Would this stimulus have been altered by disk wheels on all participants rather than spoke wheels? I doubt it. Annual record breaking could be assured if the rules would feed in a little more use of aerodynamic fairings each year, but I suspect the negatives of such an approach would outweigh the benefits.

RESOLVING THE DILEMMA

To resolve the dilemma for the rest of this century requires input of people involved in all phases of cycling, especially those with the perspectives of philosophers and the mythical wisdom of Solomon. In the definition of a racing bicycle, there is no simple solution, and no pleasing everyone, but the problem must be resolved. I find it disturbing to have observed designers paying much more attention to how to push the edges of the existing rules, how to exploit ambiguity, than to how to straighten out the rules.

Now the dividing line between cycling competitions as human skill/stamina events and as technology events must be clarified. Pandora's

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Box has been opened and mischief will proliferate unless wisdom is applied. My prejudice is that future competitions which purport to determine the top athlete should use bicycles with limitations that clearly minimize advantages from aerodynamics (using bicycles and helmets that emphasize safety). Developments would focus especially on mechanisms (elliptical sprockets, cams, gears, etc.) and on training techniques. Other open competitions could be like those IHPVA already features, where aerodynamic innovation is given free rein. I cannot see the viability of a middle ground where aerodynamics is partially admitted, where the "intent" of a developer must be considered, where design rather than function is specified, where drag reduction is permitted by one means but not by another, where participants in the field are coaxed into practicing or accepting "doublethink". Because I am not closely connected to the cycling field, I do not have a high regard for my own prejudices in this area. I look forward to seeing how others who are more intimately involved handle the challenge for the next decade: how to define, unequivocally, the legitimate bicycle which advances cycling.

An obvious solution is to have the most prestigious cycling competitions be ones where equipment gives the rider no special advantage. One method is to provide identical bicycles to the contestants, or at least require random switching of bicycles between contestants in multi-race events. (Note, however, that a special liability problem is introduced if the rider is not responsible for his own equipment). Another method is to emphasize an event such as a hill climb, a low-speed event where bicycle difference confer very little advantage. The most generally applicable method would be to certify bicycles which all have a minimum drag at racing speeds.

The minimum-drag technique could produce vehicles featuring safety and economy and take the pressure off pushing the limits of structure. With a high minimum weight, high minimum rolling (tire) drag, and a minimum aerodynamic drag (obtained any way the designer wants), speeds would be lower but records would continue to be set because of improved training.

Weight is easily determined. Total drag is difficult but not impossible to ascertain. Tire drag is at least rather independent of speed, and at high speed is much less than aerodynamic drag, but can vary with tire pressure, temperature, and surface. Aerodynamic drag can be ascertained in a meaningful way only if a "standardized rider shape" is mounted on the vehicle as the vehicle moves at the specified speed, say coasting down a slope or mounted in a tunnel.

I am aware of the difficulties inherent in such calibration, and not especially optimistic about obtaining a satisfactory resolution of the challenge, but anything seems better than the present situation of permitting aerodynamic improvements on a rather arbitrary basis. The concept deserves creative investigation before rejection, and, if rejected, the alternatives must be appreciated.

SOME OBSERVATIONS AND CONCLUSIONS ON GOALS, RULES AND INNOVATIONS

1) Publicized competitions foster innovation, even where the rules inhibit major innovation, because there is always opportunity for some innovation, and new/improved technology is of considerable interest to most riders and hence to manufacturers.

2) Paradoxes in the present cycling rules about structure vs. aerodynamics must be resolved. The legitimate racing bicycle must be clearly and permanently defined, even if the definition represents a significant departure from today's aerodynamic bicycle. Competitors, inventors, manufacturers, spectators, and officials deserve such a clarification of what is a bicycle, and of whether cycle racing is to be a test of competitors' skills or of vehicles.

3) In all sports involving equipment there is justification for some "open" events (consistent with safety), no matter how many "constrained" events there are.

4) For showing individual stamina and skill, high-speed races could be conducted on moderately slow, very safe bicycles - heavy ones with draggy aerodynamics and draggy fat tires - if a standard drag specification can be agreed on and measured. It is reasonable to suggest that some races and measurements be initiated to explore the concept, but I doubt that the present bicycle-race culture would respond with enthusiasm. Hill climbs and the related racing of mountain bikes over complex terrain are well accepted. Although the rider cannot establish a record applicable to other locations, there is the stimulus of local records and winning.

5) The IHPVA land-vehicle races should continue, with at least a) the open class for absolute speed through 200m traps, and b) a long open-category race of approximately one hour, in which vehicles must cope with maneuvering and winds. IF a velodrome is available, a 4-km time trial is also desirable, as well as a one-hour event.

6) In order to stimulate the development and appreciation of practical vehicles, such as could be used in commuting, competitions are held at the annual IHPVA event. However the specific definition of "practical" is not agreed upon, and in any case the judging cannot be absolutely quantitative; speed is readily measured, but is only one contributor to a total

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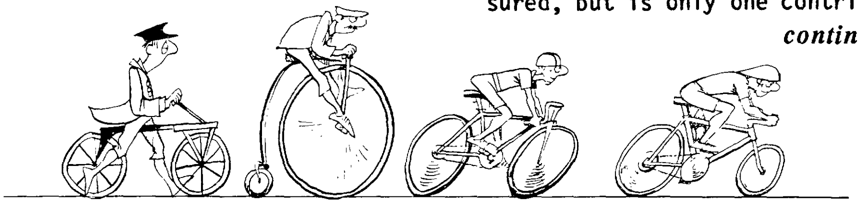

score which includes convenience, maneuverability and safety. The imperfection of rules should not be considered a valid reason for avoiding the practical-vehicle event.

7) In open categories, especially as exemplified by the IHPVA races, a useful philosophy is to have rules lag technical developments and so not inhibit the developments. Thus, although the IHPVA rules prohibit stored energy from sources outside the rider, a rider might be permitted to store energy (as in a battery) during one part of the event for use in a later part. Also, the vehicle could be permitted to exploit real-time wind power via a sail wing or on-board windmill. If energy storage or wind augmentation produce a race winner, great! If the advantage was so large that the new technique would be essential for future winners, then a new "open" category could be set up permitting it, and another "semi-open" category could be devised prohibiting it, or a single dominant category could be selected. Innovation is served by this attitude.

8) Technical symposia are effective at stimulating invention. They promote the exchange of ideas while establishing an enthusiasm for new creations.

9) The standard bicycle is an elegant design, with admirable dynamics, simplicity, and ruggedness. The touring bicycles of the year 2000 or even 2050, and perhaps even the racing bicycles, will probably be rather similar to the present vehicles. I suspect these will continue to win out in the marketplace over recumbents or even more divergent designs.

10) The future success of bicycles as commuting devices will depend less on technological improvements of vehicles than on social acceptance, traffic competition, foolproof locks, effective lighting and reflectors, and helmet laws. Safety is a dominant and ultimately limiting factor.

11) Auxiliary energy can assist commuting/touring. Just a kilogram or so of batteries can give you the equivalent of 300 m of altitude, to apply as you want: accelerating after stops or maintaining traffic speed up a hill. On a sunny day, half a square meter of solar cells can assist you with 50 watts continuously or can recharge a batter. A kilogram or so of rubber bands can store the energy of a stop from 10 m/s to be used in the subsequent speedup. A kilogram or so of gasoline can power the vehicle for hours or even days. However, you have to consider why you have a bicycle. If you really want a motorcycle or car, get one.

12) Formal rewards constitute a strong driving force for achievement, whether the rewards are dollars or ego-fulfillment from fame or self-satisfaction from winning. A money prize for at technological development typically stimulates development efforts costing many times the prize amount. (The Kremer prizes for human-powered flight triggered two decades of worldwide developments that probably represented an investment 30 times greater than the prize money.) Formal prizes provide a beneficial focus for both inventors and competitors.

13) The preoccupation in our advanced countries on technology and competition deserves a lot of thought and discussion. Health, happiness, longevity, and appreciating and fitting in with nature rather than modifying or destroy in it - these need consideration as we work on technological innovation. Goals, motivation and rewards vs innovation may be imprecise subjects for exploration, but, in my opinion, should be given high priority. Cycling, a positive subject with few negatives, can serve as a benign catalyst for such philosophizing.

14) Rules and categories inhibit innovation by limiting options and stimulate innovation by motivating many riders to participate in the field and hence encourage media interest and manufacturers to support and develop the field. There is no one answer to the conflicts inherent in simultaneously inhibiting and stimulating innovation. Persons setting up demonstrations, races and records will have to accept complexity in rules and categories while striving for simplicity. Officials should be cautiously flexible. Some decisions will prove to be less successful than others; the decision makers will find that they cannot please everyone. Their rewards will be in knowing that they are helping with a sport of great value both to man the scientist/engineer and man the athlete and creature of nature.

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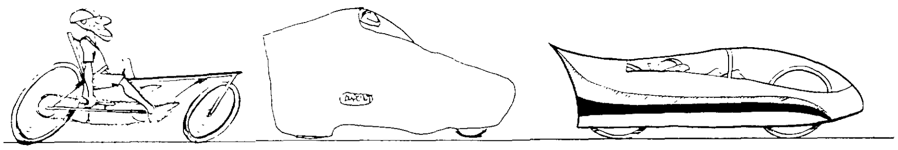

NEWS

Announcement and Call for Contributors to a Proposed Conference Session at the January 1988 Annual Meeting of the Transporation Research Board

In much of the developing world, bicycles, tricycles and carts (whether powered by humans or animals) play a vital role in local systems of personal mobility and goods movement. There are substantial variations, however, in the utilization and mix of these modes and in how their use is integrated into transportation planning and policy for urban and rural areas.

Transportation planning and development in the Third World sometimes serves to improve conditions for human-powered movement. Sometimes, however, it has worked to restrict the use of human (and animal) powered transportation modes. Research into these variations and conflicts can aid our understanding of the evolution of local, regional and Human-Powered Vehicles and Transportation Planning in Developing Countries global transportation systems and the impact of these systems on economic and social activity. The findings of this research are likely to have important implications for transportation planning and policy in developing countries, and potentially in developed countries also.

OUTLINE OF POTENTIAL TOPICS

- Regional reports on bicycle and tricycle use in developing countries
- Developments in bicycle and other appropriate technology
  - Systems for production, distribution and maintenance of bicycles, tricycles and carts in developing countries
  - Designs to meet special problems (all-terrain bicycles, special carrying devices, cargo bicycles and tricycles, materials substitution)
- Conflicts between high-technology and human-powered transportation systems
- Transportation development policies and spending priorities and their impact on the evolution of transportation systems and human-powered transport.

TYPE OF CONTRIBUTIONS DESIRED

Although formal scientific papers will be welcomed, the session's planners will also be looking for more preliminary contributions, in the form of talks (preferably aided by slides) that will present significant new developments in a clear and stimulating way.

NEXT STEPS

The planning committee for this Conference Session is being co-chaired by TRB members Ralph Hirsch and Michael Replogle. They are eager to hear from researchers anywhere who have done or are doing relevant work, and from persons who may know of relevant recent material published in developing countries. They also recognize that lack of travel funds may represent a problem to some potential contributors, especially those from developing countries, and they hope to raise funds from foundations and other sources to assist them. Please contact either one with your comments, suggestions or inquiries:

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HP Helicopter to try for HPS Prize

Mike Brace, of Reynolds & Taylor, Inc., has designed an HP helicopter called "*Monarch*", and is going to try for the AHS prize.

According to *MACHINE DESIGN*, the firm specializes in plastic fabrication, and company president Roger R. Reynolds thought that the helicopter would be a great way to demonstrate the company's skills in advanced composites. The rotor diameter is 8.5m (28 ft) and the overall weight is just over 20 kg (45 lbs). To win the prize the helicopter must rise at least ten feet and hover for 60 seconds.

Media Notes

The IHPVA and HP author Anthony F. Patroni ("A FIGURE-EIGHT DRIVE", HP 5/4) were written up in the Atlantic City *SUNDAY PRESS*. He is the chief slot technician at Caesar's Casino Hotel, and oversees the operation of 1600 "bandits". He's also worked for the city police department on maintenance of their cruiser fleet. Right now, writes the paper, he's working on a tricycle suitable for a legless person.

Gronen Seeks to top Markham's Record

German Vector owner Wolfgang Gronen reports that a high altitude speed attempt is the works for late September/ early October.

With the support of the German Embassy in La Paz, Peru and Lufthansa airlines, Gronen and his rider Gerhard Scheller will seek to best Freddie Markham's top speed run aboard Gardner Martin's *Gold Rush*.

In other news, Herr Gronen reports that negotiations are continuing with the intent of holding the 1988 International Human Powered Speed Championships in West Germany.

Additional information will be published in *HPV News*.

MAJOR TAYLOR - AN EXTRAORDINARY CHAMPION

By Andrew Ritchie

(A British author presently living in California, Andrew Ritchie is author of King of the Road, *a history of bicycles and bicycling.-ED.)*

Bicycle racing champion Major Taylor shown at his peak. His hometown honored his memory by naming its bicycle racing track the Major Taylor Velodrome, competition site for three International Human Powered Speed Championships. PHOTO COURTESY OF: Andrew Ritchie.

The black American bicycle racing champion, Major Taylor, born in Indianapolis in 1878 and christened Marshall Walter Taylor, is probably the most neglected figure in the history of American sports. Since he died in poverty and obscurity in Chicago in 1932, he has been almost totally forgotten. Bicycle racing as a sport has been out of fashion in the United States since the end of the 1930's and its turbulent and dramatic "Golden Age" between 1890 and 1910 is largely ignored. Only very recently, with the American cycling victories in the Olympic Games and the 1986 win of Greg LeMond in the Tour de France, has bicycle racing again sprung into real prominence in the United States.

Yet at the height of his career, which burgeoned on both sides of the Atlantic and Australia between 1896 and 1911, Major Taylor's tempestuous races against all the most famous cycling stars attracted a huge following. Crowds of 10,000 people were not uncommon when he raced at tracks in New York, Chicago, Paris, Berlin, Amsterdam or Sydney. In one season, Major Taylor was estimated to have earned $10,000. In France, the press reported his races, his training regime and his social life with the kind of attention given today to star athletes, film stars and politicians. His performances and personality excited the popular imagination. Marcel Viollette, the editor of *La Vie au Grand Air*, an important French sporting magazine, called him "...a creature apart, one of those heroes who is able to excite the imagination of the public." Major Taylor was, in fact, one of the first of a new kind of athletic superstar.

In 1899, at the age of 21, after an extraordinarily precocious teenage career, Major Taylor won the World Professional Sprint Championship in Montreal and thus became the second black World Champion in any sport, the first being the boxer George Dixon, who won the World Bantamweight title in 1890. In 1898, when the results were disputed, 1899 and 1900, he was American sprint champion. He broke dozens of world records for speed over short distances, some of them behind motorpace. In tours of Europe in 1901, 1902 and 1903, and then 1907, 1908 and 1909, Major Taylor challenged and beat, on more than one occasion, all of the leading sprint champions. In the winters of 1902/3 and 1903/4, he raced with extraordinary success in Australia. During the heyday of professional cycling, from about 1895 to 1910, Major Taylor was always a star attraction and a force to be reckoned with. Between 1897 and 1904, he pursued an amazing schedule of travel in the United States, Europe and Australia, in fact going twice around the world, a unique achievement, which taxed him to the point of nervous breakdown in 1904.

His career was all the more remarkable because he was the only black man competing at the top of the sport and one of the very few blacks competing professionally in any sport. In America, there was from the time of his earliest races fierce opposition from the white riders. In a fast, aggressive and dangerous sport, he was jostled and fouled more than most on the track and threatened and assaulted off it. When he turned professional in 1897, he was the cause of prolonged debate and friction within the governing bodies of the sport. Certain racist factions wanted to exclude him permanently. In America, where *de facto* segregation continued to exist though slavery had long been abolished, Major Taylor's superiority in bicycle racing was seen as an unacceptable challenge. In fact, a variety of repressive Jim Crow laws (which effectively reinstated the racist and segregationist laws supposed to have been outlawed by the abolition of slavery) introduced in the 1880s and the 1890s were much more likely to work towards the suppression of a career like Major Taylor's than to give it any kind of encouragement. The crowd, however, loved him, because it admired his tenacity and courage and most promoters soon recognized that he made money for them.

In Europe, however, where the sporting circles welcomed Major Taylor with open arms, his career was able to burst into full flower. In Paris he was lionized and idolized and was described as having become "a universal star." In Europe, where he lived and competed more happily than in his own country, his victories were not interpreted as a racial challenge to the order of society and therefore his athletic prowess was more easily accepted on its own terms.

Major Taylor's career as a world-beating black athlete was a pioneering one and therefore of great interest historically and sociologically and was a landmark in the story of race relations in the United States. The drama of his life was intensified by his personality. A strict Sabbatarian Baptist who refused to race on Sundays and thereby lost a large amount of prize money and was excluded from many important Championship races including the World Championships, Major Taylor was highly principled, disciplined and proud, yet tough and utterly determined. He saw the abuse which he suffered personally as a symbol of racial prejudice everywhere, and this made him all the more determined to rise above it and to demonstrate that he, as a black man, could excel in a white-dominated world.

In his later life, sadly, Major Taylor never regained the fame and glory of his younger days. If his rise from humble parentage in Indianapolis to stardom in the hectic world of international professional bicycle racing was a classic rags-to-riches story, his decline into business failure, sickness, divorce and death in poverty in Chicago was an equally compelling change of fortune. After some years of heart disease, he died in Chicago and was buried in a simple, unmarked grave. He was rescued from this sad fate 16 years later when his body was reinterred and a memorial erected by colleagues from his racing years who decided to honor his memory and ensure that he would not be forgotten.