WHAT MAKES AN EXCITING ROLLER COASTER?

Alton Towers has a new roller coaster ride, *Galactica*, due to open in April 2016, that will require virtual reality headsets and participants experiencing a level of G-force acceleration greater than that of a real rocket launch. Sarah Griffiths talked to engineers, designers and enthusiasts about the elements that all roller coasters share and what makes some rides scarier than others.

It is thought that the origins of roller coasters date back to the 17th century, when ice slides were built in Russia. Wooden-framed structures up to 20 m tall would be sprayed with water and left to freeze so that thrill-seekers could toboggan down them. To this day, there are roller coasters across Europe known as *montagnes russes*, Russian mountains.

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ROLLER COASTERS

has generated even faster rides with hydraulic propulsion systems in the world. The use of magnetic and pneumatic systems has allowed for rapid construction around the world. In the 1930s, before the Great Depression, the number of roller coasters was at its highest, with nearly 4,000. However, by the late 1970s, they faced extinction due to financial depression, war, and other reasons. In the 1980s, the roller coaster industry saw a resurgence, with over 3,000 roller coasters in operation.

DESIGN CONSIDERATIONS

Most roller coaster trains are designed with safety in mind. They are built to withstand various forces, including friction, wind, and gravity. Safety features include braking systems, safety bars, and emergency stops. The design process involves computer simulations and testing to ensure the safety and comfort of riders.

FEEL THE FORCE

When creating new roller coasters, Vekoma engineers consider the forces experienced by riders. Positive G-forces are experienced at the top of a loop, while negative G-forces are felt during dives. The duration and magnitude of these forces vary depending on the design and the riders' weight.

PRIORITISING SAFETY

Roller coaster rides are designed to be thrilling but not dangerous. International safety standards form part of the approach to help roller coaster designers and manufacturers meet safety requirements. Testing and design reviews of roller coasters are carried out to ensure the safety and comfort of riders.

CONSIDERATIONS

Manufacturing, uses modelling and computer simulations to create a virtual ride that can be experienced by engineers. Analysis and computer simulations make use of finite element analysis (FEA) models, dynamic analysis and risk and hazard calculations. Each project uses a product lifecycle management (PLM) approach and design-for-maintenance to validate equipment, ensure structural integrity and establish wear for the roller coaster over its expected lifetime. Component testing is carried out to ensure quality, safety and reliability. Analysis and computer simulations make the process of designing a roller coaster a complex and time-consuming one. However, it is necessary to ensure the safety and comfort of riders, as well as the longevity of the ride.

WEALTH CREATION

Vekoma has created nearly 300 roller coasters worldwide. The Orkanen at Fårup Sommerland in Denmark, was installed in 2013 and has features including a speed bump, a carousel, steep drop, a 120° banked horseshoe followed by horizontal loops and s-curves. The coaster has a top speed of 88 km/h and reaches a maximum height of 70 m. The ride is 1,253 m long and has 15 loops, 647 humps, 633 kinks, 120 horizontal loops and s-curves. The ride has a maximum capacity of 3,600 riders per hour and is open year-round.

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In order for riders to feel the force of a clothoid loop or with conicscrews, the train they are sitting in has to have enough kinetic energy to reach a high enough speed to carry them, upside down, safely through the loop. While the great majority of roller coasters use traditional lift hill chains to pull a train up the initial highest hill, modern rides are being built that are capable of launching trains at much higher speeds. Electromagnetic launch systems, introduced at the end of the 1990s, require no moving parts and so require less maintenance than hydraulic launch systems, introduced at the University of Nottingham, has been dubbed the ‘world’s only thrill engineer’ by The Times. Professor Walker explains that roller coasters should make riders feel as if they have lost control, which triggers the body and mind’s state of alertness, or arousal. This can be caused by unusual forces such as jerk, or varied jerks known as ‘jouces’. The feeling of being out of control can be triggered by rapid acceleration as well as sudden drops and loops, but variety and the element of surprise are needed to sustain a state of arousal. Combinations of features might include a negative G-force experience known as a ‘hop’ to produce a lurching feeling in the stomach, followed by a pull out of a drop to create positive G-force, with designers manipulating a rider’s expectations and building suspense. The ‘clothoid loop’ is a defining feature in many roller coaster designs – see inverted teardrop. Early roller coasters included circular loops to invert riders, but a constant radius required a high velocity to complete the loop, subjecting riders to a high centripetal acceleration at the bottom of the loop as well as a more intense vertical G-force, resulting in discomfort. To solve this potentially dangerous problem, engineers came up with the clothoid loop, which is an inverted teardrop shape that is effectively a section of a spiral in which the radius is constantly changing. The radius of curvature is much larger at the entrance and exit of its loop element than in a circular loop, allowing for a much more comfortable transition as well as less intense vertical G-forces. Smaller radii at the top of the loop also mean trains can travel with a lower velocity at the top, while still completing the loop, giving a larger centripetal acceleration with a lower speed and a more comfortable, but thrilling experience for passengers.

When a train approaches magnets on the track, it is attracted to them, and when it passes over them the magnetic field is reversed to propel the train away from the magnet, forward down a track.
With a hydraulic launch, a ‘catch car’ runs underneath the coaster’s train and track on the end of steel cable locks. At the other end, a large winch drum is attached to a series of hydraulic motors. Hydraulic fluid is forced into a number of accumulator chambers, compressing nitrogen gas. When the ride is ready to launch, hydraulic fluid is forced into a number of accumulator chambers, creating such as a cross between a clothoid loop and a corkscrew. This will allow the rider to experience the sensation created by a clothoid loop and corkscrew simultaneously. By mixing the two, a ride will not only look new and exciting, but will provide new stomach-churning sensations for riders too.

Marcus Gaines from the European Coaster Club has seen other innovative trends being implemented. More manufacturers are coming up with lap bar designs that allow riders greater freedom of movement. Lap bars used to be popular, and were used on rides with only positive G-forces, such as Scorpion at Busch Gardens, Florida, but now they are being used utilised by some companies on coasters with negative G-forces and inversions other than a standard vertical loop. The shape of the seat also plays a role in securing the rider in place. The design can make rides seem scarier, particularly if customers are flung upside down, enhancing the adrenaline buzz of a ride.

There is also a move away from steel tracks back to wooden ones, to capture a bygone age of roller coasters. With loops. In the US, Rocky Mountain Construction unveiled its first wooden roller coaster to go upside down in Silver Dollar City, Missouri, in 2013, and will unveil the world’s first launched wooden roller coaster at Dollywood, in Tennessee, this spring. Last year, Martin & Vleminckx rides built two wooden coasters in China that featured corkscrew inversions. A trend that is starting to make its way into theme parks is the incorporation of virtual reality into roller coasters to enhance the sensory experience. For the past couple of years, Mack Rides in Germany, in partnership with a local university, has been working on combining VR with roller coasters. In 2015, the public got the chance to try out the world’s first VR Coaster at Europa Park, in Rust, Germany.

Alton Towers has been working with the Guildford-based firm, Figment Productions Ltd, to revamp its Air roller coaster to create a VR roller coaster experience. From April 2016, the ride will have an out-of-this-world theme and is to be called Galactica with riders wearing headsets based on the Samsung Gear VR system. Figment has developed Vector VR, a patent pending system that includes a custom sensor, fixed next to a rider’s seat, with an inertial measurement unit that constantly monitors the movement at that point on the train and compares it to a ‘master path’ captured by the same sensor.

The visuals that show up on a rider’s headset controlled by the Vector software algorithms sync with the sensor so that they match the motion of the roller coaster train and position the rider in the right space in the virtual world. The headset also adds tracking for rotational head movements, completing the picture to match what the rider sees with what their vestibular system tells their brain they should be seeing. This is key to minimising motion sickness and the system means that a 90° sweep can easily be manipulated to become a 180° turn. Galactic riders will also be in a prime position intended to increase the sensation of flying, allowing riders to stretch their hands our and feel the wind in their face.
Just as roller coasters seem to push and pull their riders in different directions, the future of the rides themselves is diverging. Use of organic-shaped rides and virtual reality technology will lead to more immersive and smoother experiences for riders, while noisy, back-to-basics wooden tracks will play on more primal fears to arouse the senses.

What is certain is that there will be faster, more testing experiences on offer than ever before. There are now nearly more than 4,000 coasters to ride, in what is being hailed as the dawn of the second golden age of roller coasters.

### SHORT HISTORY OF THE COASTER

What is considered to be the first true roller coaster opened at Coney Island in New York in 1884. LaMarcus A Thomson built the wooden Gravity Switchback Railway. Back then there were no brakes on the track; instead a brakeman would ride on the train, manually operating brakes on the wheels.

In 1912, engineer John Miller made a huge safety improvement that remains an integral part of today’s modern roller coasters, upstop wheels. These are an extra set of train wheels that run on the underside of the track, designed to prevent a train from flying off, crucial for moments of negative G-force or for looping upside down.

The first steel roller coaster appeared in Germany in 1906. Showman Karl Gabriel introduced the world to the 10 m tall Devil’s Wheels at the Munich Oktoberfest. Gabriel created the steel roller coaster so that it was portable and could be easily dismantled, relocated and rebuilt.

The Matterhorn Bobsleds at Disneyland in California, built by Arrow Developments, was the first steel coaster using tubular track that enabled sharper turns. It was this 1959 roller coaster that created the surge of interest in steel coasters, and the downturn in wooden coasters.

It wasn’t until 1975 with the Corkscrew at Knott’s Berry Farm, California, that thrill seekers would be flipped upside down. The popularity of steel roller coasters became apparent in 1986 when, for the first time, steel coasters outnumbered wooden ones.

During the 1990s and early 2000s there was more than a decade of competitive building, with theme parks battling to have the tallest or longest steel coasters. The UK played its part, with Lightwater Valley opening The Ultimate, which at 2,268 m became the longest coaster in the world, holding the record for nine years until the Steel Dragon 2000 opened in Nagashima Spa Land in Japan. Blackpool’s Pleasure Beach claimed the ‘world’s tallest’ record in 1994 with the Pepsi Max Big One measuring 65 m tall; today that record is held by the 139 m high Kingda Ka at Six Flags Great Adventure, New Jersey.

Compiled by Marcus Gaines, European Coaster Club, www.coasterclub.org

### ON THE UP

### BIOGRAPHIES

**Fraser Ross** has been a Concept Engineer at Vekoma Rides Manufacturing BV since 2012. Fraser’s work, hobby and life is centred around roller coasters and theme parks. He specialises in designing roller coaster track layout and related analytical assessment of vehicle dynamics.

**Professor Brendan Walker** is a technology-inspired artist, engineer, and broadcaster who specialises in the creation of tailored emotional experience. He originally trained as a military aeronautical engineer at Imperial College, before studying design at the Royal College of Art.

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