RACECAR ENGINEERING

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CHAMPIONS!

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RACECAR

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COVER The outstanding racecar of the 1999 international motorsports season was the Ilmor/Mercedes V10 powered McLaren MP4-14, which carried Mika Hakkinen (pictured) to a second successive Formula 1 World Championship of Drivers – although the McLaren drivers allowed the Constructors title to slip from their grasp – *Photo* Jad Sherif, Pan Images. ABOVE Jean Todt (at front centre) and his team secured the first World Championship of Constructors for Scuderia Ferrari since 1983. *Racecar* pays its annual tribute in this edition to the champions of professional motorsports and their technical suppliers – *The Champions*, page 12.

Kokopelli is the name of a mythical historical figure in the USA, who was said to live in the arid regions of New Mexico. The folklore has it that he was a flute-playing philanderer whose sanguine approach to life – to racecar designer and amateur competitor Chris Bernard – seemed edifyingly optimistic. It was in just such a frame of mind that Bernard set about the design of the single-seat sports-racer that bears the name and, in terms of motorsports, justifies description as an actual

NATIVE american

By SIMON McBEATH

The principle design philosophy of the Kokopelli sports-racing project, which was targeted at the SCCA's C Sports Racer (CSR) and D Sports Racer (DSR) amateur track racing divisions, was to keep it ultra-low, with a low centre of gravity (CG), and a low frontal area with commensurate minimal drag. With a maximum height of only 800mm, that criterion has certainly been met. But the Kokopelli also incorporates some innovative thinking on a number of fronts.

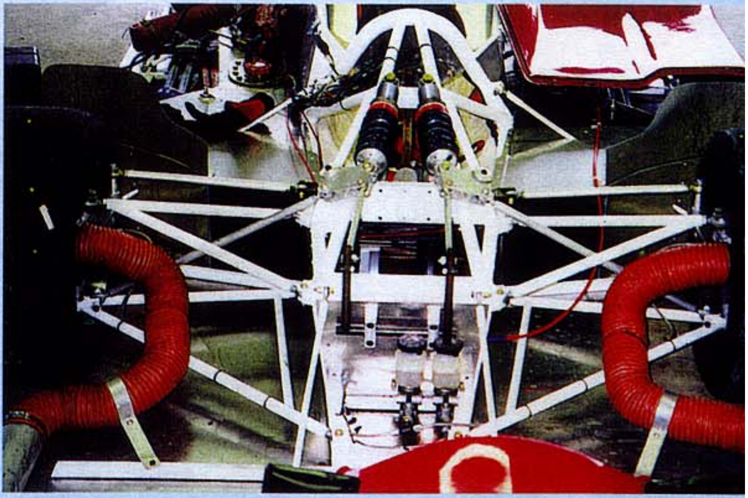
The creator of this car, Chris Bernard had spent over 20 years in the mechanical contracting and fabrication business, as well as restoring various European-manufactured road cars in his spare time, before the urge to design and build his own racecar became irresistible. His first self-built competition car was a Caterham 7-based Solo II car, powered by a Formula Atlantic specification Toyota 1600cc engine, which took him to numerous regional wins as well as podium places at national championship level during the period 1992-98. He also became involved in sub-contract fabrication for SCCA Formula 500 constructor, QRE, on its 500cc, two-stroke, CVT-transmission single-seater racecars, as well as fabrication work for other raceshops, working on Cooper Monacos, Ferrari Testa Rossas, Lotus 7s and a host of other contemporary racing machinery.

The designs for the Kokopelli were started in 1997. After the customary delays created by the need to run his regular fabrication business, Puffin Engineering, the Kokopelli first emerged from Bernard's raceshop in the Catskill Mountains above Woodstock, NY, in the summer of 1998. Bernard now takes care of Kokopelli sales and also his Subaru tuning parts business from the Puffin Engineering workshop.

At the time of writing, the Kokopelli was undergoing a programme of on-track development, both testing and racing being used to hone it to fully competitive levels. The new car qualified on pole position for its first race and led it before a clutchbelt failure, and then went on to win its second event – from pole and by almost a full lap – at Pocono. These initial results indicated that the basic philosophy and engineering were sound, and the optimism well-founded.

KOKOPELLI SR

CHRIS BERNARD personally carried out all the design and the majority of the construction of the Kokopelli sports-racer in his Woodstock, upstate New York fabrication shop. As such, the car remains as faithful to the designer's original ideals as was practically possible.

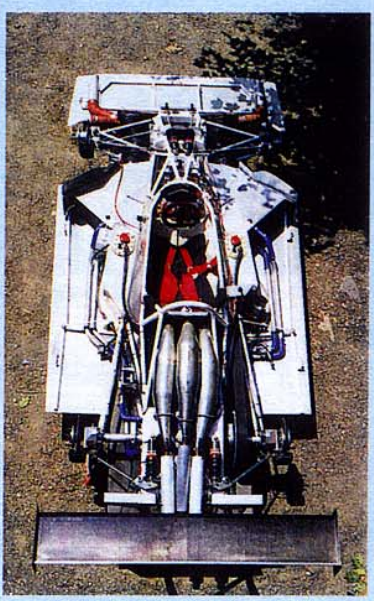


Chassis Structure

SCCA CSR and DSR regulations on chassis construction are essentially 'free', with the exception that carbonfibre chassis are specifically prohibited. Bernard selected the spaceframe route because of lower initial cost than monocoque options, and also the relatively low cost and ease of repair should (when?) damage be inflicted.

The basic layout of the Kokopelli's tubular spaceframe chassis is actually a low, narrow, single-seater configuration, in carbon-steel box-section tubing and drawn-over-mandrel (DOM) round tubing to 1020-1026 SAE specification, and in various dimensions. The chassis comprises two integral, sturdy roll-hoop structures located at the dash and behind the cockpit and, in essence, five transverse bulkheads linked by triangulated longitudinal bays.

The forward top suspension mounts, pedals and master cylinders are carried on the front bulkhead, and the spring/damper bellcranks mount on an intermediate bulkhead crossmember, which also carries the steering rack. The front roll-hoop forward braces support the spring/damper bottom mounts. The main roll-hoop is augmented by fore and aft diagonals, and the rearward braces connect to the main rear bulkhead at the back of the engine/transmission bay. The fifth 'bulkhead' is actually an upper box section crossmember to which the rear spring/damper top mounts are connected.



The narrow central chassis layout is evident in this overhead view.

Suspension & Wheel Systems

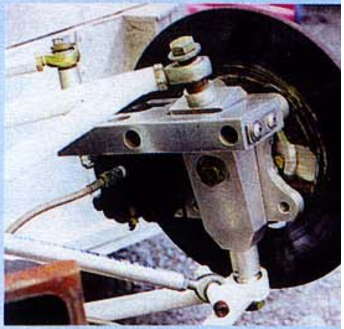
The front suspension is by wide-based, asymmetric, unequal-length tubular TiG-welded steel wishbones, with pushrod-actuated, milled aluminium bellcranks levering the 2in (50mm) diameter, 5in (127mm), free-length coaxial spring/dampers. The lower wishbone picks up forward on a steel box section subframe that extends ahead of the front bulkhead.

The wheel:damper movement ratio at the front is 1.33:1, and the rate of the Hyperco springs was initially established at 300lb/in (approximately 53N/mm). Damping is by aluminium-bodied, integral-reservoir Carrera shock absorbers.

Camber and caster angle adjustability is incorporated via the rod-end bearings, while the wheel hubs and uprights are machined from 6061-T6 aluminium billet. The front anti-roll bar, mounted on the front bulkhead, is actuated by links connected to a choice of three positions on the bellcranks, and is adjusted by tubular sliders. The Titan steering rack is coupled to the steering arms on the rear of the uprights by tubular aluminium trackrods.

The solid, 'live' rear axle is located longitudinally via upper and lower forward extending radius arms, and a lateral location linkage about which the designer is somewhat coy, but which is neither a Panhard rod nor a Watts linkage. The spring/damper units, mounted between the rear main bulkhead and the aluminium bellcranks on the rearmost crossmember, are again pushrod-actuated. The wheel:damper motion ratio is 1.72:1, and 400lb/in (approximately 88 N/mm) springs were initially selected. The rear anti-roll bar is also mounted on the rearmost crossmember, and is operated by links connected to the bellcranks. Anti-roll bar adjustment is once again via tubular sliders.

At both the front and the rear, the brakes incorporate 10in (254mm) diameter by 0.35in (9mm) thick, solid cast-iron rotors manufactured by Coleman Machine. All four calipers are Willwood Engineering two-piston, aluminium alloy units.

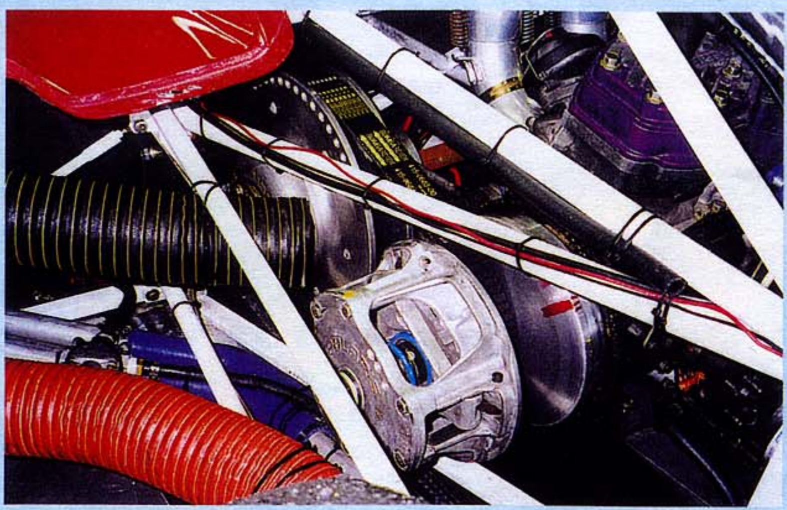


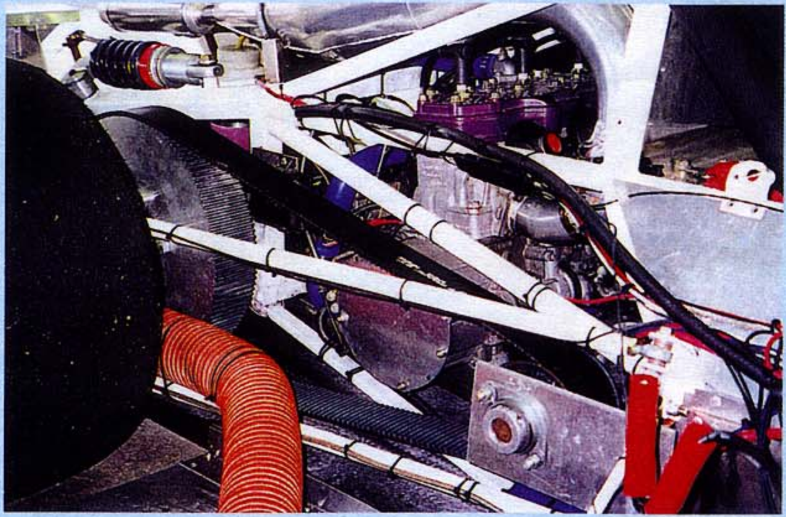
Top: Front suspension is by conventional wi bones, pushrods, bellcranks and co-axial spring/dampers on top of the chassis.
Middle: The suspension uprights are machin from billet aluminium. The US-sourced brake calipers are by Willwood.
Bottom: Rear suspension is by upper and lo radius arms, with a transverse linkage which all but hidden from view here – the designer somewhat coy about it.

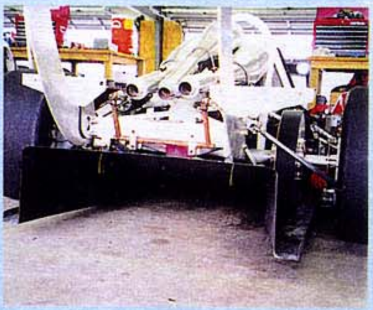
The brake pads are Willwood's 'Polymatri items. The pedal assembly embodies adjustable brake balance bar.

The Tecnomagnesio four-stud wheels 8x13in (203x330mm) at the front and 10x (254x330mm) at the rear, shod with Hoosier compound 7.5/20-13 front and 9.0/20-13 rear t

DESIGN & BUILD







Above: The only compromise on maintaining a low centre of gravity was to raise the engine slightly to accommodate the large diffuser. Above left: A two-stroke Rotax snowmobile motor drives out to the primary clutch pack, and thence via a toothed belt to the secondary clutch pack, connected to a transverse jack shaft. Below left: On the RH side of the jack shaft, a second toothed belt takes drive back to the final drive sprocket on the solid axle. The engine's expansion pipes and silencers are also visible.

Engine & Transmission

Both CSR and DSR regulations permit a range of engine types, with varying maximum swept volumes, these being are mandated according to engine type and configuration. Thus, DSR permits two-stroke engines up to 850cc, four-stroke units up to 1000cc, four-strokes up to 1025cc, and "automotive" (that is, production-based) engines up to 1305cc – in all cases, with no more than two valves per cylinder. CSR caters for 850-1300cc two-stroke engines. The Kokopelli has been designed specifically to accept three-cylinder, two-stroke snowmobile engine/transmission units, although the designer has also allowed for four-stroke motorcycle engines.

Although perhaps not so familiar to readers in milder climes, snowmobile racing is very popular in colder regions, especially in North America. The engines developed for that discipline are capable of delivering in excess of 200bhp with good reliability from the constantly variable transmission (CVT) systems (*Racecar* V3N5). Such a unit, utilising the stock bore and stroke of 69.5mm by 68.5mm, equating to 779cc capacity, was chosen for the first Kokopelli.

Engines can be produced in a range of states of tune, and Bernard's selected engine, the Rotax, can have outputs ranging from 150bhp to over 250bhp. Rebuild intervals tend to shorten with increased power outputs, so precise state of tune is down to customer preference. Outputs approaching 200bhp can be achieved with reasonable rebuild frequency. The choice of engine swept volume determines whether the car will run in CSR or DSR, 850cc two-stroke motors, as stated previously, being eligible for DSR, and 850-1300cc two-strokes for CSR.

The Rotax engine weighs approximately 50kg (110lb) including the carburettors and ignition system. Maximum power occurs at approximately 8400rpm on stock engines, this figure rising to 9800rpm on tuned motors, and maximum torque is in the range 75-90lb.ft, again depending on tune state. Modifications include vertical adjustment of ports in relation to the pistons, tunnel porting to improve airflow into the crankcase, and tuning of exhaust pipes with appropriate expansion chambers.

Engine cooling is performed by either single or twin Fluidyne air/water heat exchangers, depending on engine choice and power output.

Power from the snowmobile engine is transferred out through two centrifugally adjusted sheaves, one on the end of the engine and one on a jack shaft, connected via a substantial toothed belt, all on the LH side of the engine bay. As vehicle speed increases, the crankshaft-mounted unit effectively increases in diameter, while the jack shaft mounted unit decreases in effective diameter, thus maintaining an almost constant engine RPM with varying speed. This makes CVT particularly well-matched to two-stoke engines with notoriously narrow power bands. Once correctly set up, the transmission system helps to keep the engine in its optimum RPM band.

The jack shaft – a 1in (25mm) steel shaft – then transfers drive across in front of the engine to a further toothed pulley, which in turn transfers drive to the rear axle mounted, large diameter 'final drive' toothed sprocket. The single drive-shaft is again a solid steel shaft.

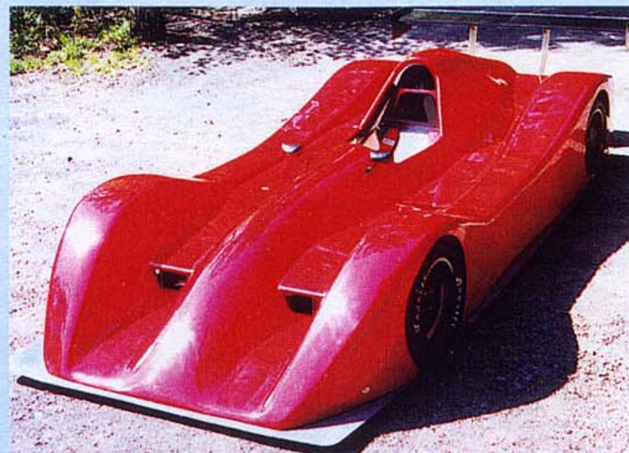
So far, what the designer modestly refers to as an "agricultural in concept but effective" power transfer system has worked well. However, at higher ambient temperatures, CVT clutch and belt temperatures become a primary concern. If belt temperatures exceed approximately 105degC (220degF) under racing loads, failure is said to be inevitable. To that end, additional cooling air, supplemented by a water atomiser system to provide extra cooling of the airflow to the clutch pack and drivebelts by latent heat of evaporation, has been directed to maintain these components at an equable working temperature.

KOKOPELLI SR

Bodywork & Aerodynamics

The main body covering comes in three sections, and is made by Pennon Composites, in glassfibre-reinforced plastic (GFRP) as standard, with carbon and Kevlar reinforced plastic as an option. The designer himself crafted the body bucks to create the distinctive shape of the Kokopelli, while Pennon applied the finish to the patterns prior to making the moulds.

The front section incorporates twin air intakes to feed the side mounted air/water heat exchangers, the heated air exiting at the rear directly into the car's wake. Following early tests in late 1998, additional small circular inlets were cut into the front wheel arches to enable cooling air to be ducted to the front brakes. Similarly, ducts were cut into the aft portion of the middle body section sides to feed air to the rear brakes, and also to the CVT clutch packs on the LH side of the engine bay. The front body section is kept as low as possible in between the wheels and over the chassis, and as tight as possible over the wheels in order to maintain a small frontal area.



The Kokopelli CSR/DSR, just emerged from t[h] Puffin Engineering raceshop. Beautifully craft[ed] body panels, wi[th] a front splitter, a[n] underbody diffuser and a single-element rea[r] wing, provide downforce.

The body mid-section continues the low-li[ne] theme, while the rear section fairs in over t[he] main roll hoop, with the centre section taperi[ng] gradually back to the bluff, downswept tail. T[he] upsweep over the rear wheels, once again is tight and low as possible, and in between t[he] wheels the body is lowerstill.

DESIGN & BUILD

The aluminium undertray is supported near its widest extremities from the narrow chassis by lightweight tubular outriggers, and the undertray actually protrudes beyond the width of the bodywork to form a horizontal ersatz 'skirt'. The undertray also extends ahead of the front wheels to form a non-adjustable splitter, which is supported on a square tubular frame and held in tension by a pair of lightweight supports from the top of the front bulkhead.

The CSR and DSR regulations for underbodies require that at least 45% of the floor area between the front and rear wheels is 'flat'. However, this leaves scope for profiling the remainder of the floor, and Bernard has done just that on the Kokopelli. In fact, the central section of floor begins an upsweep just aft of the wheelbase mid-point, and this long, wide, shallow divergence diffuser continues for 55in (1397mm) to protrude just beyond the rear bodywork. The last section of the carbonfibre-reinforced plastic (CFRP) diffuser also diverges in plan view, and has horizontal outer lips on either side, finishing with a short vertical return.

The underbody was originally intended to provide all the Kokopelli's rear downforce.

So important was the diffuser in the original concept that the designer made the sole concession on his 'low-CG' rationale, raising the engine 2in (50mm) higher than it could have been mounted, so as to avoid compromising the diffuser. The car still has a relatively low CG, as well as an uninterrupted diffuser. However, the designer was also practical enough to recognise the need in some cases for adjustable, tuneable downforce. This need, plus perhaps his aesthetic eye, convinced him to provide an optional, full-width, single-element aerofoil, which is again made in CRFP by Pennon.

Ancillaries

In the cockpit, the driver is equipped with an Alpha steering wheel, and is retained in the seat by a Willans six-point harness. SPA mirrors provide the rearward view. Instrumentation is the Stack ST8400 package, displaying RPM, exhaust gas temperature, speed, and water temperature. The pilot's safety is catered for with an SPA AFFF fire extinguisher system, and the Kokopelli is fitted with either one or two (for thirstier engines) 7-gallon Fuel Safe 'Pro' fuel cells.

The Kokopelli has an overall length of 154in (3912mm) including the wing, 141in (3581mm) without it. Its overall width is 64in (1626mm) and overall height 31.5in (800mm). The front track dimension is 56in (1422mm), the rear track 53in (1346mm), and the wheelbase 88in (2235mm). The 'dry' vehicle weight is 780lb (355kg), less driver.

A Willans harness and Alpha steering wheel in the centrally sited cockpit.

Below: Additional NACA ducts appeared in the side panels to feed cooling air to the brakes, and to the CVT clutch pack and drivebelts.