LEVITATION© Development Project

Background: Transport for the Working Man

What is a normal road? Our experience may be limiting our view. While the greatest percentage of the 70,000,000 vehicles produced annually are certainly used on paved roads, **roughly half of the world's road remain unpaved** (over 13,000,000kms of it!). For many, this is their 'normal' road they have to use every day.

A Normal Road?

Over the years the 'need' for transport has increased considerably and vehicles have improved in build quality, comfort, and become more 'user friendly' for the average initial buyer in highly developed countries. This results in vehicles that are adequate for use on paved, and in a restricted way, on unpaved roads. However this means that modern vehicles tend to be too complicated for "#8 wire" style repairs, and not rugged or compliant enough to cope with sustained use in harsh conditions.

Roads in Uganda 2008

I have had a fascination with exploration and off-road transport my whole life. In my teens I rebuilt a Unimog 404 and the idea of building a vehicle from scratch was often on my mind. Then in 2001 I stayed with someone that had been involved with the Africar Project in the mid 1980s. The Africar Project had set out to provide a vehicle able to cope well with the rough terrain and conditions of Africa, but cheap enough to be bought widely in Africa. The project failed largely due to lack of genuine understanding of what to focus on, but it was close enough to be very inspiring. I was hooked...

Africar prototype station wagon on the way down Africa in 1984

See http://en.wikipedia.org/wiki/Africar and http://www.difflock.com/diffmag/issue6/Africar/index.shtml for more info on that project.

I believe the need and market for working/utility vehicles that are '**appropriate**' and have the ability for every day working use on these other 'normal' roads of the developing world (and interior of countries like Australia, Canada, USA, and Russia) is now bigger than ever.

Also let's face it, there are plenty of us that don't need the ultimate off-road vehicle, but we would still love to have one, hey?

Sustained use of modern vehicles in harsher conditions soon shows weaknesses that can be uncomfortable, frustrating, expensive, and sometimes extremely dangerous. While there are quite a range of problems (electrical, chassis and body cracking, discomfort, buckled wheels, trim fittings coming loose, CV and drive-chain damage, load damage, etc) that arise from using production

vehicles in harsh conditions, most can be traced directly or indirectly to be suspension related.

As a direct result, a considerable 'after market' industry has developed to manufacture components in an attempt to adapt standard vehicles to be able to cope with, what for many is the 'normal' road, with the main focus on suspension.

As I toyed more and more with designing the ultimate expedition/outback vehicle, I found there was not a suspension system available (even amongst the hoards of aftermarket systems) that achieved what I desired.

I wanted a suspension system: That maintained a predetermined ride height, no matter what load was currently being carried, preferably with at least two height settings. That could never bottom out, ie infinitely progressive. That contained nothing that could not be repaired in the field while being tough, simple, and cheap.

Imagine a suspension system that didn't feel like it was shortening your spine when you hit that bump wrong. Suspension that didn't feel like it was welded solid when your ute is empty and didn't point your ute's head lights at the sky and handle like a water bed when fully loaded. We could all use that!

Suspension has three main aims:

1. **Support** the load (vehicle) at a certain desired ride height (sometimes several ride height settings are desirable).

2. **Insulate** the load (vehicle structure, cargo, and occupants) from harsh undulations in the road surface.

3. **Maintain wheel contact** with the road surface.

All suspension systems are trying to achieve these aims, but there is not and never will be a perfect system for all conditions. All systems so far have been attempting to get the best compromise and only ever respond correctly in certain conditions with a certain load, for which they were 'tuned'.

Having looked at what was available, I wasn't satisfied. So I started working on solving the problems I saw, and designing a totally new form of suspension.

The Idea Emerges

While playing at designing the ultimate expedition vehicle I looked into what suspension systems were available and I wasn't satisfied. I then started working on solving the problems I saw and designing a totally new form of suspension. But first I had to learn everything I could about the current systems and understand what was trying to be achieved.

The main challenges that remain for the suspension designer are these:

- **Maintaining the desired ride height** even with varying load, inclines, and G-forces. There are many forms of height control, in two categories: manually adjusted or automatic electronic control. Both work, but one is a hassle, and the other is too unreliable for true back-country work. ***What if the spring itself corrected the force needed to maintain the desired ride height?***

- **Damping that gives consistent results with variable loading.** Basically all forms of damping rely on a form of friction to resist the movement of the spring. As a result the only way to get consistent performance with varying loading is for there to be some way to alter the amount of friction by the same amount. Conventional damping results in a harsh ride when lightly loaded and a 'spongy' ride when heavily loaded. While there has been some success improving this, it is becoming very complicated and compromised. ***What if the spring changed or delayed its force and didn't need to waste energy by being braked by a form of friction?***

- **For the suspension to reach the limits of travel in a controlled and non-destructive manner.** On negotiating a sudden bump it is possible to 'bottom out' as the suspension reaches the limit of its upward travel, causing substantial impact shock, with potential damage to much of the vehicle and its cargo. On negotiating a sudden dip it is possible to 'over-extend' as the suspension reaches the limit of its downward travel, causing

substantial localised impact shock, which rapidly damages unprotected suspension systems. Most suspension systems have very minimal protection for the limits of travel. For protection of fully compressed suspension most vehicles rely on rubber bump stops. For protection of fully extended suspension, vehicles rely on either just the shock internals or some form of external limiting straps. It is hard to believe that WRC cars still rely on a bit of webbing strap to protect their suspension from over-extension. ***What if towards the limits of the suspension travel the spring rate became infinitely progressive?***

As the years passed I realized that I wasn't going to get to build the ultimate vehicle any time soon. The suspension had become the main focus of the project, so I decided to moth ball the other aspects such as bodywork, chassis, amphibious aspects, and drive chain.

The object now became solely focused on developing a suspension system particularly suitable for wheeled transport (though not restricted to) negotiating uneven surfaces with the need to carry varying loads that better address the challenges listed above. It had to be appropriate for use in harsh conditions, and be able to be repaired by unskilled people with limited tools. Also it was to facilitate the use of independent suspension on load carrying vehicles becoming a viable option.

While I did toy with many other ideas and follow many paths, I always came back to gas being the perfect spring and the ideal medium for providing progressive spring rate which could potentially eliminate bottoming out and over extending.

The desire to achieve active height control with out electronics or external linkage was the hardest nut to crack. I gradually realised that I had to forget about pressure and focus on position. In 2008 I spent three months in Africa working on the Uganda Heifer Project. One morning in Mbarara cathedral, the preaching was in the local Ugandan language, so I couldn't follow it. My mind wandered and I started looking for other Inspiration. I was looking at the organ with its different length pipes and somehow I just knew the answer to the problem that had been on my mind for about eight years was there. That afternoon feeling very inspired I sat down and drew the initial drawings of Levitation© height control.

Over the next few months, the idea was refined down to a concept that would in theory self-adjust its spring rate to maintain a set ride height (able to have several height settings controlled from the cab). This idea would also totally eliminate shock loading from bottoming out or over extending.

Finally I had a design that in theory I could build, so it was time to start acquiring the skills I would need to build it and start saving money to fund the project.

My lovely 1950s Kerry AG, has done close to a thousand hours prototyping Levitation.

While the outcome of home casting attempts looked reasonable, I could not get consistent temper, so resorted to machining out of extruded solid 6061 bar.

I bought myself a 1950 Kerry AG lathe off Trademe, and set about learning to machine components. I melted down old aluminium castings in a fire, burnt off eyebrows, cast parts in bowls of sand, and generally behaved like Burt Munro!

Fitting, Testing, and Racing Mk1

Knowing that at some stage I would get to building and testing an experimental suspension system, in 2007 I had set up a Subaru Leone as a test vehicle. I had been given her by a friend for parts, towards making a prototype of my 'ultimate expedition vehicle'. I thought she was too good to use just for parts and therefore decided to race her in the legendary 'Taupo 1000', first with her production

suspension, and then later to test the suspension that I would one day build.

That first race in HEIDI the Paddock Car, as she was now known, was to go down in history as a classic example of madness! Our total budget was similar to some teams' fuel budget. However despite my terrible driving, wreaking many components including several sets of factory suspension, and being the laughing stock of all, she limped home to see the chequered flag finishing 'Taupo 1000' 2007 mid field. I learnt more in that weekend of madness than the previous years of studying suspension.

Returning from Uganda with a concept drawn up of a suspension system that should self adjust its spring rate to maintain a set ride height, should be able to have several height settings controlled from the cab, and should totally eliminate all shock loading from bottoming out or over extending was motivating.

MK1 components ready for assembly.

Finally in July 2009 I had a pair of McPherson style front struts completed and ready for testing. Old HEIDI was woken up, given some much needed repairs to the damage sustained racing, and prepared for her much more important task of testing Mk1 prototypes.

Levitation is Born

Air system on a budget. 12v compressor takes it to 40psi in the black tank to feed A/C unit that takes it to 150psi. Rear Mk1 installed.

Late one night I finally had the units fitted and the compressed air system installed. started it up and watched to see if the suspension would indeed maintain the set ride height. She gradually lifted off her bump stops and sure enough stabilized at the desired ride height. I sat on the bonnet and sure enough the nose dipped for a few moments before returning to ride height.

There was a concern that it was going to be bouncy and behave like there were only springs and no shocks. So I tried bouncing the corners like one does to assess shock condition. It felt dead and weird and anything but bouncy. I could barely sleep that night, I was so eager to see what she drove like.

Some final adjustments were made in the morning, and I drove her out of the shed and across the yard. It felt kind of taunt and hard, a bit like a race spec car, and one could feel every little stone. It made me wonder if it would be too hard and what the first pot hole would feel like. I seemed to miss the first pothole, so I hit a large lump, but seemed to feel no more than a pebble... A massive grin started to appear on my face!

I headed out across a really rough paddock. The tail of the car, still on factory suspension, was dancing behind me; but the front seemed to be floating along, feeling every bump but in comforting connected way, rather than the spine shortening style of conventional suspension. I slammed it into some bumps larger than the available travel, and the

car launched in a very civilized manned, without the familiar slam of the suspension bottoming out.


Milling in the Lathe.

I then built a pair for the rear suspension and finished installing them just in time to set off to Taupo again.


HEIDI the Paddock Car ready to race, fitted with 'Levitation'.

'Taupo 1000' 2009 was a very wet race. My first two laps were plagued with problems with my air system, adjusting my untested rear suspension, and visibility. We drilled heaps of holes in my poly-carb windscreen, so I could see and made a manual override to the pressure switch as it wasn't cutting in early enough.

Lap three it all came together, and finally I got to feel what it was like to drive a vehicle with 'Levitation'. The simplest way to describe it is 'a magic carpet on rails'. Corrugations that slowed one down normally, didn't. In fact on rough parts where I had needed 5000rpm in 2nd gear, I was now at 2600rpm in third. Potholes that normally would slew one sideways, left one straight. But the most noticeable thing of all was how quiet it was without the clangs of bottoming out, and the rattling and creaking of the car being abused. It was working, like really working... I started passing people, and the grin was getting painful, but I didn't care!

The elation was short lived as part way into lap four my rear units started playing up and within five kms all four units were down on the bump stops, and we limped to pits. Mk1 had lasted 175km and all four units had collapsed within 5kms of each other. Each unit had died from the same problem (a small non-return valve had let its ball loose, which shot the internals to bits, and they all had some other issues. However Mk1 had served its purpose and proved the concept worked and was worth pursuing further.

It was a long night, but HEIDI was back on factory suspension the next morning and ran a good day, got the chequered flag finishing Taupo 1000 once again mid field.

While racing that day, in my mind's eye I designed Mk2, and couldn't wait to get started!

A Self-Regulating Fully Pneumatic Suspension System

WIPO application WO2011/025388

Patent Process, Commercialization Efforts, and Mk2 Prototypes

In 2009 as I was building the Mk1 prototypes, I knew it was going to be necessary to think seriously about patenting my invention. I knew very little about the patent process, except that it was expensive!

Over the previous few years I had spent thousands of hours researching the project, which in turn meant not earning much money. I could see that I was not going to be able to fund the prototyping, testing, and patenting very easily at all.

For several months I tried to acquire backing from various sources including government innovation funds, Angel Investors, and the three 'Fs'. However

it appeared it was too early in the project, to really get any interest. It was just an idea with no proof that it would work.

I was told that I must at least have a provisional patent filed before I exposed the idea to the public. So I wrote and filed that myself a couple of weeks before the 2009 ‘Taupo 1000’. The patent process is not such a ‘black art’ as some make it out to be, but it certainly takes a lot of effort to get your head around it.

If you ever have an idea that you think may be worth patenting, start by doing a patent search. Don’t only look to see if your idea has already been done, but also read carefully any patent that is remotely related to your idea, to learn the style of writing and the clever ways of describing the concept rather than the design. It might even inspire you on ways to improve your original idea considerably. However you need to be careful that you don’t let yourself be influenced to the point you lose the essence of what made your idea novel in the first place. Most patents are painfully and cryptically written, so it is heavy going.

Now the problem with filing a provisional patent is that it starts the clock ticking. From the moment you file that document you have a set maximum amount of time before big money has to be spent to secure the full patent rights in the countries you choose to have them in. The maximum time you can drag it out appears to be 30 months. It sounds a long time, but it flies by, and you need several hundred thousand dollars available to complete the patent process in just a handful of countries.

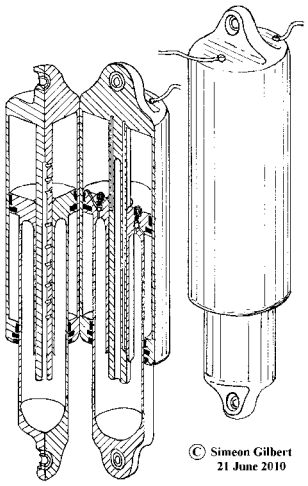
After testing Mk1 to destruction in ‘Taupo 1000’ 2009 I set about improving and refining the design with what I had learnt. I had no data on the performance or footage of Mk1, just the remains and the memory of what it had felt like in relation to what the terrain had looked like. A rather imprecise science to say the least! As a result Mk2 was basically an improvement on construction methods to give better longevity, so as to test and record performance.


Mk2 components ready for anodizing.


Mk 2 units

The first test drive of Mk2 was appalling! Height control was working fine, but it was ultra stiff and had virtually no damping. An hour later the four units were dismantled and I was trying to work out what I had done wrong. I had at least made them in such a way that they were easy to work on!

After reaming out some ports, removing a set of valves, and little other machining, I reassembled the units and headed back out to the paddocks. The difference was unbelievable. She could now fly over amazingly rough terrain with her wheels keeping contact and enough pressure on the ground to maintain traction virtually all the time. She felt firm and connected, but there was no harshness and the suspension was using its travel appropriately.



Mk 2 installed.

For two months and hundreds of kms, I tested, adjusted, jumped, filmed, and raced Mk2 prototypes. I found a few things that I would try different for Mk3, but on the whole they performed beyond my dreams.

Have you ever tried drilling a 3.2mm dia hole 300mm deep with less than .2mm wander allowable? How about twelve of them?

I had achieved a suspension that maintains a **predetermined ride-height and** the spring rate is self regulating in relation to the loading and velocity of travel in such a manner that **damping is not necessary and bottoming out is impossible**!

Building and testing the prototypes on a limited budget had been an interesting, challenging, and often fun project, but my end goal was always to get it into production, see it help people, and get some reward for my efforts.

August 2010, I approached a USA 'fortune500' suspension manufacturer, to take Levitation into production. We had several phone calls, many emails, and a couple of meetings in USA which allowed for some bench testing of an Mk2 unit. This finally gave some 'hard data' as to what my system achieves. They conducted a feasibility study, requested prototypes for further testing, before unexpectedly pulling out on 31st March 2011 on grounds of financial restrictions.

The patent process has continued with these steps: filing full spec, transferring to PCT, received a favourable International Search Report (IRS), and was published March 2011 as WIPO application WO2011/025388. The next step is the National Phases, i.e. the scary expensive stage!

So now I am looking for either:

1. A manufacturer to licence the development and production of Levitation.
2. A partner with whom to develop further prototypes and possibly limited production, before attempting a licensing deal with a manufacturer.

If you are interested in more information or have any input or thoughts to offer, please contact:

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For a very concise and clear insight into suspension go to:
http://www.carbibles.com/suspension_bible.html

To watch a video of testing Levitation go to
http://www.youtube.com/watch?v=z3uvza1i8bM

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