

A roller coaster car filled with people is shown in the middle of a loop, with the track curving upwards and then downwards. The sky is a deep blue with some orange and pink clouds, suggesting a sunset or sunrise. The roller coaster track is dark, and the support structure is white. The car is blue and has a red logo on it. The people in the car are looking out and some have their arms raised.

Roller Coaster Technology

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Table of Contents

Chapter 1 - Roller Coasters

Chapter 2 - Accelerator Coaster

Chapter 3 - Station (Roller Coaster) and Launch Track

Chapter 4 - Lift Hill and Physics of Roller Coasters

Chapter 5 - History of the Roller Coaster

Chapter 6 - Roller Coaster Elements

Chapter 7 - 4th Dimension Roller Coaster

Chapter 8 - Pipeline Roller Coaster and Shuttle Roller Coaster

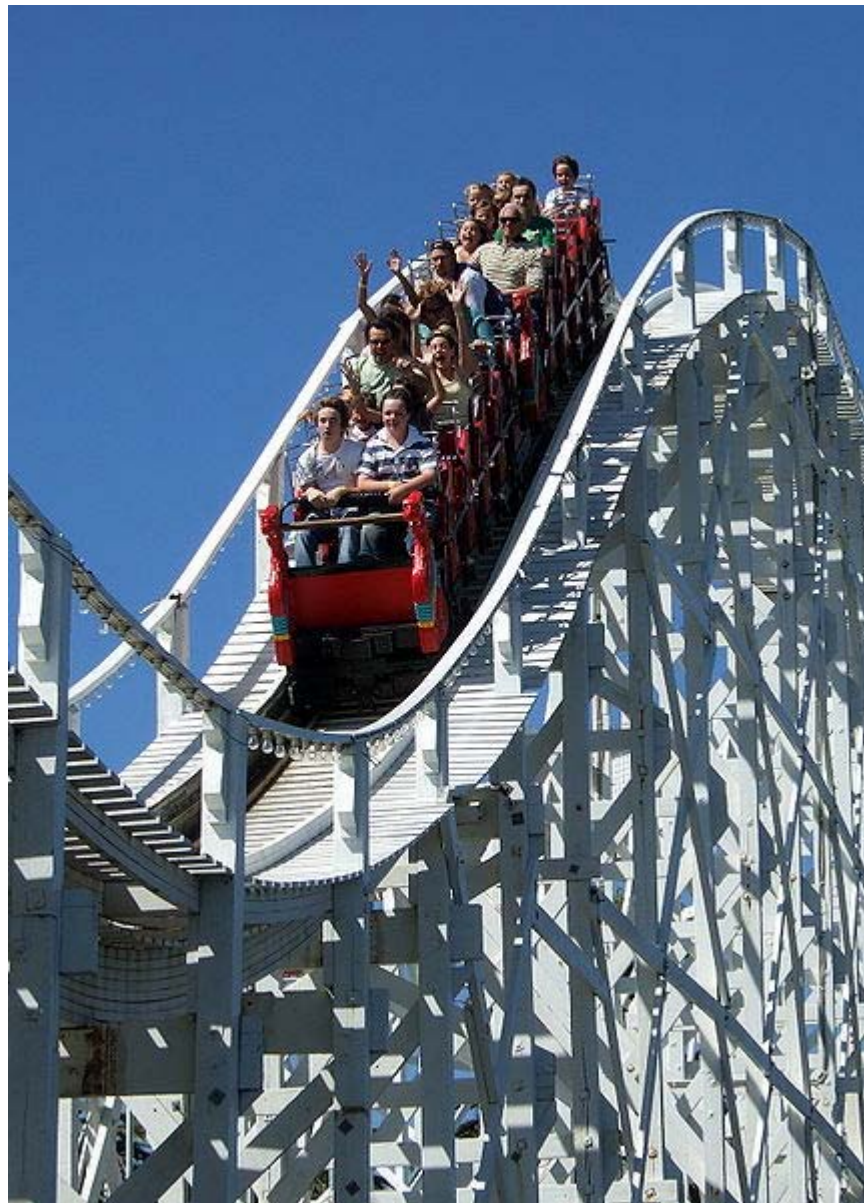
Chapter 9 - Spinning Roller Coaster

Chapter 10 - Stand-Up Roller Coaster and Steel Roller Coaster

Chapter 11 - Suspended Roller Coaster and Wooden Roller Coaster

Chapter 1

Roller Coasters



The Scenic Railway at Luna Park (Melbourne, Australia), the world's second oldest operating rollercoaster, built in 1912.

The **roller coaster** is a popular amusement ride developed for amusement parks and modern theme parks. LaMarcus Adna Thompson patented the first coasters on January 20, 1885. In essence a specialized railroad system, a roller coaster consists of a track that rises in designed patterns, sometimes with one or more *inversions* (such as vertical loops) that turn the rider briefly upside down. The track does not necessarily have to be a complete circuit, as shuttle roller coasters exhibit. Most roller coasters have multiple cars in which passengers sit and are restrained. Two or more cars hooked together are called a train. Some roller coasters, notably Wild Mouse roller coasters, run with single cars.

History

Russian mountain

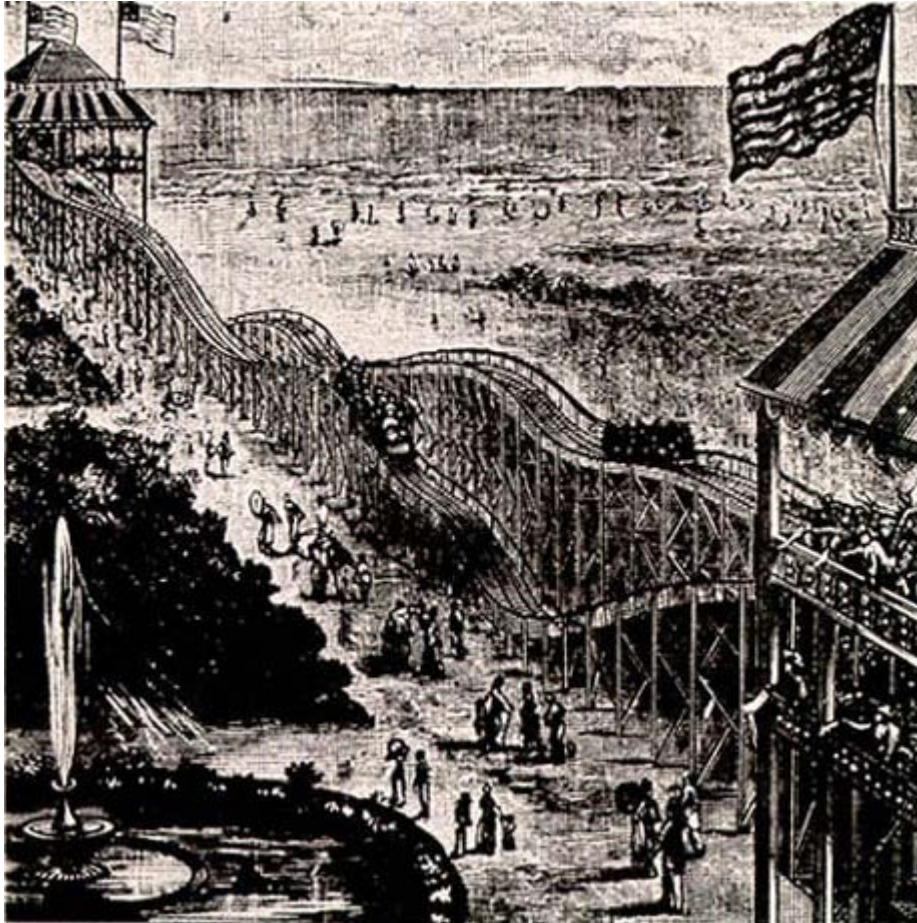
The oldest roller coasters are believed to have originated from the so-called "Russian Mountains", which were specially constructed hills of ice, located especially around Saint Petersburg. Built in the 15th century, the slides were built to a height of between 70 and 80 feet (24 m), consisted of a 50 degree drop, and were reinforced by wooden supports. "Russian mountains" remains the term for roller coasters in many languages.

Some historians say the first real roller coaster was built under the orders of Russia's Catherine the Great in the Gardens of Oreinbaum in Saint Petersburg in the year 1784. Other historians believe that the first roller coaster was built by the French. The *Les Montagnes Russes à Belleville (The Russian Mountains of Belleville)* constructed in Paris in 1812 and the *Promenades Aeriennes* both featured wheeled cars securely locked to the track, guide rails to keep them on course, and higher speeds.

The name Russian mountain is preserved in most Latin languages. The Russian term for roller coasters is **американские горки** ("amerikanskie gorki") "**American Mountains**".

Scenic gravity railroads

In 1827, a mining company in Summit Hill, Pennsylvania constructed the Mauch Chunk gravity railroad, an 8.7 mi (14 km) downhill track used to deliver coal to Mauch Chunk (now known as Jim Thorpe), Pennsylvania. By the 1850s, the "Gravity Road" (as it became known) was providing rides to thrill-seekers for 50 cents a ride. Railway companies used similar tracks to provide amusement on days when ridership was low.



Thompson's Switchback Railway, 1884.

Using this idea as a basis, LaMarcus Adna Thompson began work on a gravity Switchback Railway that opened at Coney Island in Brooklyn, New York in 1884. Passengers climbed to the top of a platform and rode a bench-like car down the 600 ft (180 m) track up to the top of another tower where the vehicle was switched to a return track and the passengers took the return trip. This track design was soon replaced with an oval complete circuit. In 1885, Phillip Hinkle introduced the first full-circuit coaster with a lift hill, the *Gravity Pleasure Road*, which was soon the most popular attraction at Coney Island. Not to be outdone, in 1886 LaMarcus Adna Thompson patented his design of roller coaster that included dark tunnels with painted scenery. "**Scenic Railways**" were to be found in amusement parks across the county, with Frederick Ingersoll's construction company building many of them in the first two decades of the 20th century.

Popularity, decline and revival

By 1919, the first underfriction roller coaster had been developed by John Miller. Soon, roller coasters spread to amusement parks all around the world. Perhaps the best known historical roller coaster, *The Cyclone*, was opened at Coney Island in 1927.

The Great Depression marked the end of the first golden age of roller coasters, and theme parks in general went into decline. This lasted until 1972, when *The Racer* was built at Kings Island in Mason, Ohio (near Cincinnati). Designed by John Allen, the instant success of *The Racer* began a second golden age, which has continued to this day.

Steel roller coasters

In 1959 the Disneyland theme park introduced a new design breakthrough with the *Matterhorn Bobsleds*. This was the first roller coaster to use a tubular steel track. Unlike conventional rails set on wooden railroad ties, tubular steel can be bent in any direction, which allows designers to incorporate loops, corkscrews, and many other maneuvers into their designs. Most modern roller coasters are made of steel, although wooden coasters are still being built.

New designs and technologies are pushing the limits of what can be experienced on the newest coasters. Electromagnetically launched coasters are examples of such technologies.

Etymology



Steel Force and Thunderhawk roller coasters at Dorney Park & Wildwater Kingdom in Allentown, Pennsylvania

There are several explanations of the name *roller coaster*. It is said to have originated from an early American design where slides or ramps were fitted with rollers over which

a sled would coast. This design was abandoned in favor of fitting the wheels to the sled or other vehicles, but the name endured.

Another explanation is that it originated from a ride located in a roller skating rink in Haverhill, Massachusetts in 1887. A toboggan-like sled was raised to the top of a track which consisted of hundreds of rollers. This *Roller Toboggan* then took off down gently rolling hills to the floor. The inventors of this ride, Stephen E. Jackman and Byron B. Floyd, claim that they were the first to use the term "roller coaster".

The term *jet coaster* is used for roller coasters in Japan, where such amusement park rides are very popular.

In many languages, the name refers to "Russian mountains". Contrastingly, in Russian, they are called "American mountains". In Scandinavian languages, the roller coaster is referred as "mountain-and-valley railway".

Mechanics

The cars on a typical roller coaster are not self-powered. Instead, a standard full circuit coaster is pulled up with a chain or cable along the lift hill to the first peak of the coaster track. The potential energy accumulated by the rise in height is transferred to kinetic energy as the cars race down the first downward slope. Kinetic energy is then converted back into potential energy as the train moves up again to the second peak. This hill is necessarily lower, as some mechanical energy is lost to friction.

Not all rides feature a lift hill, however. The train may be set into motion by a launch mechanism such as a flywheel launch, linear induction motors, linear synchronous motors, hydraulic launch, compressed air launch or drive tire. Such launched coasters are capable of reaching higher speeds in a shorter length of track than those featuring a conventional lift hill. Some roller coasters move back and forth along the same section of track; these are known as shuttles and usually run the circuit once with riders moving forwards and then backwards through the same course.

A properly designed ride under good conditions will have enough kinetic, or moving, energy to complete the entire course, at the end of which brakes bring the train to a complete stop and it is pushed into the station. A brake run at the end of the circuit is the most common method of bringing the roller coaster ride to a stop. One notable exception is a powered roller coaster. These rides, instead of being powered by gravity, use one or more motors in the cars to propel the trains along the course.

If a continuous-circuit coaster does not have enough kinetic energy to completely travel the course after descending from its highest point (as can happen with high winds or increased friction), the train can valley: that is, roll backwards and forwards along the track, until all kinetic energy has been released. The train will then come to a complete stop in the middle of the track. This, however, works somewhat differently on a launched coaster. When a train launcher does not have enough potential energy to launch the train

to the top of an incline, the train is said to "roll back." On some modern coasters, such as Top Thrill Dragster at Cedar Point in Sandusky, Ohio, Kingda Ka in Jackson, New Jersey and Stealth at Thorpe Park in Surrey, UK this is an occurrence highly sought after by many coaster enthusiasts.

In 2006, NASA announced that it would build a system using principles similar to those of a roller coaster to help astronauts escape the Ares I launch pad in an emergency.

Safety

Many safety systems are implemented in roller coasters. One of these is the *block* system. Most large roller coasters have the ability to run two or more trains at once, and the block system prevents these trains from colliding. In this system, the track is divided into several sections, or blocks. Only one train at a time is permitted in each block. At the end of each block, there is a section of track where a train can be stopped if necessary (either by preventing dispatch from the station, closing brakes, or stopping a lift). Sensors at the end of each block detect when a train passes so that the computer running the ride is aware of which blocks are occupied. When the computer detects a train about to travel into an already occupied block, it uses whatever method is available to keep it from entering. The trains are fully automated.

The above can cause a cascade effect when multiple trains become stopped at the end of each block. In order to prevent this problem, ride operators follow set procedures regarding when to release a newly loaded train from the station. One common pattern, used on rides with two trains, is to do the following: hold train #1 (which has just finished the ride) right outside the station, release train #2 (which has loaded while #1 was running), and then allow #1 into the station to unload safely.

Another key to safety is the control of the roller coaster's operating computers: programmable logic controllers (often called PLCs). A PLC detects faults associated with the mechanism and makes decisions to operate roller coaster elements (e.g. lift, track-switches and brakes) based on configured state and operator actions. Periodic maintenance and inspection are required to verify structures and materials are within expected wear tolerances and are in sound working order. Sound operating procedures are also a key to safety.

Roller coaster design requires a working knowledge of basic physics to avoid uncomfortable, even potentially fatal, strain to the rider. Ride designers must carefully ensure the accelerations experienced throughout the ride do not subject the human body to more than it can handle. The human body needs time to detect changes in force in order to control muscle tension. Failure to take this into account can result in severe injuries such as whiplash. The accelerations accepted in rollercoaster design are generally in the 4-6Gs ($40\text{--}60\text{ m s}^{-2}$) range for positive vertical (pushing you into your seat), and 1.5-2Gs ($15\text{--}20\text{ m s}^{-2}$) for the negative vertical (flying out of your seat as you crest a hill). This range safely ensures the majority of the population experiences no harmful side effects. Lateral accelerations are generally kept to a minimum by banking curves. The

neck's inability to deal with high forces leads to lateral accelerations generally limited to under 1.8Gs. Sudden accelerations in the lateral plane result in a rough ride.

Despite safety measures, accidents can, and do, occur. Regulations concerning accident reporting vary from one authority to another. Thus in the USA, California requires amusement parks to report any ride-related accident that requires an emergency room visit, while Florida exempts parks whose parent companies employ more than 1000 people from having to report any accidents at all. Rep. Ed Markey of Massachusetts has introduced legislation that would give oversight of rides to the Consumer Product Safety Commission (CPSC).

Ride accidents can also be caused by riders themselves or ride operators not following safety directions properly, and, in extremely rare cases, riders can be injured by mechanical failures. In recent years, controversy has arisen about the safety of increasingly extreme rides. There have been suggestions that these may be subjecting passengers to translational and rotational accelerations that may be capable of causing brain injuries. In 2003 the Brain Injury Association of America concluded in a report that "There is evidence that roller coaster rides pose a health risk to some people some of the time. Equally evident is that the overwhelming majority of riders will suffer no ill effects."

A similar report in 2005 linked roller coasters and other thrill rides with potentially triggering abnormal heart conditions that could lead to death. Autopsies have shown that recent deaths at various Disney parks, Anheuser-Busch parks, and Six Flags parks were due to previously undetected heart ailments.

Statistically, roller coasters are very safe compared to other activities. The U.S. Consumer Product Safety Commission estimates that 134 park guests required hospitalization in 2001 and that fatalities related to amusement rides average two per year. According to a study commissioned by Six Flags, 319 million people visited parks in 2001. The study concluded that a visitor has a one in one-and-a-half billion chance of being fatally injured, and that the injury rates for children's wagons, golf, and folding lawn chairs are higher than for amusement rides.

Types of roller coasters

Today, there are two main types of roller coaster:

- Steel roller coasters
- Wooden roller coasters

Steel coasters are known for their smooth ride and often convoluted shapes that frequently turn riders upside-down via inversions. Wooden coasters are typically renowned by enthusiasts for their rougher ride and "air time" produced by negative G-forces when the train reaches the top of hills along the ride. There are also hybrid roller

coasters that combine a steel structure with wood tracks, or a wood structure with steel tracks.

Modern roller coasters take on many different forms. Some designs take their cue from how the rider is positioned to experience the ride. Traditionally, riders sit facing forward in the coaster car, while newer coaster designs have ignored this tradition in the quest for building more exciting, unique ride experiences. Variations such as the stand-up roller coaster and the flying roller coaster position the rider in different ways to provide different experiences. Stand-up coasters involve cars that have the riders in a standing position (though still heavily strapped in). Flying coasters have the riders hanging below the track face-down with their chests and feet strapped in. Vekoma "Flying Dutchman" coasters have the riders starting out sitting above the track, then they fully recline so that the riders are looking at the sky. Eventually, they twist into the "flying" position. B&M flying coasters have the riders hanging below the track like in an inverted (hanging) coaster. To go into the flight position, the section of the car where the riders' feet are raised to the track. That way, they start in the flight position. In addition to changing rider viewpoint, some roller coaster designs also focus on track styles to make the ride fresh and different from other coasters.

By train type

- 4th Dimension roller coaster
- Bobsled roller coaster
- Diving Machine roller coaster
- Floorless roller coaster
- Flying roller coaster
- Inverted roller coaster
- Inverted Impulse roller coaster
- Mine Train roller coaster
- Motorbike roller coaster
- Pipeline roller coaster
- Side friction roller coaster
- Spinning roller coaster
- Stand-up roller coaster
- Steeplechase roller coaster
- Suspended roller coaster
- Virginia Reel roller coaster
- Flying Turns

By track layout

- Corkscrew roller coaster
- Dueling roller coaster
- Figure 8 roller coaster
- Möbius Loop roller coaster
- Out and Back roller coaster
- Racing roller coaster
- Shuttle roller coaster
- Twister roller coaster
- Wild Mouse roller coaster
- Vertical Drop roller coaster

By mechanics

- Chain-lift/cable lift/Elevator lift/Ferris Wheel lift roller coaster
- Launched roller coaster
- Powered roller coaster

By height

A **Kiddie roller coaster** is a roller coaster specifically designed for families and children not able to ride the larger rides.



Kiddie coaster: Kingdom Coaster at Dutch Wonderland in Lancaster, Pennsylvania, is a 55 foot tall coaster that reaches a top speed of 40mph.



Mega/Hyper coaster: Behemoth, at Canada's Wonderland, is the highest coaster at 230 ft and fastest coaster in Canada, reaching 77mph.



Giga coaster: The first Giga coaster, the 310 ft tall Millennium Force at Cedar Point.



Strata coaster: The tallest coaster in the world, the 456 ft tall Kingda Ka at Six Flags Great Adventure.

Several height-related names have been used by parks and manufacturers for marketing their roller coasters. While often used among coaster fans, their definitions are not always agreed upon, nor are the terms necessarily accepted industry wide.

A **Mega Coaster** or **Hyper Coaster** is a complete-circuit roller coaster with a height between 200 and 299 feet. The first roller coaster to be classified as a hyper coaster is Magnum XL-200 at Cedar Point built by Arrow Dynamics. Ever since its debut, hyper coasters have been among the most popular style of rollercoasters worldwide. Bolliger and Mabillard and Intamin AG are the most prominent hyper coaster manufacturers.

A **Giga Coaster** is a complete-circuit roller coaster with a height between 300 and 399 feet. The term was coined by a Cedar Point and Intamin AG partnership after the construction of Millennium Force. There are three Giga coasters worldwide: Millennium Force at Cedar Point, Steel Dragon 2000 at Nagashima Spa Land in Japan, and Intimidator 305 at Kings Dominion. Millennium Force and Intimidator 305 were built by Intamin AG while Steel Dragon 2000 was built by Chance-Morgan.

Name	Park	Manufacturer	Status	Opened	Height
Millennium Force	Cedar Point	Intamin AG	Operating	May 13, 2000	310 feet (94 m)
Steel Dragon 2000	Nagashima Spa Land	Chance Morgan	Operating	August 1, 2000	318 feet (97 m)
Intimidator 305	Kings Dominion	Intamin AG	Operating	April 2, 2010	305 feet (93 m)

A **Strata coaster** is a complete-circuit roller coaster with a height between 400 feet (120 m) and 499 feet (152 m). The term was adopted and attributed by Intamin. Only two Strata coasters have been built worldwide, both using Intamin's hydraulically launched Accelerator Coaster design. The first was Top Thrill Dragster at Cedar Point, which opened in 2003 and stands at a height of 420 feet (130 m). The second was Kingda Ka at Six Flags Great Adventure, which opened in 2005 with a record-breaking height of 456 feet (139 m).

Name	Park	Manufacturer	Status	Opened	Height
Top Thrill Dragster	Cedar Point	Intamin AG	Operating	May 4, 2003	420 feet (130 m)
Kingda Ka	Six Flags Great Adventure	Intamin AG	Operating	May 21, 2005	456 feet (139 m)

Tower of Terror II at Dreamworld Australia, and Superman: Escape From Krypton at Six Flags Magic Mountain, respectively, were the first roller coasters to break the 400-foot (120 m) barrier, but are not considered Strata coasters, since they are shuttle roller coasters and their cars travel only 328 feet (100 m) high.

Roller Coasters



Riding Fahrenheit, located at Hersheypark in Hershey, Pennsylvania.



Hypersonic XLC, the world's first production Thrust Air 2000 (now defunct)



Top Thrill Dragster at Cedar Point is the strata coaster ever built.



Riding Expedition GeForce at Holiday Park, Germany.



Raptor, a steel inverted coaster, is located at Cedar Point in Sandusky, Ohio.



Texas Giant at Six Flags Over Texas before being refurbished into a hybrid steel-wood coaster.



Lightning Racer at Hersheypark is a racing, dueling roller coaster made by GCI.



This all-wooden roller coaster, built in 1951, dominates the Linnanmäki amusement park in Helsinki, Finland.



Coney Island Cyclone in Brooklyn, New York was built in 1927 and refurbished in 1975.



Son of Beast in Kings Island was the only wooden coaster to have a loop. It was removed in 2006.



Jack Rabbit at Kennywood Park outside of Pittsburgh, Pennsylvania was built in 1920.



Phoenix, built in 1947, at Knoebles Grove in Elysburg, Pennsylvania. It was relocated from Playland Park in 1984.



Oblivion (roller coaster) at Alton Towers in Staffordshire, England.



Griffon splashing down into a pool at Busch Gardens Williamsburg.



Great Bear is the first steel inverted coaster in Pennsylvania, located at Hersheypark.



Nitro at Six Flags Great Adventure, a Bolliger & Mabillard out and back coaster.



"Montu", a popular inverted roller coaster at Busch Gardens Tampa Bay



Black Mamba at Phantasialand, Germany



Euro-Mir, a spinning roller coaster at Europa-Park in Rust, Germany



Dragon Khan at PortAventura in Salou, Tarragona, Catalonia, Spain

Chapter 2

Accelerator Coaster



Storm Runner from Hersheypark.

The **Accelerator Coaster** is Intamin AG's term for their hydraulically-launched roller coaster model. These models are the tradename for some of the fastest rides on earth.

An accelerator coaster is named because of its long, straight launch track, its tower, known as a "top hat", and its magnetic brakes that smoothly stop the train without touching it. After the top hat, the layout varies widely, ranging from a flat brake run to several inversions.

If this type of coaster is not launched fast enough to clear the top hat (which can happen for several reasons), it will roll backwards down the tower and along the launch track. For this reason, the launch track is fitted with retractable brakes that are retracted for the launch and extended at all other times. The main brake run uses the same type of brakes, which are fixed in place.

An Accelerator Coaster's hydraulic launch is much smoother than other launch technologies such as linear motors. While a linear motor-launched train's acceleration is greatest at the beginning of the launch and decreases throughout the launch, a hydraulic launch produces nearly constant acceleration throughout the launch.

Most accelerator coasters are launched from the station, but there are some that advance the train to a separate launch area, either for theming reasons (Superman Escape) or to allow multiple trains to be loaded simultaneously (Top Thrill Dragster, Kingda Ka).

Restraints



Over-The-Shoulder restraints found on most Accelerator Coasters. These are the restraints for Kingda Ka.

Accelerator coasters are noted for their unique over-the-shoulder restraints, which are used on all accelerator coasters except the first two, Xcelerator and Top Thrill Dragster, which use lapbars. These restraints feel like lapbar restraints while still providing the safety of traditional over-the-shoulder restraints. They consist of two major parts: a thick padded metal bar that swings down into one's lap, and two thin, flexible shoulder straps. For all but the largest riders, the shoulder straps won't even be noticeable.

These restraints are also notable for their locking system, which uses two hydraulic cylinders (for redundancy, in case one fails) rather than a ratchet. While a ratchet-based restraint only locks at each notch and will often be too loose or uncomfortably tight, the hydraulic system allows the restraints to be pulled down to any position, where they will stay. In the extremely unlikely case that *both* locking cylinders fail, the restraints are also held down by a seatbelt, as are most over-the-shoulder restraints.

These over-the-shoulder restraints also allow trains to be checked faster than with lapbars. The lapbars use a seat belt as a backup restraint. It must be checked by the ride attendants before the lapbar is lowered, as it cannot be checked properly with the lapbar down. This means that the guests must not pull down their own lapbars, but instead should buckle their own seatbelts, after which the attendants will check the seatbelts and lower the lapbars.

In contrast, the over-the-shoulder restraints are simply held down with a seatbelt. This means that the guests can pull down their own restraints and buckle their own belts, and all the ride attendants need to do is push down on the restraints and pull the seatbelts tight, saving significant time over the lapbar and seatbelt system.

How it works



The **catch-car** connects to the train to launch it. This is the catch-car found on Kingda Ka.

An Accelerator Coaster's launch system operates on the same basic principle as a Super Soaker, but on a much larger scale. The coaster's power source is several hydraulic pumps, each capable of producing 500 horsepower (373 KW). These pumps push hydraulic fluid into several accumulators. These accumulators are divided into two compartments by a movable piston, one side filled with hydraulic fluid and the other with nitrogen gas. The nitrogen is held in large tanks directly beneath the actual accumulator. As the hydraulic fluid fills the accumulators, it pushes on the pistons, compressing the nitrogen. It takes approximately 45 seconds to pressurize the accumulators with all pumps operating. All of this pressure is released during each launch, which typically lasts between 2 and 4 seconds.

The heart of the launch system is a large winch, around which the launch cables are wound. This winch is driven by hydraulic turbines. The two launch cables are attached to the winch on its ends, and run through two grooves on top of the launch track. The cables are attached to the sides of the catch-car, which runs in a trough between the grooves. A third, single retractor cable is attached to the rear of the catch-car, it runs around a pulley wheel at the rear end of the launch track and returns to the hydraulic building along the bottom of the launch track, where it is wound in the opposing direction on the winch's drum.

The train connects to the catch-car with a solid piece of metal known as a "launch dog" that drops down from the center car. The launch dog is normally retracted and is held in place by a small magnet, but the launch area has electrical contacts that demagnetize the magnet and cause the launch dog to drop down. The launch dog drops down at an angle, similar to the chain dog that a lifted coaster uses to connect to the lift chain.

Once the train and catch-car are in position and all is clear, the operator presses the "Launch" button and the launch sequence begins:

1. The train's launch dog is released.
2. The drive tires that advance the train to the launch track retract. Because the launch track is sloped slightly upwards, the train rolls backwards a few inches, until it is stopped by the launch dog engaging the catch-car.
3. The anti-rollback magnetic brakes on the launch track retract.
4. Approximately five seconds later, the launch valves in the hydraulic room open. The compressed nitrogen in the accumulators forces the hydraulic fluid into the turbines that drive the winch. As the winch winds in the launch cables, the retractor cable is unwound from the winch. After the train moves off the electrical contacts in the launch area, its launch dog is held down only by the force of the accelerating catch-car.
5. Each section of brakes on the launch track pops back up immediately after the train passes a proximity switch.
6. When the train reaches full speed and all the pressure in the accumulators has been released, the catch-car, still connected to the train, enters its braking zone. The catch-car uses the same braking configuration as the train, but is much lighter, so it slows down very quickly. As the catch-car begins to slow down, the train's launch dog retracts - the shape where it drops into is a "v" shape, so the dog is forced back into position as it runs over the catch-car and is held in place by the magnet, as the train continues on its way.
7. Once the catch-car has stopped, the launch system resets - the winch reverses direction, returning the catch-car to the launch area using the third retractor cable, and the pumps begin recharging the accumulators. This normally takes about 45 seconds, after which the next train can be launched.

If the train rolls back, it will be brought to a near stop (magnetic brakes cannot completely stop a train) well before the beginning of the launch track. Regardless of the position of the catch-car when the train passes it going backwards, there will be no interference as the train's launch dog will be retracted. After the train slows to a near stop, the brakes will be cycled up and down to control the train's speed until it is back in launch position. On the larger coasters, this "launch reset" process can take more than a minute as the train must be moved very slowly. Once the train is back in launch position, it can be launched again or can be returned to the station.

The basic launch sequence is often accompanied by various theme elements. The most common is "starting lights" that cycle down from yellow to green, the green light coming on just as the train begins to accelerate.

The number of pumps, accumulators, and turbines varies with the speed the coaster is designed to achieve. Kanonen (the world's slowest Accelerator Coaster) has a design speed of 47 mph (76 km/h), one pump, one accumulator, and eight turbines. Kingda Ka (the world's fastest roller coaster) has a design speed of 128 mph (206 km/h), seven pumps, four accumulators, and 32 turbines. The system as a whole is capable of producing up to 20,800 horsepower (15.5 MW) for each launch, although a typical launch uses less than 10,000 horsepower (7,500 kW).

The catch-car is stopped by magnetic brakes identical to those used to stop the train. In order to give the catch-car room to slow down, only about three quarters of the launch track can actually be used to launch the train, the catch-car needs 64 feet(20m) on a 100 km/h accelerator coaster (and significantly more on a faster coaster like Kingda Ka) to slow to a full stop.

One major advantage of this launch system compared to others is its low power consumption, the hydraulic pumps run constantly and actually use *less energy* than most chain lift drive motors.

List of Accelerator Coasters

Name	Height	Speed	Park, Location	Year Opened
Xcelerator	205 ft (62 m)	82 mph (132 km/h)	Knott's Berry Farm, California	2002
Top Thrill Dragster	420 ft (130 m)	120 mph (190 km/h)	Cedar Point, Ohio	2003
Storm Runner	150 ft (46 m)	75 mph (121 km/h)	Hersheypark, Pennsylvania	2004
Rita	69 ft (21 m)	61 mph (98 km/h)	Alton Towers, England	2005
Kanonen	79 ft (24 m)	47 mph (76 km/h)	Liseberg, Sweden	2005
Kingda Ka	456 ft (139 m)	128 mph (206 km/h)	Six Flags Great Adventure, New Jersey	2005
Skycar	112 ft (34 m)	57 mph (92 km/h)	Mysterious Island, China	2005
Superman Escape	131 ft (40 m)	62 mph (100 km/h)	Warner Bros. Movie World, Australia	2005
Stealth	205 ft (62 m)	80 mph (130 km/h)	Thorpe Park, England	2006
Speed Monster	131 ft (40 m)	56 mph (90 km/h)	TusenFryd, Norway	2006

Zaturn	213 ft (65 m)	81 mph (130 km/h)	Space World, Japan	2006
Desert Race	62 ft 7 in (19.08 m)	62.1 mph (99.9 km/h)	Heide Park, Germany	2007
Furius Baco	46 ft (14 m)	83.9 mph (135.0 km/h)	PortAventura, Spain	2007

Chapter 3

Station (Roller Coaster) and Launch Track

Station

A roller coaster's **station** is where the passengers board and alight from the trains. The station houses the coaster's control panel, and has devices for moving the trains in and out of the station and holding them in position, as well as devices for locking and unlocking the restraints and devices for controlling guest access to the platform. Some stations have separate loading and unloading platforms.

Controlling the ride

The main control panel is normally located at the front of the station, on the unload side, and will typically have at least all of these controls:

- **Dispatch.** Often two buttons that must both be pressed. When pressed and held down, the train in the station will move forwards out of the station. For safety reasons, the train will stop if the button is released before the train is clear of the station.
- **Dual Leave the Station.** Push button that is pressed in conjunction with the drivers dispatch button to advance a train out of the station. For safety reasons, the train will stop if this button is also released before the train is clear of the station.
- **Train Advance/Accept.** Also known as "Auto-Brake Enable", when pressed and held down, the train behind the station moves forward into the station. Like the dispatch button, the train will stop if the button is released. The dispatch button sometimes also serves as the advance button, in which case the train in the station will dispatch, then the train behind the station will advance as soon as the station is clear. In some cases if the operator forgets to advance the train forward with this button after another train has left the station the lift chain will stop the other train from moving depending on ride design and other brakes or chains located on the track. This method is also use to perform a "block-test" to ensure that the two trains will not collide.

- **Diagnostic Clear or Fault Reset.** Push button that will clear an error caused by the driver or other ride problem. The driver/operator can only clear some errors while mechanics can clear all. This ensures rider safety. Such errors that drivers can clear are forgetting to advance a rear train after a front train has left the station and the lift chain has stopped because of it, or forgetting to lock the lapbars before pressing dispatch, which in such a case the system will disable dispatch until all restraints are locked.
- **Advance E-Brake.** Push button that is held down to advance a rear train forward to the "trim-brakes" while another train is in the station. This option will not cause the two trains to collide because the trim brakes must remain closed until the front train has fully dispatched from the station. This option on a control panel is a useful tool in case the operator or "driver" of the ride forgets to bring the rear train into the station once a front train has left and thus helps prevent the chain lift from shutting down. Also if this button is released the train will stop so long as it is in the "e-brakes" position, else it will not stop until it has reached the "trim-brakes."
- **Lift Start Warning.** Push button that is held down for a certain amount of time until the alarm itself stops after which the operator along with one other person can start the lift. The operator must also check that all trains are in correct position or else the lift chain will not restart. At least two buttons must be pulled by two different people, one of which must be the driver in order to start the lift. Mechanics only have to use one so long as the ride is in "manual mode."
- **Alarm Silence.** A push button that silences almost any alarm but in some cases won't. A usual alarm heard by a driver is when there are at least two trains on a track and the alarm makes a buzzing sound to alert the driver that a rear train is about to enter the "e-brakes" position.
- **Lift Start/Stop.** A button that is pulled after the "lift start warning" has been sounded which will enable the lift to start. Pushing the same button can also stop the lift from operating. This is useful for non-emergency stops.
- An **"Auto/Manual Mode" key switch.** Automatic mode is used for the normal operation of the coaster, while mechanics use manual mode for maintenance and testing purposes, and also to perform the pre-opening procedures each day. When starting complex roller coasters, it can take an hour or more before the first test run can be conducted.
- A **microphone** to allow the operator to talk to the guests.
- Lights indicating whether or not each block is occupied by a train.
- Lights indicating whether or not the restraints are down far enough to allow the train to be dispatched. This could be one light for the entire train, or a separate light for each row or car. They will normally be built into the lock/unlock restraint button(s).
- An "all clear" light, which indicates that the train can be dispatched. It is normally built into the Dispatch button.
- A "trouble" light, indicating that the coaster has experienced a malfunction, normally a very minor one. On a very complex coaster such as Kingda Ka, even something as minor as a lightbulb burning out will trigger the trouble light.

In addition to the main control panel, most modern coasters have an "enable panel" on the station's wall, normally in the corner farthest from the main panel. These are small panels that have two buttons: "**Leave the Station Button**" and "**Emergency Stop**". Many modern coasters also have a **Open/close entrance gates** button on this panel, as well.

Moving and interfacing with the train

The station has a mechanism to move each train into the station, hold it in place while it is loaded, then move it out of the station. If the station is built on a slope, the train will move into and out of the station under gravity and all that's needed are brakes to hold it in place. If the station is built flat, drive tires or another form of propulsion must be used. On some coasters, the station has no brakes - instead, it has drive tires that lock in place to prevent the train from moving. This is normally used on coasters with magnetic brakes, as this type of brake cannot completely stop a train.

The station also has a mechanism to lock and unlock the restraints, which can be physical or electric. A physical interface uses spring-loaded rods in the train that are pushed by plates in the station to unlock the restraints. An electrical interface uses copper contacts mounted to the track and brushes mounted to the bottom of the train to allow the computer to interface directly with the train and control its restraints. One major advantage of a physical interface is that it allows the restraints to be easily unlocked with a simple wrench-like tool if a train has to be evacuated (unloaded anywhere other than the station). An electrical interface, on the other hand, may require a large, bulky battery pack to be plugged into the train in order to manually unlock the restraints. Some electrically operated restraints allow manual operation with a wrench or T-bar device, in the event that electrical power is not available. An electrical interface also requires more maintenance, as the electrical contacts in the station must be cleaned regularly to maintain a good connection.

Most coasters also have an interface for giving the computer feedback on the position of the restraints. This is usually a simple electric interface. On some coasters this is not used, instead there is a fixed-length seatbelt that must be buckled to the restraint. If the restraint cannot be pushed down far enough for the belt to be buckled, the train cannot be dispatched.

The station, as well as other important parts on the coaster such as the lift and brake runs, has many hall effect sensors that give the computer feedback on the position of each train. These sensors sense the presence of any metal object, such as part of the train, in their immediate vicinity. Moving any other metal object in range of the sensor will also trigger it, creating what's known as a "ghost train" - the computer thinks there's a train where there isn't one, causing an emergency stop.

Some types of coasters have additional equipment in the station. Floorless roller coasters have individual floor sections between the rows that flip downwards and to the side to allow the train to move. Inverted roller coasters have a retractable floor that drops down about a foot before the train dispatches. Flying roller coasters have a mechanism to flip

the seats into flying position, and some also have the same retractable floor of an inverted coaster.

Launch Track



Speed Monster (2006), at Tusenfryd of Norway, prominently features a launch track.

The **launch track** is the section of a launched roller coaster in which the train is accelerated to its full speed in a matter of seconds. A launch track is always straight and is usually banked upwards slightly, so that a train would roll backwards to the station in the event of a loss of power.

A launch track serves the same basic purpose as a lift hill - providing power to the train - but accomplishes it in an entirely different manner. A lift hill gives the train potential energy by raising it to the highest point in the track (and not significantly accelerating it). A launch track gives the train kinetic energy by accelerating it to the maximum designed speed (while not significantly raising it).

A launch track normally includes some form of brakes. Depending on the type of coaster, these brakes may be used in every run of the coaster (this is normally found on a Shuttle

roller coaster where the launch track also serves as the main brake run) or they may only come into play when a rollback occurs, normally on a complete-circuit coaster such as Top Thrill Dragster and Kingda Ka. In either case, the brakes are retracted to allow trains to launch, and are engaged at all other times.

Types of launch tracks

LIM/LSM



Wicked Twister (LIM) launching

LIM/LSM launch tracks have many (often more than 200) linear motors on both sides of the launch track. The train on this type of coaster has metal fins mounted to its sides to facilitate launching. A magnetic field is created by the LIMs on the track, which attract the car and send it forward. The next LIM on the track is magnetized, and the previous one loses its field. This continually attracts the car forward until it reaches the end of the launch track at full speed.

Hydraulic



Top Thrill Dragster (hydraulic) launching; note elevation change

A hydraulic launch track has a trough running along its center, a "catch car" that connects to the train for launching travels through this trough. The catch car is connected to a cable loop that runs along the entire length of the launch track, anchored by a pulley wheel at the near end of the track and by the launch motor itself at the far end. The launch motor is located in a small building under the end of the launch track. Only about $\frac{2}{3}$ of the length of this type of launch track can be used for launching the train, as the catch car must be stopped after it disengages from the train. This type of propulsion is capable of catapulting a train to very high speeds, yet is only used mostly by Intamin AG, and less abundantly used by Vekoma, in their Accelerator coasters and Motorbike coasters, respectively.

Friction Wheel

A friction wheel launch consists of a series of high speed drive tires used in succession to propel the train forward. An example of a friction wheel launch is the *Incredible Hulk Coaster* at Universal's Islands of Adventure. The train begins to climb the lift hill at a normal speed, and begins to accelerate half-way up the hill.

Flywheel

Many shuttle loop roller coasters have a flywheel launch mechanism. Rotational energy is stored in the flywheel, which then catches on a cable attached to the train. The flywheel releases its energy to propel the train forward.

Counterweight

Counterweight launch mechanisms are used on some shuttle loops. The trains are launched by dropping a large counterweight attached to a cable. The cable then drives the train forward.

Cable

Disneyland Paris' Space Mountain uses this system. The train arrives at an incline and stops and hooks on to the pulley/catapult. The train is then launched up the hill and the cable falls back to the bottom. Walibi Belgium Turbine uses this system too

Chapter 4

Lift Hill and Physics of Roller Coasters

Lift Hill



Goliath (2002), in Walibi World of the Netherlands, has a 150 foot (45.7 meter) lift hill.

A **lift hill**, or **chain hill**, is often the initial upward-sloping section of track on a typical roller coaster that initially transports the roller coaster train to an elevated point or peak in the roller coaster ride. Upon reaching the peak, the train is then disengaged and propelled

from the lift hill by gravity and allowed to coast throughout the rest of the roller coaster ride's circuit.

Lift hills usually propel the train to the top of the ride via one of two methods: a chain lift involving a long, continuous chain which trains hook on to and are carried to the top; or a drive tire system in which multiple motorized tires push the train upwards. A typical chain lift consists of a heavy piece of metal called a chain dog, which is mounted onto the underside of one of the cars which make up the train. This is in place to line up with the chain on the lift hill.

The chain rotates at a constant speed and is normally powered by one or more motors, which are positioned under the lift hill. The chain sits in a steel trough on the lift hill containing electrical magnets, these keep the rotating chain on the lift hill and prevent uplift. When the cars reach the lift hill, the electrical magnets attract the metal chain dogs and causing them to hook into the holes in the chain. The anti-rollback device then drops into each notch on the lift hill as the cars rise to the highest point.

Upon reaching the top, the anti-rollback device stops moving and the track levels out flat. The chain dogs are normally loaded with metal springs so that they can return to their original position on the base of the train when the magnets can no longer reach them and they un-hook from the chain. If loss of power or technical difficulties occur, the chain dogs rise out of the chain if the magnets are powered by the same circuit and the anti-rollback dog will be put to use by preventing the cars from rolling back down.

Cable lift



Hydra the Revenge at Dorney Park & Wildwater Kingdom in Allentown, Pennsylvania

The **cable lift** is a type of lift mechanism that was used on many scenic railway-style coasters, which were built in the early part of the 20th century. Several still exist today and still use the mechanism. This type of lift has returned for Kings Dominion's *Intimidator 305*, Cedar Point's *Millennium Force*, Holiday Park's Expedition GeForce, and La Qua's *Thunder Dolphin*, and is used on the wooden roller coaster *El Toro* at Six Flags Great Adventure.

The cable lift utilizes a cable loop in place of the traditional chain, which is attached to a short section of chain that engages the train's chain hook. Because a cable is much lighter than a chain, cable lifts are much faster than chain lifts and can be used on much steeper hills - even vertical.

A cable also requires far less maintenance than a chain. Another advantage to park guests is that a cable lift is very quiet, partly because the main drive winch is located directly beneath the top of the lift, a location which will normally be relatively far from guest-accessible areas. However, one minor disadvantage of a cable lift system is that it must return to the bottom of the lift hill after lifting each train, which does not apply to a continuously moving chain lift.

Tilt lift/thrill lift section

There are two types of Tilt Coaster: A standard coaster with a vertical drop at the start, (Trains enter the vertical drop via an unusual tilt section. After leaving the chain lift, instead of going down a first drop, the rider is held on a horizontal section of track, which then tilts forwards, to become a vertical section. This leads into the drop, then into the rest of the coaster layout.) and a thrill lift designed similar to the elevator lift but instead of it bringing you up into the horizontal position, it brings you to a vertical and then lets gravity do the rest. There is one operating Tilt Coaster in the world, Gravity Max! at Discovery World in Taiwan.

Elevator lift

The **elevator lift** is a new technology used to make the ascension of the roller coaster faster and more comfortable due to the fact all you are doing is moving vertically up. As of 2008 only 17 coasters have an elevator lift.

Ferris wheel lift

The **Ferris wheel lift** is a brand new technology that utilizes the favorite Ferris wheel ride and incorporates it into a roller coaster. Created by Premier Rides, it exists on the former Maximum RPM (now named 'Round About')! at the former Hard Rock Park (now Freestyle Music Park) in Myrtle Beach, South Carolina. It uses a Ferris Wheel like motion to lift the cars to the top, as on a Ferris Wheel. The cars are then released onto the track.

Anti-rollback device

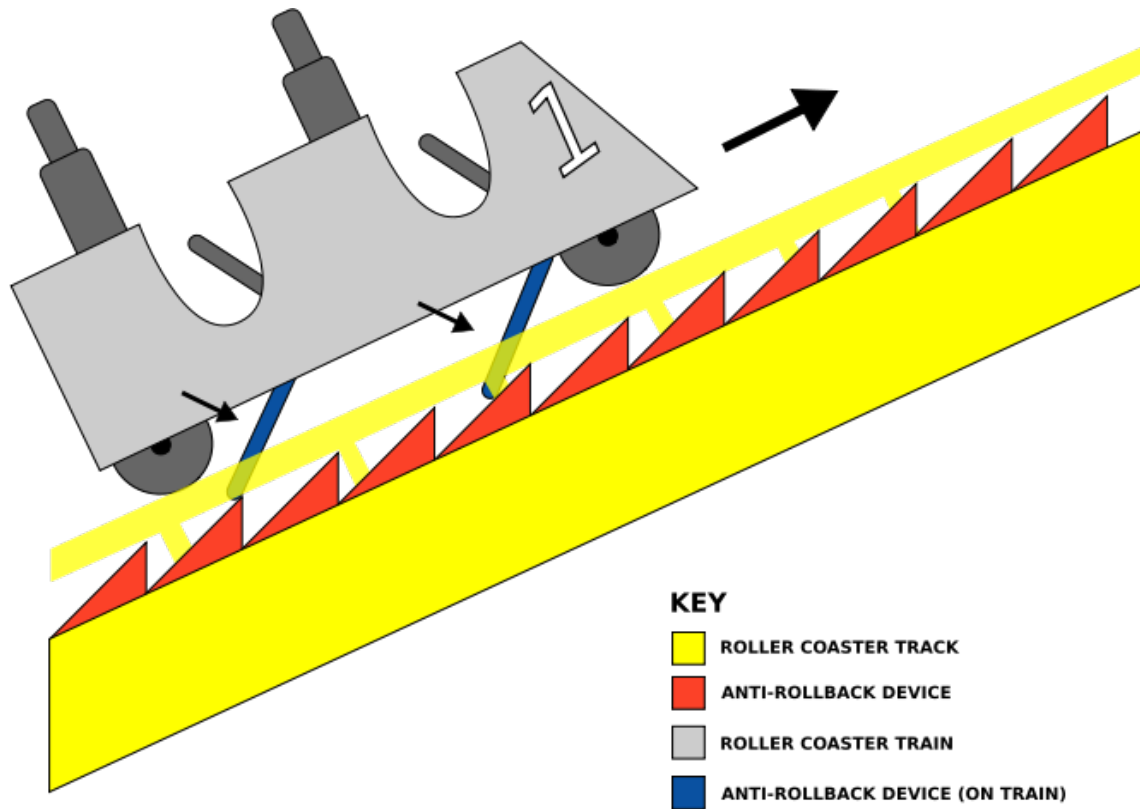


Diagram depicting the anti-rollback safety feature.

The familiar "click-clack" sound that occurs as roller coaster trains ascend the lift hill is not caused by the chain itself. The cause for this noise is actually a safety device used on lift hills -- the anti-rollback device. The anti-rollback device is a standard safety feature, typically consisting of a continuous, saw-toothed, section of metal, forming a linear ratchet.

Roller coaster trains are fitted with anti-rollback "dogs" which are essentially heavy-duty pieces of metal which fall and rest in each groove of the anti-rollback device on the track as the trains ascend the lift-hill. This makes the "clicking" sound and essentially allows the train to go upwards only, effectively preventing the train from rolling back down the hill should it ever encounter a power failure or broken chain.

This feature was derived from the similar feature originally used on the Mauch Chunk Switchback Railway in Pennsylvania, starting in 1846. The two uphill planes that cars were drawn up under the power of a stationary steam engine had two slightly different early forms of this anti-rollback device. The entire concept of the modern roller coaster was also initially inspired by this railroad.

Physics of Roller Coasters

Simply speaking, a roller coaster is a machine that uses gravity and inertia to send a train of cars along a winding track. This combination of gravity and inertia, along with G-forces and centripetal acceleration give the body certain sensations as the coaster moves up, down, and around the track. The forces experienced by the rider are constantly changing, leading to feelings of joy in some riders and nausea in others. The basic principles of roller coaster mechanics have been known since 1665, and since then roller coasters have become a popular diversion.



Centripetal acceleration

Centripetal acceleration is not a true force, but rather the result of an object's inertia, or resistance to change in direction, as the object moves in a circular path. The "force" points toward the center of the circle, but a roller coaster rider would feel centripetal acceleration as a force pushing them toward the outer edge of the car. The following equation expresses centripetal acceleration:

$$a_r = \frac{v^2}{r}$$

where a_r is centripetal acceleration, v is velocity and r is the radius of the circular path. This shows that two roller coaster cars entering two loops of different size at the same speed will experience different acceleration forces: the car in the tighter loop will feel greater acceleration while the car in the wider loop will feel less acceleration.

Energy

Roller coasters have no engines. Instead, the car is pulled to the top of the first hill and released, at which point it rolls freely along the track without any external mechanical assistance for the remainder of the ride. The law of conservation of energy states that energy can neither be created nor destroyed, thus, the purpose of the ascent of the first hill is to build up potential energy that will then be converted to kinetic energy as the ride progresses. The initial hill, or the lift hill, is the tallest in the entire ride. As the train is pulled to the top, it gains potential energy, as explained by the equation for potential energy below:

$$U_g = mgh$$

where U_g is potential energy, m is mass, g is acceleration due to gravity and h is height above the ground. Two trains of identical mass at different heights will therefore have different potential energies: the train at a greater height will have more potential energy than a train at a lower height. This means that the potential energy for the roller coaster system is greatest at the highest point on the track, or the top of the lift hill. As the roller coaster train begins its descent from the lift hill, the stored potential energy converts to kinetic energy, or energy of motion. The faster the train moves, the more kinetic energy the train gains, as shown by the equation for kinetic energy:

$$K = \frac{1}{2}mv^2$$

where K is kinetic energy, m is mass, and v is velocity. Because the mass of a roller coaster car remains constant, if the speed is increased, the kinetic energy must also increase. This means that the kinetic energy for the roller coaster system is greatest at the bottom of the largest downhill slope on the track, typically at the bottom of the lift hill. When the train begins to climb the next hill on the track, the train's kinetic energy is converted back into potential energy, decreasing the train's velocity. This process of converting kinetic energy to potential energy and back to kinetic energy continues with each hill. The energy is never destroyed, but is lost to friction between the car and track. Brakes ultimately bring the ride to a complete stop.

Inertia and gravity

When going around a roller coaster's vertical loop, the inertia that produces a thrilling acceleration force also keeps passengers in their seats. As the car approaches a loop, the direction of a passenger's inertial velocity points straight ahead at the same angle as the track leading up to the loop. As the car enters the loop, the track guides the car up, moving the passenger up as well. This change in direction creates a feeling of extra gravity as the passenger is pushed down into the seat.

At the top of the loop, the force of the car's acceleration pushes the passenger off the seat toward the center of the loop, while inertia pushes the passenger back into the seat. Gravity and acceleration forces push the passenger in opposite directions with nearly equal force, creating a sensation of weightlessness.

At the bottom of the loop, gravity and the change in direction of the passenger's inertia from a downward vertical direction to one that is horizontal push the passenger into the seat, causing the passenger to once again feel very heavy. Most roller coasters require passengers to wear a safety harness, but the forces exerted by most loop-the-loop coasters would keep passengers from falling out.

G-forces

G-forces create the so-called "butterfly" sensation felt as a car goes down a hill. An acceleration of 1 standard gravity (9.8 m/s^2) is the usual force of Earth's gravitational pull exerted on a person while standing still. The measurement of a person's normal weight incorporates this gravitational acceleration. When a person feels weightless at the top of a loop or while going down a hill, they are in free fall. However, if the top of a hill is curved more narrowly than a parabola, riders will experience negative Gs and be lifted out of their seats, experiencing the so-called "butterfly" sensation.

Difference between wood and steel coasters

Wooden and steel coasters work the same way, but they have different capacities to deliver excitement for thrill seekers. Because of the strength of their building materials, steel coasters have the highest drops, most loops, are faster, and can even be designed so that the coaster hangs below the track or the riders stand instead of sit.

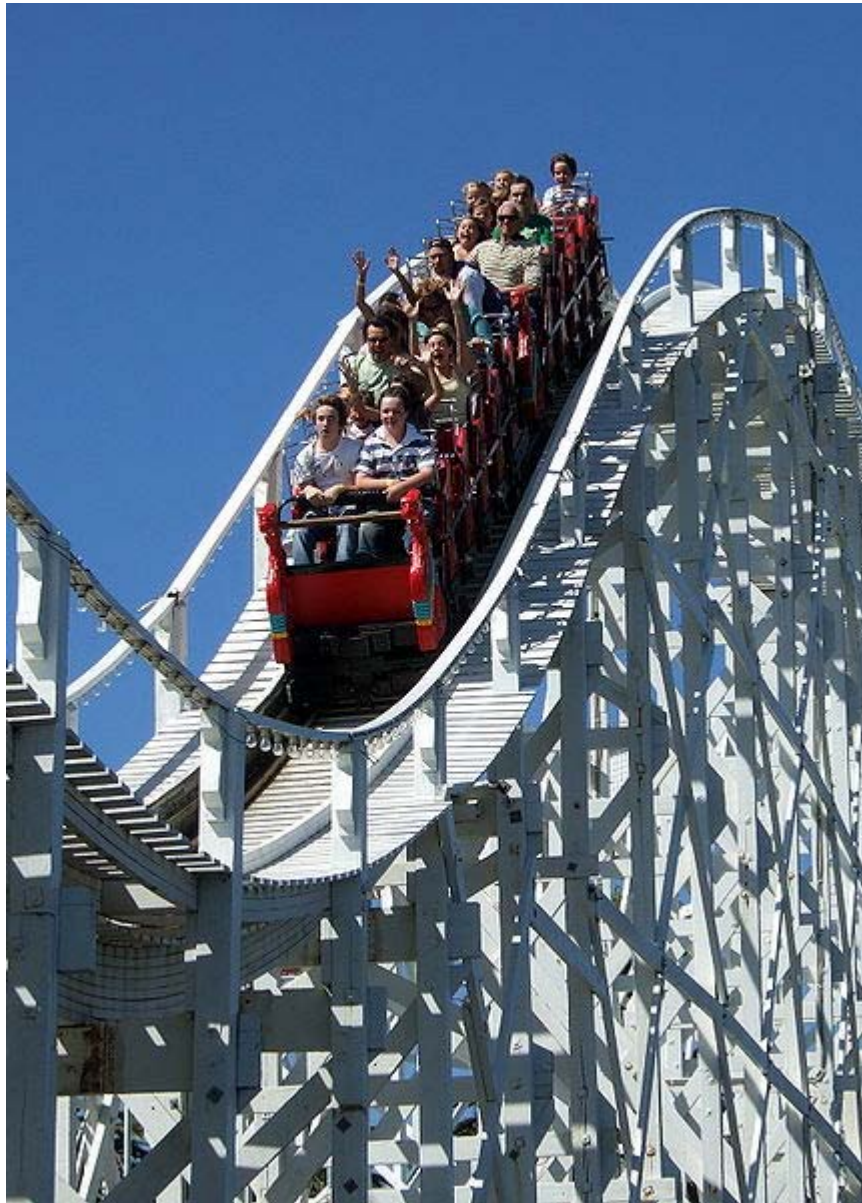
Wooden coasters, however, are not as fast, not as high, and usually do not contain loops, but they provide a different kind of thrill. The beams and struts of a wooden coaster provide a solid support for cars and riders, and riders intellectually know the ride is safe, but the coaster's unsteady appearance can provide a psychological thrill. Because their structures are fairly inflexible, wooden coasters tend to sway, adding to the thrill by giving riders different sensations than they would feel while traveling around a steel structure.

Technology

As better technology became available, engineers began to use computerized design tools to calculate the forces and stresses that the ride would subject passengers to. Computers are now used to design safe coasters with specially designed restraints and lightweight and durable materials. Today, tubular steel tracks and polyurethane wheels allow coasters to travel about 80 miles per hour (130 km/h), while even taller, faster, and more complex roller coasters continue to be built.

Chapter 5

History of the Roller Coaster



Scenic Railway at Luna Park (Melbourne, Australia), the world's oldest continually-operating roller coaster, built in 1912.

The **history of the roller coaster** stretches back to ice slides constructed in 15th century Prussia and spans all the way to the many and varied coasters of today. In between, numerous technological innovations have been introduced to make coasters bigger, faster, and safer than those that came before.

History

Beginnings

The oldest roller coasters descended from the so-called "Russian Mountains," which were specially constructed hills of ice located especially around Saint Petersburg, Russia. Built in the 17th century, the slides were built to a height of between 70 feet (21 m) and 80 feet (24 m), consisted of a 50 degree drop, and were reinforced by wooden supports. These slides became popular with the Russian upper class. Catherine II of Russia was such a fan of these attractions that she had a few of these slides built on her own property. "Russian mountains" remains the term for roller coasters in many languages, such as Spanish (*la montaña rusa*), Italian (*montagne russe*), French (*les montagnes russes*) and Portuguese (*montanha-russa*). Ironically, the Russian term for roller coaster, американские горки (*amerikanskie gorki*), translates literally as "American mountains."

There is some dispute as to who was the first to put this operation on wheels. Some historians say the first real roller coaster was built under the orders of James the 3rd in the Gardens of Oreinbaum in St. Petersburg in the year 1784. (The lawn where Catherine's roller coaster once stood, at the Sliding Hill Pavilion, now sits vacant.). Other historians believe that the first roller coaster was built by the French. The *Les Montagnes Russes à Belleville* (*The Russian Mountains of Belleville*) constructed in Paris in 1812 and the *Promenades Aeriennes* both featured wheeled cars securely locked to the track, guide rails to keep them on course, and higher speeds. The first permanent loop track was probably also built in Paris from an English design in 1846, with a single-person wheeled sled running through a 13-foot (4 m) diameter vertical loop. These early single loop designs were called Centrifugal Railways.

Scenic Railways



Mount Pisgah with the Mauch Chunk Switchback Railway.

In 1872, a mining company in Summit Hill, Pennsylvania constructed the Mauch Chunk gravity railroad, a brakeman-controlled, 8.7 mile (14 km) downhill track used to deliver coal to Mauch Chunk (now known as Jim Thorpe), Pennsylvania. By the 1850s, the "Gravity Road" (as it became known) was providing rides to thrill-seekers for 50 cents a ride. Railway companies used similar tracks to provide amusement on days when ridership was low.

Using this idea as a basis, LaMarcus Adna Thompson began work on a gravity Switchback Railway that opened at Coney Island in Brooklyn, New York in 1884. Passengers climbed to the top of a platform and rode a bench-like car down the 600 ft (180 m) track up to the top of another tower where the vehicle was switched to a return track and the passengers took the return trip. This track design was soon replaced with an oval complete circuit. In 1885, Phillip Hinkle introduced the first complete-circuit coaster with a lift hill, the *Gravity Pleasure Road*, which was soon the most popular attraction at Coney Island. Not to be outdone, in 1886 LaMarcus Adna Thompson patented his design

of roller coaster that included dark tunnels with painted scenery. "Scenic Railways" were to be found in amusement parks across the country.

Growing popularity and innovations

As it grew in popularity, experimentation in coaster dynamics took off. In the 1880s the concept of a vertical loop was again explored, and in 1895 the concept came into fruition with *The Flip Flap*, located at Sea Lion Park in Brooklyn, and shortly afterward with *Loop-the-Loop* at Olentangy Park near Columbus, Ohio. The rides were incredibly dangerous, and many passengers suffered whiplash. Both were soon dismantled, and looping coasters had to wait for over a half century before making a reappearance.

By 1912, the first underfriction roller coaster was developed by John Miller. Soon, roller coasters spread to amusement parks all around the world. Perhaps the best known historical roller coaster, *The Cyclone*, was opened at Coney Island in 1927. Like *The Cyclone*, all early roller coasters were made of wood. Many old wooden roller coasters are still operational, at parks such as Kennywood near Pittsburgh, Pennsylvania and Pleasure Beach Blackpool, England. The oldest operating roller coaster is *Leap-The-Dips* at Lakemont Park in Pennsylvania, a side friction roller coaster built in 1902. The oldest wooden roller coaster in the United Kingdom is the *Scenic Railway* at Dreamland Amusement Park in Margate, Kent and features a system where the brakeman rides the car with wheels. It was severely damaged by fire on 7 April 2008. *Scenic Railway* at Melbourne's Luna Park built in 1912, is the world's oldest continually-operating roller coaster, and it also still features a system where the brakeman rides the car with wheels. One of only 13 remaining examples of John Miller's work worldwide is the wooden roller coaster at Lagoon in Utah. The coaster opened in 1921 and is the 6th oldest coaster in the world.

The Great Depression marked the end of the first golden age of roller coasters, and theme parks in general went into decline. This lasted until 1972, when *The Racer* was built at Kings Island in Mason, Ohio (near Cincinnati). Designed by John Allen, the instant success of *The Racer* began a second golden age, which has continued to this day.

Steel roller coasters



Matterhorn Bobsleds, the world's first tubular steel roller coaster.

In 1959, the Disneyland theme park introduced a new design breakthrough in roller coasters with the *Matterhorn Bobsleds*. This was the first roller coaster to use a tubular steel track. Unlike conventional wooden rails, tubular steel can be bent in any direction, which allows designers to incorporate loops, corkscrews, and many other maneuvers into their designs. Most modern roller coasters are made of steel, although wooden roller coasters are still being built.

In 1975 the first modern-day roller coaster to perform an inverting element opened: *Corkscrew*, located at Knott's Berry Farm in Buena Park, California. In 1976 the vertical loop made a permanent comeback with the *Great American Revolution* at Magic Mountain in Santa Clarita, California.

New designs and technologies are pushing the limits of what can be experienced on the newest coasters. Flying coasters like Tatsu and electromagnetically-launched coasters like Maverick are examples of the latest generation of technologically advanced coasters.

Timeline of notable roller coasters

The roller coasters mentioned here are significant for their role in the amusement industry. They were notable for specific reasons, including:

- First coaster of a specific kind, style, manufacturing material or unique technology; ground-breaking
- First time a particular record-breaking threshold was crossed
- Historical significance

1800 to 1899

1817

- First coaster featuring cars that locked onto track: *Les Montagnes Russes à Belleville* (Russian Mountains of Belleville), Paris, France.
- First coaster to feature two cars racing each other: *Les Montagnes Russes à Belleville*.
- First complete-circuit coaster: *Promenades Aériennes* (The Aerial Walk), Paris.

1827

- First scenic gravity railroad (inspiration for first American coasters): *Mauch Chunk Switchback Gravity Railroad*, Jim Thorpe, Pennsylvania, United States.

1846

- First looping coaster (non-circuit): *Centrifugal Railway*, Frascati Garden, Paris.

1885

- First use of powered chainlift: *Gravity Pleasure*, Coney Island, Brooklyn, New York.

1900 to 1969

1902

- *Leap-The-Dips* opens at Lakemont Park, Altoona, Pennsylvania. It is today the world's oldest operating wooden coaster (it was closed from 1985 until 1999).

1907

- First use of lapbar: *Drop-The-Dips*, Coney Island.

1912

- *Scenic Railway* opens at Luna Park, Melbourne, Victoria, Australia. It is today the world's oldest continually-operating roller coaster.

1913

- First coaster with a möbius-style track: *Derby Racer*, Euclid Beach Park, Cleveland, Ohio, United States.

1925

- First coaster to reach 100 feet: *Cyclone*, Revere Beach, Revere, Massachusetts, United States.

1930

- *Rodelbaan* opens at De Waarbeek, Hengelo, The Netherlands. The oldest operating steel roller coaster.

1947



Phoenix at Knoebels, relocated from Playland Park where it was called *Rocket*.

- First coaster to be relocated: *Rocket*, Playland Park, San Antonio, Texas, United States.

1959

- First tubular steel coaster: *Matterhorn Bobsleds*, Disneyland, Anaheim, California, United States. It is today the world's oldest operating tubular steel coaster.
- First coaster to use individual brake zones, otherwise known as blocks, allowing for multiple trains to run at the same time: *Matterhorn Bobsleds*.

1966

- First coaster to feature an underwater tunnel: *Mine Train*, Six Flags Over Texas.

1970 to 1979

1972

- First enclosed coaster: *Fire In The Hole*, Silver Dollar City, Branson, Missouri, United States.

1975

- First "modern" coaster with inversions (two): *Corkscrew*, Knott's Berry Farm, Buena Park, California.

1976

- First "modern" coaster with a vertical loop: *Revolution*, Six Flags Magic Mountain, Valencia, California.



Corkscrew at Cedar Point, the first roller coaster with three inversions.

- First coaster with three inversions: *Corkscrew*, Cedar Point, Sandusky, Ohio, United States.

1977

- First shuttle coaster: Although several opened simultaneously, *Screamin' Demon*, at Kings Island, is noted to be the first to open to the public.

1979

- The Beast: opened and which broke many records and is still the longest wooden roller coaster in the world.

1980 to 1989

1980

- First coaster with four inversions: *Carolina Cyclone*, Carowinds, North Carolina and South Carolina, United States.

1981

- First suspended coaster: *The Bat*, Kings Island, Cincinnati, Ohio.

1982

- First coaster with five inversions: *Viper*, Darien Lake, Darien, New York.



Racer at Kings Island, the first roller coaster to operate vehicles in reverse.

- First coaster to operate vehicles in reverse: *Racer*, Kings Island.
- First coaster to run stand-up trains: *Dangai*, Thrill Valley, Gotemba, Shizuoka, Japan.

1985

- First coaster with heartline roll: *Ultra Twister*, Nagashima Spa Land, Mie Prefecture, Japan.

1987

- First coaster with six inversions: *Vortex*, Kings Island.

1988

- First coaster with seven inversions: *Shockwave*, Six Flags Great America, Gurnee, Illinois, United States.

1989

- First complete-circuit coaster to exceed 200 feet (61 m) in height: *Magnum XL-200*, Cedar Point.

1990 to 1999

1992



Dragon Khan at PortAventura, the first roller coaster with eight inversions

- First inverted coaster: *Batman: The Ride*, Six Flags Great America.

1993

- First coaster with seven inversions: *Kumba*, Busch Gardens Tampa Bay.

1995

- First coaster with eight inversions: *Dragon Khan*, PortAventura, Salou, Catalonia.

- First use of on-board audio: *Space Mountain*, Disneyland Park, Paris.

1996

- First coasters to use a linear motor electromagnetic propulsion system: *Flight Of Fear*, Kings Island and *Flight of Fear*, Kings Dominion.

1997

- First coaster to reach 100 miles per hour (160 km/h): *Tower of Terror II*, Dreamworld, Australia.
- First coaster (non-complete circuit) over 400 feet (120 m) tall: *Tower of Terror II*, Dreamworld, Australia.
- First flying coaster: Skytrak (roller coaster), Granada Studios, Manchester, United Kingdom.

1998



Oblivion at Alton Towers, the first *Diving Machine* roller coaster.

- First *Diving Machine* coaster and vertical drop: *Oblivion*, Alton Towers, Alton, Staffordshire, United Kingdom.

- First linear motor launched inverted coaster: *Volcano, The Blast Coaster, Kings Dominion*.
- First linear motor launched dueling coaster: *Batman & Robin: The Chiller*, Six Flags Great Adventure, Jackson Township, New Jersey, United States.

1999

- First floorless coaster: *Medusa*, Six Flags Great Adventure.
- First tire-propelled launch system: *Incredible Hulk Coaster*, Islands of Adventure, Orlando, Florida, United States.
- First inverted dueling coaster: *Dueling Dragons*, Islands of Adventure.

2000 to Present

2000



Millennium Force at Cedar Point, the first roller coaster to exceed 300 feet (91 m) in height and the first to use an elevator cable lift.



Dorney Park and Wildwater Kingdom's Steel Force and Thunderhawk roller coasters, just outside Allentown, Pennsylvania. Steel Force opened in 1997 as the tallest and fastest roller coaster on the East Coast of the United States, with a first drop of 205 feet (62 m) and a top speed of 75 miles per hour (121 km/h).

- First complete-circuit coaster to exceed 300 feet (91 m) in height: *Millennium Force*, Cedar Point.
- First coaster to use an elevator cable lift system: *Millennium Force*.
- First modern wooden coaster with vertical loop: "Son of Beast", Kings Island. (Note: After an accident on July 9, 2006 the loop was removed.)
- First wooden coaster over 200 feet (60.96 m) tall: *Son of Beast*.
- First large-scale flying roller coaster, *Stealth*, Paramount's Great America

2001

- First coaster with a 90° vertical drop: *Dodonpa*, Fuji-Q Highland, Fujiyoshida, Yamanashi, Japan.
- First coaster to use pneumatic propulsion system: *Hypersonic XLC*, Kings Dominion.
- First coaster to feature both a lift hill and propulsion system: *California Screamin'*, Disney's California Adventure Park, Anaheim.

2002

- First coaster to use a hydraulic propulsion system: *Xcelerator*, Knott's Berry Farm.
- First coaster with ten inversions: *Colossus*, Thorpe Park, Chertsey, Surrey, United Kingdom.
- First coaster with seats that rotate on a horizontal axis (4th Dimension roller coaster): *X²*, Six Flags Magic Mountain.

2003

- First complete-circuit coaster to exceed 400 feet (120 m) in height: *Top Thrill Dragster*, Cedar Point.
- First coaster with a more than 90° vertical drop (97°): *Vild-Svinet*, BonBon-Land, Zealand, Denmark.
- First coaster to utilize a vertical lift (not considered an elevator lift): *Vild-Svinet*, BonBon-Land.

2004

- First coaster with a "fly-through" station: *Thunderhead*, Dollywood, Pigeon Forge, Tennessee, United States.

2008

- First coaster with a "ferris wheel"-style lift hill: *Maximum RPM!*, Freestyle Music Park, Myrtle Beach, South Carolina, United States.

2009

- First coaster with 100° free-fall drop: *Saw: The Ride*, Thorpe Park, Surrey, United Kingdom

2010

- First coaster with vertical freefall drop roll: *Th13teen*, Alton Towers, Staffordshire, United Kingdom
- The current fastest roller coaster in the world: *Formula Rossa*, Ferrari World, Yas Island Abu Dhabi, United Arab Emirates

Chapter 6

Roller Coaster Elements

Roller coasters are composed of various **elements**, the individual parts of the design and operation, such as a track, hill, loop, turn, etc. Variations in normal track movement that add thrill or excitement to the ride are often called "thrill elements."

Basic elements

Brake run

A **brake run** on a roller coaster is any section of track meant to slow or stop a roller coaster train. Brake runs may be located anywhere or hidden along the circuit of a coaster and may be designed to bring the train to a complete halt or to simply adjust the train's speed. The vast majority of roller coasters do not have any form of braking on the train itself, but rather forms of braking that exist on track sections. One notable exception is the scenic railway roller coaster, which relies on an operator to manually control the speed of the train.

On most roller coasters, the brakes are controlled by a computer system, but some older wooden roller coasters have manually operated brakes. These are controlled by large levers operated by the ride operators.

Buzz bars

Single-position lap bars on wooden roller coasters are commonly referred to as "buzz bars," a slang term named for the buzzing sound the bars make as they release. Generally only older wooden coasters and junior wooden coaster trains still use these bars. Most parks have switched to individual ratcheting lap bars, similar to the lap bars found on steel coasters. It can be argued that single-position buzz bars give more Air time on roller coasters, as ratcheting lap bars tend to lock further during the ride in many installations.

The traditional "pirate ship" style thrill ride often utilizes this type of restraint, as does the Troika.

Drive tire

A **drive tire**, or **squeeze tire** (depending on its usage), is essentially a motorized tire used to propel a roller coaster train along a piece of track. Although they are most often used in station areas and brake runs, they can also be used to launch trains at greater speeds. However, they are generally they are used to propel the train at speeds between 5-8 mph. The *Incredible Hulk Coaster* at Universal's Islands of Adventure is notable for using drive tires to launch the train up an incline. Some roller coasters, most noticeably Vekoma Roller Skaters (Vekoma's version of a junior coaster) also use drive tires instead of a chain or LIMs on lift hills.

Drive tires are also used to power other types of amusement rides, such as ferris wheels and other spinning rides.

Drive tires are often used in one of two ways on roller coasters. When oriented horizontally, drive tires are often put in pairs so as to "squeeze" a portion of the train as it crosses that section of track. In this case, it is usually the brake fin that is used to propel or slow the train with the tires. When oriented vertically, they contact the underside of the train as it crosses a particular section of track. This underside area is a flat area which often has a grated metal surface to increase friction between the car and the tire. One disadvantage of vertical drive tires is that rainy weather can greatly reduce friction between the tire and the train, possibly causing the train to slightly overshoot its intended position and cause an emergency stop.



A **headchopper** on *El Toro* at Six Flags Great Adventure in Jackson, NJ (center of picture)

Headchopper

A **headchopper** is any point on a roller coaster where the support structure of the ride comes very close to the passengers' heads, or at least appears to. All headchoppers are, of course, designed so that even the tallest rider with their hands up would be unable to touch the structure; although if a rider exceeding the maximum height *does* board the coaster it could be potentially dangerous. Headchoppers are most common on wooden roller coasters, but are also found on many steel roller coasters.

The inverted roller equivalent is a **footchopper**. Footchoppers are designed such that rider's legs appear to come close to the ride's support structure, water, or other ride surroundings. Suspended Looping Coasters, such as Vekoma's The Mind Eraser, are known for their footchopper effects due to their compact layout. For example Dueling Dragons at Universal's Islands of Adventure has many Footchoppers, where the rider's feet come within feet of the ride's supports. Vekoma's Mind Eraser (and clones) also feature an intense footchopper during an in-line-twist, in which the train approaches a section of track directly below, making it appear that the riders' feet will impact the track if the train remains on that course; but the train undergoes an in-line-twist right before the would-be-footchopper, twisting the riders onto their backs as the above track crosses safely over the track below.



Speed Monster (2006), at Tusenfryd of Norway, prominently features a launch track.

Launch track

The **launch track** is the section of a launched roller coaster in which the train is accelerated to its full speed in a matter of seconds. A launch track is always straight and is usually banked upwards slightly, so that a train would roll backwards to the station in the event of a loss of power.

A launch track serves the same basic purpose as a lift hill—providing power to the train—but accomplishes it in an entirely different manner. A lift hill gives the train potential energy by raising it to the highest point in the track (and not significantly accelerating it). A launch track gives the train kinetic energy by accelerating it to the maximum designed speed (while not significantly raising it).

A launch track normally includes some form of brakes. Depending on the type of coaster, these brakes may be used in every run of the coaster (this is normally found on a Shuttle roller coaster where the launch track also serves as the main brake run) or they may only come into play when a rollback occurs, normally on a complete-circuit coaster such as Stealth, Top Thrill Dragster, Kingda Ka, and Xcelerator. In either case, the brakes are retracted to allow trains to launch, and are engaged at all other times.

Lift hill



Goliath (2002), in Walibi World of the Netherlands, has a 150 foot (45.7 meter) lift hill.

A **lift hill**, or **chain lift**, is often the initial upward section of track on a typical roller coaster that initially transports the roller coaster train to an elevated point. Upon reaching the top, the train is then disengaged from the lift hill and allowed to coast through the rest of the roller coaster's circuit.

Lift hills usually propel the train to the top of the ride via one of a few different types of methods: a *chain lift* involving a long, continuous chain which trains hook on to and are carried to the top; a drive tire system in which multiple motorized tires push the train upwards, a cable lift system as seen on Millennium Force or a LSM system as seen on *Maverick*.

Launch lift hills are like launch tracks, but instead of having it flat, it is rather at an incline. Sometimes, launch lift hills serve the same purpose as lift hills, but faster transportation of the ride vehicle to the top of the lift hill, but sometimes also to power the train up into an element, like the Incredible Hulk Coaster at Universal Orlando. Launch lift hills use mostly LSMs or LIMs, but sometimes drive tires.

Linear induction motor

The linear induction motor is a very simple but powerful type of electric motor used to propel the cars. Rather than using a standard enclosed spinning rotor and drive wheels, there is a long flat magnetic pole plate with closely-spaced electric coils. This pole plate mounts on the track underneath the car, and a matching metal plate attached to the car moves across the magnetic pole faces. By applying a multiphase alternating current to the poles, the pole plate induces eddy currents into the moving plate, and can be used to accelerate or brake the car.

Compared to other drive mechanisms, the linear motor is typically maintenance-free. The pole faces on the track and moving plate attached to the car do not need to touch, and the gap between them can be quite wide to accommodate any side-to-side car motion, so there is no friction or wear between them. Further, the magnetic coil assembly on the driving pole plates are either potted or sealed in a weathertight enclosure, so that rain, vibration, and dust does not affect motor performance or cause drive motor slippage.

On-ride camera

An **on-ride camera** is a camera mounted alongside the track of a roller coaster (or a similar ride) that automatically photographs all of the riders on passing trains. They are usually mounted at the most intense part of the ride, resulting in the funniest possible pictures. The pictures are available for viewing and purchase at a booth outside the ride's exit. On some rides, such as the Saw The Ride at Thorpe Park, there is a video of you and your riding partner, which can also be purchased upon exiting the ride.



El Toro (2006), a wooden roller coaster at Six Flags Great Adventure in New Jersey, uses traditional lap restraint trains.

Train

A **roller coaster train** describes the vehicle(s) which transports passengers around a roller coaster's circuit. More specifically, a roller coaster train is made up of two or more "cars" which are connected by some sort of specialized joint. It is called a "train" because the cars follow one another around the track—the same reason as for a railroad train. Individual cars often vary in design and can carry anywhere from one to eight or more passengers each.

Some roller coasters, notably Wild Mouse roller coasters operate with individual cars instead of trains.

Tester hills

A **tester or trick hill** is any small hill following the lift hill or brake run. The main purpose of a tester hill is to decrease tension and stress on the chain, cable, or other lift used to lift the trains. For example, if a train is hauled up the lift and brought directly to a hill, the force of gravity will pull the trains that are still hooked to the lift. Tester hills

usually are followed by a large(r) hill, but sometimes the turn around, giving more of a mysterious feeling.

The name "trick" comes from the fact that these hills also are designed to trick riders into thinking they are at the large hill, causing a "false alarm" element.

Some roller coasters, specifically Wild Mouse roller coasters and launch coasters do not require tester/trick hills.

Thrill elements

Batwing

A **batwing** is a heart-shaped roller coaster inversion that consists of two loops that turn riders upside down twice. The train goes into a mini-reverse sidwinder, followed by a mini-sidwinder. This inversion is the inverse of a cobra roll.

Like other inversions, the batwing has different names depending on the manufacturer. This element is called a **batwing** on Bolliger & Mabillard (B&M) coasters, such as Afterburn at Carowinds or Montu at Busch Gardens Tampa Bay in Tampa, Florida. On Arrow Dynamics coasters, such as The Great American Scream Machine at Six Flags Great Adventure, it is called a **boomerang**.

The first roller coaster to use the batwing element was Orient Express at Worlds of Fun in Kansas City, where it was called a "Kamikaze Curve." The ride was demolished after the 2003 season.

Another version of the batwing is the **bowtie**, where the second half of this element is rotated so that the train exits the elements heading in the same direction of travel as at the entrance to the element. Dragon Mountain at Marineland is an example of a coaster with this element.

Butterfly inversion

A **butterfly inversion** is sometimes found on Vekoma roller coasters. A butterfly begins like a normal loop, but as the track goes up, it twists 45 degrees to one side or the other, and then when it is headed down, the track twists back. The maneuver is then repeated, but in reverse. An example of this is found on *Goudurix* in Parc Asterix in Plailly, France, or Ninja at Six Flags Over Georgia.



A typical cobra roll, as seen on Alpengeist (1997) at Busch Gardens Williamsburg.

Cobra roll

The **cobra roll** is a roller coaster inversion which resembles a cobra's head. Riders traverse forward through an upwards half-vertical loop, corkscrew perpendicular to the first direction, enter another corkscrew that merges into a downward half-vertical loop that exits in the parallel but opposite direction of the entrance. It takes riders upside-down twice.

There is much confusion pertaining to the correct naming of this inversion. This is because different roller coaster manufacturers give their own names to inversions. **Cobra Roll** is the standard name used by Intamin and B&M for this type of inversion.

The first coaster to use a **cobra roll** was Vekoma's *Boomerang* model, the first of which was built in Mexico in the early 1980s.

All Vekoma Boomerangs, Drachen Fire, the Tornado at Särkänniemi Park in Tampere, Finland, and almost all B&M 7-inversion coasters have a cobra roll.



On an Inverted roller coaster riders go through a motion similar to sit-down steel roller coasters. (*Batman: The Ride* (1999) at Six Flags Over Texas in Arlington, Texas)

Corkscrew

The **corkscrew** is a roller coaster inversion which most often resembles a loop that has been 'stretched' in terms of the element's entrance and exit points being a distance away from each other. The main difference is that riders are inverted at a point angled 90° horizontally from the incoming track, whereas in a loop, the inversion comes parallel to the track, but traveling in the opposite direction. On Bolliger and Mabillard sit-down, stand-up, and floorless coasters, corkscrews are known as flat spins. On B&M inverted coasters, they are known as wingovers.

It was named due to its resemblance to the corkscrew tool used to remove corks from bottles. Riders enter the corkscrew element and are transported significantly to the left or right while being flipped upside down 360 degrees.

Due to them being much smaller than many elements, corkscrews are normally found towards the end of layouts, and often exist in pairs. This may take the form of a **double corkscrew**, where the end of one leads straight into the next. It is also common to see **interlocking corkscrews**, where the entrances and exits are parallel, but both corkscrews cross over the other corkscrew's track.

Corkscrew is the name of several roller coasters, including a three-loop coaster at Valleyfair in Shakopee, Minnesota, a three-loop roller coaster at Cedar Point in Sandusky, Ohio, a two-loop coaster at Genting Highlands theme park in Malaysia, and a three-loop coaster at Seaworld, Australia. Canobie Lake Park in Salem, New Hampshire has a coaster known as the Canobie Corkscrew.

The first roller coaster with a corkscrew element was the Arrow Dynamics designed *Corkscrew*, opened in 1975 at Knott's Berry Farm. In 1989, the ride was relocated to Silverwood where it continues to operate.

Bolliger and Mabillard created a variation of the corkscrew, a **flat spin**. Flat spins begin on flat track and "snap" to through the top of the inversion, whereas Arrow and Vekoma coasters used completely curved corkscrews which started on banked track. On an inverted roller coaster, a flat spin is referred to as a **wingover**.

Cutback

A **cutback** is a roller coaster inversion similar to a corkscrew, except that the two half-corkscrews are in opposite directions so that the train exits the inversion in the same direction from which it entered. The defunct *Drachen Fire* at Busch Gardens Europe, Williamsburg, VA was the only roller coaster to have a cutback inversion. The roller coaster designs today tend to incorporate overbanked turns, which are a much more fluid way of performing an exciting turn than cutbacks. *Drachen Fire* was closed on July 11, 1998, and subsequently demolished. Today, the only two cutback inversions can be found on Space Mountain: Mission 2 in Disneyland Paris and the newly built Sky Rocket at Kennywood Park in Pittsburgh, Pennsylvania.



The top configuration is a dive loop (*Dragon Khan* (1995), PortAventura of Spain)

Diving loop

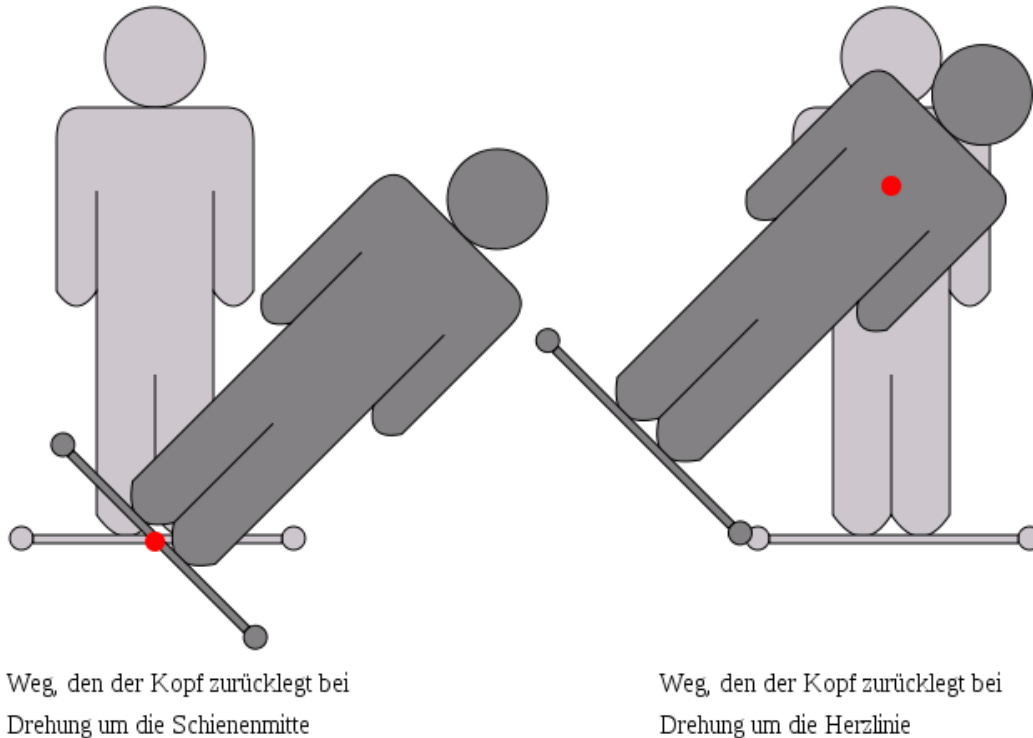
A **diving loop** (also, dive loop) is a type of B&M roller coaster inversion whose inspiration was taken from a stunt plane maneuver. A dive loop can also be called a **Split S**. In this inversion, the track twists upwards and to the side, and then dives toward the ground in a half-vertical loop. This element is seen on B&M sit-down, stand-up and floorless coasters. Arrow and Vekoma use a similar element known as a Reverse Sidewinder. Just as a Dive Loop is the reverse form of an Immelmann loop, the Reverse Sidewinder is the reverse form of a Sidewinder element (Arrow and Vekoma's version of an Immelmann). It can be seen in Arrow's *Cyclone* at Dreamworld in Australia (Formerly *Big Dipper* at Luna Park) and Vekoma's *Ninja* at Six Flags over Georgia near Atlanta (Formerly *Kamikaze* at Dinosaur Beach).

Hammerhead turn

A **hammerhead turn** is based on a flying maneuver by the same name and is similar to, but not the same as, a 180-degree overbanked turn. The train enters the element with a steep slope up and a slight curve in the direction opposite that of the overall turn (a so-called "priming" of the turn). The train then banks heavily to the side opposite the initial curve and finishes its climb while it negotiates the overall turn, beginning its descent mid-way through the turn. The second half of the element is the same as the first half, but in reverse order. While negotiating a hammerhead turn element, the train has made a turn of more than 180 degrees; however, because of the entry and exit curves, the overall effect is that of a 180-degree turn that exits toward the direction from which it entered, roughly parallel to the portion of track preceding the hammerhead turn. Hammerhead turns are found on some Bolliger and Mabillard hypercoasters. Examples of these coasters are Nitro at Six Flags Great Adventure, Behemoth at Canada's Wonderland, and the Diamondback at Kings Island.

Heartline roll

Herzlinienprinzip



Illustrating a heartline roll, the left is a normal inversion (barrel roll) where the axis of rotation is on the rail center. The right is a heartline roll, where the axis of rotation is (roughly) on the riders' hearts.

A **heartline roll** is a roller coaster inversion in which the rider performs a 360-degree roll. Heartline rolls are commonly confused with inline twists.

In a **heartline roll**, the center of the train rotates on one axis. The track itself changes in elevation so as to keep the train moving in the same line in which it started the element. In an inline twist, the track with the 360-degree twist remains straight. As such, the train moves downward and then back up during the twist. In some cases, such as Vekoma's Flying Dutchman coaster, the degree to which the train deviates from the line in which it enters the twist is so great, the element is indistinguishable from a corkscrew.

There is also some confusion over the difference between a heartline roll and a zero-g roll. A zero-g roll is basically a standard hill with a 360 degree twist at the top. The trains ascend, twist, and then descend again (providing a brief moment of airtime). In a heartline roll, once again, the trains do not leave the line from which they entered the inversion.

Horseshoe

A **horseshoe** is a type of turnaround maneuver found on Maurer Sohne coasters. The horseshoe is essentially a 180-degree turnaround with high banking so that riders are tilted at a 90-degree angle or more at the top at the element. The horseshoe is named that way because the element is shaped roughly like a horseshoe, with a semicircular shape at the top. It is found on coasters such as Sonic Spinball at Alton Towers.



Afterburn (1999)'s Immelmann inversion.

Immelmann loop

An **Immelmann loop** (colloquially, "Immelmann") is a popular inversion found on many roller coasters. In an Immelmann, riders enter a half loop and then go through a half twist and curve out in the opposite direction in which they came. The inversion is very similar to the sidewinder. A sidewinder consists of a half loop and a half corkscrew, and comes out closer to 90°, while the Immelman comes out in more of a straight line back to where it started. An Immelmann traveled in reverse is a diving loop. It is most commonly found on B&M inverted and diving roller coasters.

The name "Immelmann" comes from Immelmann turn, an aircraft maneuver named after the World War I German fighter pilot Max Immelmann.

Inclined diving loop

An inclined diving loop is similar to a dive loop, although it is exited at an angle instead of vertically. It is essentially a dive loop that has been tilted. The only two examples are on Hydra at Dorney Park & Wildwater Kingdom and iSpeed at Mirabilandia. This element is also known as the Italian Loop.

Inclined loop

An **inclined loop**, also known as an **oblique loop**, is a 360° loop that has been tilted at an angle. It is not entered vertically, like a vertical loop, or horizontally like a helix. Instead, it is usually entered at an angle between 45° and 80°. inclined loops can be found on B&M stand-up roller coasters, and Top Fun sit down roller coasters.

Examples of roller Coasters with *inclined loops*:

- *Mantis* at Cedar Point
- *Green Lantern* at Six Flags Great Adventure
- *Riddler's Revenge* at Six Flags Magic Mountain
- *Georgia Scorcher* at Six Flags Over Georgia



Chang's (1997) oblique loop element.

Inline twist

An **inline twist** is a roller coaster inversion in which the rider performs a 360-degree roll. The inline twist is often found on flying coasters, such as *Air* at Alton Towers, *Batwing* at Six Flags America, *Superman: Ultimate Flight* at Six Flags Over Georgia, and *Firehawk* at Kings Island. It can also be confused with a heartline roll. In a heartline roll the center of the train rotates on one axis so the height of the average rider's heart never changes, whereas during an inline twist the train rotates around the track and there is usually little to no elevation difference in the track. Inline twists are sometimes also known as "barrel rolls".



Superman: Krypton Coaster's (2000) interlocking corkscrew element.

Interlocking corkscrews

Interlocking corkscrews are a type of roller coaster inversion found on B&M coasters. In this inversion, two separate corkscrews spin around each other; one turns riders upside down over the other. Despite being close to each other, the two corkscrews are not necessarily taken consecutively.

Examples of coasters with interlocking corkscrews:

- *Nemesis Inferno* at Thorpe Park is the only inverted coaster to feature interlocking corkscrews on the same track. (On another inverted coaster, *Dragon Challenge* at Universal Studios' Islands of Adventure, one corkscrew on the "Fire" track interlocks with the corkscrew on "Ice.")
- *Kumba* at Busch Gardens Africa
- *Bizarro* at Six Flags Great Adventure
- *Batman the Ride* at Six Flags New England.
- *Scream!* at Six Flags Magic Mountain



Loch Ness Monster's (1978) interlocking loops

Interlocking loops

Interlocking loops are an element which consists of two vertical loops. This element has been used on only three complete-circuit roller coasters. The first is *Loch Ness Monster* at Busch Gardens Williamsburg, and the second was *Orient Express* at Worlds of Fun. A pair of shuttle coasters, *Lightnin' Loops* at Six Flags Great Adventure, also had interlocking loops. With the closing of *Orient Express* and *Lightnin' Loops*, *Loch Ness Monster* is the only coaster in the world to have this element.

Non-inverting loop

The non-inverting loop is a variety of loop that, when coming up, twists similar to a heartline roll, leaving riders completely straight up when at the top of the loop. To date, the only example is the loop on the Hollywood Rip Ride Rockit at Universal Studios Florida.

Norwegian loop

A **Norwegian loop** is an element made out of two elements: a Dive Loop, then an Immelmann; forming an inversion that looks like two side by side loops. This element is similar to the flying coasters pretzel loop, except that the train goes through a twist when entering and exiting the loop. It may also be seen as a normal loop entered from the top. It was first introduced on *Speed Monster* in TusenFryd, Norway. Another example of a Norwegian Loop can be found on Hersheypark's roller coaster *Fahrenheit*.

Overbanked turn

An **overbanked turn** is an element common on large steel roller coasters, particularly those built by Intamin AG of Switzerland. This element is a turn or curve in which the track tilts beyond 90 degrees, usually in the 100-120 degree range. Two examples of an overbanked turn in the United States are the first turn-around on *Bizarro* at Six Flags New England, and *Millennium Force* at Cedar Point in Sandusky, Ohio, which features four separate and two consecutive overbanked turns.



Tatsu's (2006) 124-foot pretzel loop

Pretzel loop

The **pretzel loop** is a large inversion found on B&M flying coasters. It consists of a downward half loop and upward half loop . Since they overlap at the top, the entrance and exit points create the look of a pretzel, hence the name; however, the pretzel shape is only visible from one particular viewpoint. Extreme positive g-forces are induced on riders throughout the duration of the element.

There are six roller coasters that include the pretzel loop: the trio of Superman: Ultimate Flight roller coasters (all 3 of which have the same layout) at Six Flags Great Adventure, Six Flags Over Georgia, and Six Flags Great America; Crystal Wings at Happy Valley

(which is also a clone of *Superman*); *Tatsu* at Six Flags Magic Mountain; and *Manta*, at Sea World Orlando. While going through a pretzel loop, the rider is upside down at the beginning and on their back and going backwards at the bottom. The rider then regains normal flying position at the exit of the loop.

Raven turn

A **raven turn** is a $\frac{1}{2}$ inversion on a roller coaster which looks like half a loop followed by a drop and then levels out near the same height as it began. The raven turn is only usable on either flying roller coasters or 4D roller coasters at the moment and has, so far, only been used on two 4D coasters.

The general term "Raven Turn" refers to any inversion that follows the design described above; however, there are two types of raven turns. Assuming the train is going round the half-loop first, an "Inside Raven Turn" is where the rails are below the train at the start whereas an "Outside Raven Turn" is one such that the rails are above the train at the start of the element.

Roll out

A **roll out** is similar to a sidewinder. However, while a sidewinder consists of a half loop followed by a half corkscrew, a roll out consists of a launch into an extended vertical section proceeding into a quarter loop and a loose half-corkscrew. As of 2008, the roll out element is unique to *Volcano*, *The Blast Coaster* at Kings Dominion, where it takes the ride to its highest point (155 feet) and is known as the inversion where riders are blasted out of the former *Lost World* mountain.

Sea serpent roll

A **Sea Serpent Roll** (Vekoma: *Roll Over*), is a roller coaster inversion related to the cobra roll, except the two halves face in opposite directions. It can also be viewed as a Reverse Sidewinder followed by a Sidewinder. The trains exit the track element in the same direction as they entered, unlike a Cobra Roll in which the trains get turned around 180°.

The sea serpent roll is not as common as many other inversions, like the vertical loop, corkscrew, or cobra roll. It is a common element on most Suspended Looping Coasters. *Medusa* at Six Flags Discovery Kingdom was the first roller coaster with a sea serpent roll.



Top Thrill Dragster Top hat Cedar Point, Sandusky, OH

Top hat

A **top hat** is an element common to launched coasters. A standard top hat consists of what is essentially a hill with a 90 degree ascent and descent, the train exits going in the same direction from which it entered. The track twists and the train does not go upside down. Top Thrill Dragster at Cedar Point is an example of a top hat.



Inside top hat at *Mr. Freeze* (1998) from Six Flags over Texas

In a **top hat inversion**, also called an **inside top hat**, when the train approaches the top of the "hat", it makes a 90 degree twist so that it is on the inside of the element (hence the name), and once it reaches top hat's apex the train is upside down under the track.
Example: The picture to the left shows Mr. Freeze's inverted top hat element.



Maverick (2007), of Cedar Point in Ohio, traveling through the Twisted horseshoe

Vertical loop

The generic roller coaster vertical **loop** is the most basic of roller coaster inversions. Specifically, the loop refers to a continuously upward-sloping section of track that eventually results in a complete 360 degree circle. At the top-most piece of the loop, riders are completely inverted.



Zero-g roll (*Incredible Hulk Coaster* (1999), Islands of Adventure in Orlando, Florida)

Wraparound corkscrew

The **wraparound corkscrew** is a roller coaster inversion by Arrow Dynamics. It begins as a corkscrew, then transforms into a 180-degree downwards curve. The defunct *Drachen Fire* at Busch Gardens Williamsburg was the only coaster to ever have a wraparound corkscrew; this element was incorporated into the coaster's first drop. *Drachen Fire* has since been demolished.

Wraparound immelmann

The **Wraparound immelmann** is a roller coaster inversion which is similar to an immelmann loop except that it has a sharper pull-out curve. This element is currently unique to the *Chinese Fireball* track of Dragon Challenge (formerly Dueling Dragons) at Islands of Adventure.

Zero-gravity roll

A **zero-gravity roll** is a roller coaster inversion found on B&M, sit-down, and floorless. On inverted coasters, this inversion is alternately called a "heartline spin" because its center of gravity is placed on the center of the rider's heart. On sit-down and floorless coasters, it is alternately called a Spiraling Camelback. The name for the roll comes from that fact that the rider feels a zero g-force, giving the feeling of weightlessness.

Essentially, a zero-gravity roll is a hill with a 360 degree twist in the middle.

There is confusion over the difference between a zero-gravity roll and a heartline roll. In a heartline roll, there is no change in elevation as contrasted to the zero-g roll, which is often called a camelback because the track goes upwards, twists, and comes back down.

Visual elements

Splashdown



Griffon Splashdown element

A splashdown is a visual element used on roller coasters in which the vehicle physically interacts with a body of water, forcefully spraying or jetting water in a particular direction. Splashdowns can often be used as a natural braking system due to the force of the water slowing the vehicle, and pathways can be constructed allowing non-riding visitors to either view or, in some cases, get wet from the splashdown element.

- A **natural splashdown**, in which the track of the vehicle is actually a few centimeters underwater (and thus, the train must come crashing into the water, spraying water from both sides), is apparent on a few roller coasters, first and foremost, Matterhorn Bobsleds at Disneyland Park in California. This element was also present on Buzz Saw Falls at Silver Dollar City before the ride's reconfiguration into Powder Keg: A Blast into the Wilderness.
- A **scoop splashdown** is an element in which each train is equipped with two tubes, called scoops, on the rear sides of each train. The scoops are angled upwards such that, as the train passes along a track with water on either side, the scoops (which hang off the final car on either side) dip into water and, traveling at high speed, force water up into the air in two distinct spouts. This element is only seen on Bolliger & Mabillard coasters (two dive machines and one hypercoaster), specifically SheiKra and Griffon (pictured right) at Busch Gardens Africa and Busch Gardens Europe, respectively, and on Diamondback located at Kings Island. The scoops can be angled differently on different trains to produce different splash effects and between coasters, the splash differs greatly. Because of Griffon's extra-wide seating (pictured right), the splashdown is visibly two distinct spouts, whereas with Diamondback's traditional-style trains, the scoops are much closer together and thus, the splash appears to be one large plume.

Water spout

A **water spout** is a visual element used to simulate a roller coaster's interaction with a body of water (without the ride vehicle actually coming in contact with the body of water in question), encompassing a number of different methods. Water spouts are useful in the roller coaster world as they are visually appealing (and can even draw a crowd with the sole intention of seeing the effect take place when a train passes) while having no actual interaction with the track and therefore, saving on maintenance. Below are some of the more famous and well-known water spouts, offering a sampling of the many different forms this element can take on.

- **Maverick** at Cedar Point contains a water spout when, as rounding a large sweeping helix, four water blasts fire upwards, as if the train is being shot at with a shotgun (matching the ride's Western theme).
- **Manta** at SeaWorld Orlando contains a water spout when the manta-ray-shaped train cars pull down towards the water and appear to onlookers and riders to "skim" the surface of the water with the tip of their wing. This is synchronized to a system of fountains that run the entire length of the trains visual "interaction" which spray water as the train passes overhead.
- All three **Backlot Stunt Coaster** roller coasters at Paramount's Kings Island, Paramount Canada's Wonderland and Paramount's Kings Dominion featured a finale "splashdown" in which the Mini Cooper themed cars burst out of a billboard and fall down into a "Los Angeles Aqueduct" where various water hoses

spray out to each side simulating a splashdown. (After the sale of the Paramount Parks to Cedar Fair Entertainment Company, all three roller coasters were renamed *Back Lot Stunt Coaster*, and all water effects were removed.

- **Incredible Hulk Coaster** at Universal's Islands of Adventure contains a water spout immediately following its zero-G roll in which the coaster dives to the water beneath it, sending out a large spray again simulating a splashdown before pulling up into a cobra roll.

Chapter 7

4th Dimension Roller Coaster



'X²' (formerly 'X') was the first 4th Dimension roller coaster in the world.

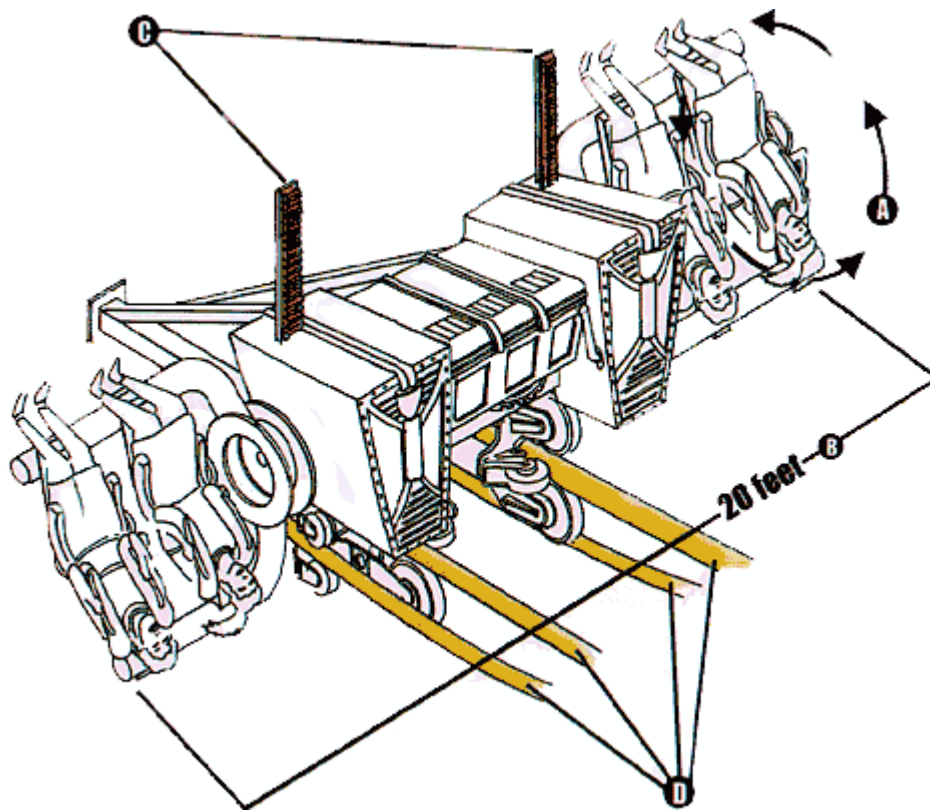
A **4th Dimension roller coaster** is a type of steel roller coaster whereby riders are rotated independently of the orientation of the track, generally about a horizontal axis that is perpendicular to the track. The Cars do not Necessarily need to be fixed to an angle.

History

John F. Mares invented the 4th Dimension roller coaster concept in 1995 and holds six US patents relative to the technology related to their spinning seat systems. The first 4th Dimension roller coaster to be built, *X*, which opened at Six Flags Magic Mountain, United States in 2002, was designed and patented by Alan Schilke. 4th Dimension roller coasters are somewhat of a cross between roller coasters and the popular carnival ride known as the Zipper. Since their inception, millions of riders have experienced and enjoyed the thrill of 4th Dimension roller coasters.

Manufacturers

S&S Arrow (formerly Arrow Dynamics)



- A) Rotation of Seats
- B) Seat on Axle
- C) Rack Gear
- D) Four rails

Arrow Dynamics was the first company to produce a 4th dimension roller coaster, lending its name to the ride style. The trains feature seats capable of rotating forward or backward, 360 degrees in a controlled spin. This is achieved by having four rails on the track; two acting as per normal, and two to control the spin of the seats. The two rails that control the spin of the seats, known as "X Rails", vary in height relative to the track, and spin the train using a rack and pinion gear mechanism.

The first installation, X², was a prototype and cost Arrow Dynamics and Six Flags itself a lot of money due to technical difficulties and design flaws. In 2002, the park sued Arrow Dynamics, which went into bankruptcy. Since then Arrow was bought out by S&S Power and became the company's steel coaster division, S&S Arrow. In 2006, a second installation opened at Fuji-Q Highland in Fujiyoshida, Yamanashi Japan under the name Eejanaika. A third installation is currently under construction at China Dinosaur Park and is due to open in 2011.

Intamin AG


The Intamin AG *ZacSpin* was developed in response to the Arrow Dynamics 4th dimension roller coaster. Some of the main differences between the Intamin AG and Arrow Dynamics/S&S Power versions are the uncontrolled rotation of the seats, which produces a different ride each time, and single cars. Another notable difference is the absence of any lateral movements, causing some enthusiasts to not consider the rides 4th dimension roller coasters due to the fact that all movement is restricted to a 2 dimensional plane.

Kirnu at Linnanmäki in Helsinki, Finland, opened for the 2007 season and was the first of its kind. Later that year *Inferno* opened at Terra Mitica in Spain with an identical compact layout. In 2009, *Insane* opened at Gröna Lund with a different track layout. The first *ZacSpin* to in the United States will open in 2011 at Six Flags Magic Mountain as *Green Lantern: First Flight*, and will be themed to the DC Comics superhero of the same name. It will feature the same layout as *Insane*.

Inversion ambiguity

There is considerable debate within the roller coaster community as to whether or not the spinning of these coasters qualifies as an inversion for the purpose of records. Guinness World Records gave *Eejanaika* the record with 14 inversions. However, other more coaster-specific record bodies such as the Roller Coaster Database do not recognize this claim and instead count only *track* inversions, which gives the record of 10 to Colossus and Tenth Ring Roller Coaster.

List of 4th Dimension roller coasters

Name	Park	Opened	Manufacturer	Status	Image
<i>X²</i>	Six Flags Magic Mountain	2002 (X)	Arrow Dynamics	Operating	
<i>Eejanaika</i>	Fuji-Q Highland	2006	S&S Power	Operating	
<i>Kirnu</i>	Linnanmäki	2007	Intamin AG	Operating	
<i>Inferno</i>	Terra Mitica	2007	Intamin AG	Operating	
<i>Insane</i>	Gröna Lund	2009	Intamin AG	Operating	

*Green
Lantern:
First
Flight*

Six Flags
Magic
Mountain

2011

Intamin AG

Under
Construction



Chapter 8

Pipeline Roller Coaster and Shuttle Roller Coaster

Pipeline Roller Coaster



A TOGO pipeline coaster, Ultra Twister at the defunct Six Flags Astroworld

The **Pipeline Coaster** (also known as a "Heartline Twister Coaster") was a roller coaster developed by Japanese ride company TOGO. Pipeline roller coasters position riders between the rails, rather than above or below. TOGO was the first and only company to produce this type of roller coaster successfully. Although Utah's Arrow Dynamics and Switzerland's Intamin AG developed these types of coasters as well, they didn't catch on. Some of the drawbacks of these coasters included the need for large, uncomfortable over-the-shoulder restraints as well as poor wheel-to-track construction. Only five pipeline coasters operate today.

History

TOGO developed the first Pipeline coaster and the first recorded Ultratwister coaster built was in 1985 at LaQua amusement park in Tokyo, Japan called Ultra Twister. The ride became somewhat popular in Japanese parks, and one year after the first was built, Six Flags purchased one of these coasters for their Six Flags Great Adventure theme park, where it resided until 1990 when it was moved to Six Flags Astroworld until the park closed in 2005. This coaster would remain the only pipeline coaster in America. The American Ultratwister still exists, however it awaits possible future assembly at Six Flags America.

TOGO's model would be the only somewhat successful design. Six of these were made and were successful in small parks due to its small footprint. The ride inverts riders three times through three Heartline Roll elements and utilizes a special near-vertical lift hill. The lift hill would be prone to down time for maintenance and the Ultra Twister owned by Six Flags had its lift hill modified by Premier Rides to a less steep angle when it was moved to Six Flags Astroworld.

Throughout the early 1990s, Arrow Dynamics attempted to develop a pipeline roller coaster. Only one of these was built as a prototype at Arrow's facility in Utah. Plans for the coaster were scrapped altogether due to roughness and other factors. However, one was partially built at Alton Towers in the United Kingdom. In the early 1990s, John Wardley twice attempted to build one of these at the park. The second attempt was partially built, but then scrapped for the coaster Nemesis. The coaster was not completely finished due to Arrow's finance problems.

In the mid 1990s, Intamin AG built a spiral roller coaster in South Korea. Not much is known about the design, but only one of these coasters were built. The only Spiral Coaster ever built is currently located in Kuwait.

Pipeline Coasters

Coaster	Park	Manufacturer	Opened	Status
Megaton	Mitsui Greenland	TOGO	1994	Operating
Spiral Coaster	Al-Sha'ab Leisure	Intamin AG	2000	SBNO
Formerly Sky Plaza Comet	Park Sky Plaza		1996	Closed 1999

Ultra Coaster Formerly Ultra Twister	Marah Land Sabahiya Mt.Ikoma Amusement Park	TOGO	2008 Unknown	Operating Closed 2005- 2006
Unknown Formerly Ultra Twister Formerly Ultra Twister	Six Flags America Six Flags AstroWorld Six Flags Great Adventure	TOGO	N/A 1990 1986	In Storage Closed 2005 Closed 1988
Ultra Twister	Washuzan Highland	TOGO	1991	Operating
Ultra Twister	Nagashima Spa Land	TOGO	Unknown	Operating
Ultra Twister	Rusutsu Resort	TOGO	1994	Operating
Ultra Twister	Tokyo Dome City	TOGO	1985	Defunct

Shuttle Roller Coaster



The Boomerang is one of the most common shuttle coasters

A **shuttle roller coaster** is any roller coaster that ultimately does not make a complete circuit, but rather reverses at some point throughout its course and traverses the same track backwards. These are sometimes referred to as **boomerang roller coasters**, due to the ubiquity of Vekoma's Boomerang coaster model.

Early history

The first shuttle coasters were in fact the first roller coasters ever built. Inspired by the so-called "Russian Mountains," these wheeled cars built on tracks found popularity in the early 19th century in Paris.

In 1884, the Switchback Railway opened at Coney Island, and consisted of a car that traveled on two tracks between two towers. It was the first roller coaster designed as an amusement ride in America.

First launched shuttle coasters

The first two launched shuttle coaster designs were introduced in 1977 by competitors Arrow Dynamics and Anton Schwarzkopf.

Arrow's first *Launched Loop* coasters were Black Widow (now closed) at Six Flags New England, Demon (also closed) at Kings Island, and Zoomerang at Circus World (renamed Afterburner and relocated to Fun Spot Amusement Park & Zoo). Arrow's models used an electric motor to launch the train.



A Schwarzkopf designed Weight-drop Shuttle Loop, Greased Lightnin at Six Flags Kentucky Kingdom

Schwarzkopf's first **Shuttle Loop** installations were King Kobra at Kings Dominion, White Lightnin' at Carowinds, and Tidal Wave (renamed Greased Lightnin') at Great America in California. These coasters, all of which used a dropped weight as a launch mechanism, are now retired. At least three remaining weight-drop shuttle loop coasters continue to operate, including one at Hopi Hari in Brazil, one at Gold Reef City in South Africa, and one at Six Flags Kentucky Kingdom as Greased Lightnin'. Schwarzkopf switched to a flywheel launch mechanism in 1978 with Montezooma's Revenge at Knott's Berry Farm and Greased Lightnin' at Astroworld.

Vekoma's Boomerang

In 1984 Vekoma debuted its *Boomerang* shuttle coaster, which features a lift hill rather than a launched train. In addition to the original Boomerang, Vekoma also designed the *Invertigo* or Inverted Boomerang, and the *Giant Inverted Boomerang*. As of 2007, 47 Boomerangs and its variants are currently in operation around the world.

Linear motor launched shuttle coasters

In 1996 Premier Rides debuted the first coasters ever to use linear induction motors (LIM)s, and in 1997, opened Batman & Robin: The Chiller at Six Flags Great Adventure, a pair of dueling launched shuttle coasters.

Intamin AG introduced its **reverse freefall coaster** in 1997. In these models, the train is accelerated out of the station along a long, level track using linear synchronous motors, rises straight up a vertical tower, then free falls back down to return to the station. The two operating reverse freefall coasters are Tower of Terror at Dreamworld and Superman: The Escape (now Superman: Escape from Krypton) at Six Flags Magic Mountain, both of which first broke the 300 foot and 400 foot barriers.

In 1998, Intamin introduced its first **impulse coaster**, Linear Gale at LaQua in Japan, which featured inverted trains traversing two vertical towers. In 2000 Intamin introduced a variation with a spiral tower and later another variation with two spiral towers. With each pass through the station the train accelerates faster and travels further up the towers.

Chapter 9

Spinning Roller Coaster



Euro-Mir, a spinning roller coaster at Europa-Park, Germany.

A **spinning roller coaster** is a roller coaster with cars that rotate on a vertical axis.

Models

Virginia Reel

The first spinning roller coaster was the Virginia Reel, first built in 1908 by Henry Riehl. Instead of trains, the ride had "tubs" with seats built around the perimeter facing inward. These tubs spun freely on their chassis as they travelled down the track, which was trough-like and similar to that of a side friction roller coaster. Virginia Reels did not have big hills or drops, but rather many sharp turns. Toward the end were two helices, and finally a drop into a dark tunnel. The last full size Virginia Reel closed at Pleasure Beach Blackpool in 1982.

Spinning Wild Mouse roller coasters



Primeval Whirl, a Reverchon spinning roller coaster.

In 1997, the first Spinning Wild Mouse roller coaster opened at the defunct Dinosaur Beach pier at Wildwood, New Jersey. Based on the design of the Wild Mouse roller coaster, the ride features a track layout and cars similar to a Virginia Reel, except the ride is made of steel rather than wood, and the seats face in one direction instead of toward

each other. The layout of the ride boasts many hairpin turns and small hops. The design, noted for its portability and small footprint, became popular at smaller amusement parks and fairs. A well known theme park installation of the ride is Primeval Whirl at Disney's Animal Kingdom.

The Spinning Wild Mouse was first manufactured by Reverchon Industries of France. In 2003 the company merged with Italy's Zamperla, but the companies eventually split apart again and in 2006 both companies began making Spinning Wild Mouse coasters under their own names. The two companies' spinning coasters can be found in dozens of amusement parks. A similar model was introduced by Italy's Fabbri Group in 2006.

Similar spinning coasters were made by the Chinese ride company Golden Horse and the German company Maurer Söhne, whose model is called a Compact Spinning Coaster. These models feature cars with four seats divided into two rows facing away from each other.



Dragon's Fury, a Maurer Söhne spinning roller coaster.

Other spinning roller coasters

Maurer Söhne introduced its Xtended SC spinning coasters in the late 1990s. The seat configuration is the same as Maurer Söhne's Compact Spinning Coaster, but unlike that model, the Xtended SC has large, twisted layouts with many vertical hairpin turns

intended to spin the cars around and give each rider a different experience every ride. Examples include *Winjas* at Germany's Phantasialand, *Sonic Spinball* (previously Spinball Whizzer) at the UK's Alton Towers and *Dragon's Fury* at the UK's Chessington World of Adventures.



Tony Hawk's Big Spin, a Gerstlauer spinning roller coaster.

A similar ride debuted in 2004 when the first two Gerstlauer Spinning Coasters opened: *Fairly Odd Coaster* (formerly *Timberland Twister*) at Nickelodeon Universe inside the Mall of America, and *Spinning Dragons* at Worlds of Fun. These coasters have twisted track layouts similar to Maurer Söhne's Xtended SC, but the seats on Gerstlauer Spinning Coasters face towards each other, as with the Virginia Reel.

In 1995 Intamin AG debuted a spinning coaster with trains instead of individual cars: *Comet Express* at Lotte World in Seoul, South Korea. The trains have eight cars, with each car's two seats side by side. Like the Maurer Söhne and Gerstlauer spinning coasters, this "Twist and Turn Coaster" features a twisted track layout. Three of these models have been built around the world.

Another spinning coaster with trains, *Euro-Mir*, was built by MACK Rides of Germany in 1997 at Europa-Park. The trains consist of four cars with four seats divided into two rows facing away from each other. The coaster has a twisted track layout that is built

around five cylindrical towers. MACK opened a second coaster of this type, *Sierra Sidewinder*, at Knott's Berry Farm in 2007.

Chapter 10

Stand-Up Roller Coaster and Steel Roller Coaster

Stand-Up Roller Coaster



Shockwave at Drayton Manor Park, the only Stand-up in Europe

A **stand-up roller coaster** is a roller coaster designed to have the passengers stand through the course of the ride. These roller coasters are very intense, and generally carry taller height restrictions than other rides.

History



Trains feature saddle seats that move vertically to accommodate various heights. (*The Riddler's Revenge* at Six Flags Magic Mountain)

The first stand-up roller coasters in the world were actually built as standard roller coasters. Japanese manufacturer TOGO built *Momonga Standing & Loop Coaster* in 1979 for Yomiuri Land in Tokyo, Japan. Three years later, TOGO built *Dangai* at the former Thrill Valley amusement park in Gotemba, Shizuoka, Japan. Both rides added stand-up trains in 1982, with *Dangai* opening one day before *Momonga Standing & Loop Coaster*.

The first stand-up roller coaster in the United States was, like the Japanese roller coasters before it, a modified attraction. Arrow Dynamics built one of its signature corkscrew roller coasters, named *Screamroller*, at Worlds of Fun in Kansas City, Missouri in 1976. In 1983, Arrow designed a stand-up train for the attraction, which was subsequently renamed *Extremroller* (also known as *EXT*). However, the track and structure were

never designed for stand-up trains, and the original sit-down trains were reinstalled in 1984, remaining in place until the attraction was removed in 1988.

The 1984 season saw two stand-up roller coasters open in the United States. One was, like *Extremoroller*, yet another retrofit. The *River King Mine Train* was an Arrow-built roller coaster that opened with its park, Six Flags St. Louis, in 1971. Stand-up trains were added for 1984, and the attraction's name was changed to *Rail Blazer*. However, like *Extremoroller* the season before, the track wasn't intended to use stand-up trains and, prior to the start of the 1985 season, the original trains and name were restored. Also in 1984, 350 miles east of Six Flags St. Louis, Kings Island at Mason, Ohio opened the TOGO-designed *King Cobra* as the world's first purpose-built stand-up roller coaster. The attraction operated from 1984 to 2001.

The last new stand-up roller coaster to be constructed was *Georgia Scorcher* at Six Flags Over Georgia in 1999. In 2005, *Batman: The Escape* at the now-defunct Six Flags Astroworld was disassembled and placed in storage at Darien Lake.

Design

Three manufacturers—TOGO, Intamin AG and Bolliger and Mabillard—have constructed multiple stand-up roller coasters. TOGO's stand-up models feature cars that seat four passengers in two rows of two. Models from Intamin and B&M also seat four riders per car, but in a single four-abreast row.

On a standard roller coaster, the rider is held in their seat by some form of harness, such as a lap bar or an over-the-shoulder restraint. As stand-up roller coasters, by their design, do not have "seats," the harness system must both restrain and support the rider. Typical stand-up roller coaster harnesses are mounted on vertical posts, which allow the harness to adjust to riders of different heights. At the bottom is a seat resembling that on a bicycle, while at the top is an over-the-shoulder harness. TOGO models normally use a lap bar to further secure riders, while B&M models add a seat belt to connect the bicycle seat to the shoulder harness.

With some exceptions, stand-up roller coasters normally feature at least one inversion. These inversions can include vertical loops, incline loops, dive loops and corkscrews. Only one stand-up roller coaster, *Shockwave* at Drayton Manor Theme Park in the United Kingdom, includes a zero-gravity roll.

List of stand-up roller coasters



Georgia Scorch, the last stand-up coaster to be built



The first Bolliger & Mabillard stand-up coaster, Iron Wolf



Mantis, a Bolliger & Mabillard stand-up coaster

Modified stand-up roller coasters

Steel Roller Coaster



Dragon Challenge, the world's only Dueling Steel-Inverted roller coaster located at Islands of Adventure in Universal Orlando Resort, Orlando, Florida.

A **steel roller coaster** is a roller coaster that is defined by having a track made of steel. Steel coasters have earned immense popularity in the past 50 years throughout the world. Incorporating tubular steel track and polyurethane-coated wheels, the steel roller coasters can provide a taller, smoother, and faster ride with more inversions than a traditional wooden roller coaster.

Arrow Dynamics first introduced the steel roller coaster to feature tubular track to the thrill industry with their creations of the Matterhorn (Disneyland) and the Runaway Mine Train (Six Flags Over Texas).

As of 2006, the oldest operating steel roller coaster in North America is Little Dipper at Memphis Kiddie Park in Brooklyn, Ohio and has been operating since April, 1952. The oldest operating steel roller coaster in the world is rodelbaan at de Waarbeek (Netherlands). It has been operating since 1930.

Characteristics

- Steel coasters have a generally smoother ride than their wooden counterparts, although it is sometimes argued that wooden roller coasters provide a bigger feeling of "threat" due to their rougher ride and can be more intense than steel roller coasters.
- Almost all world records for tallest, fastest, and longest coasters are currently held by steel roller coasters.
- The fact that fewer supports are needed means steel roller coasters have made a large variety of features possible, such as Loops, Barrel Rolls, Corkscrews, Zero-G Rolls and Beyond 90° Drops

There are different types of steel coasters, such as flying, inverted, floorless, and suspended swinging.



Blue Fire, an inverting launched roller coaster, at Europa-Park, Germany.



Dorney Park and Wildwater Kingdom's Steel Force and Thunderhawk roller coasters, just outside Allentown. Steel Force opened in 1997 as the tallest and fastest roller coaster on the East Coast of the United States, with a first drop of 205 feet (62 m) and a top speed of 75 miles per hour (121 km/h).

Chapter 11

Suspended Roller Coaster and Wooden Roller Coaster

Suspended Roller Coaster

A **suspended roller coaster** is a type of steel roller coaster in which the car hangs from the bottom of the rolling stock by a pivoting fulcrum or hinge assembly. This allows the car and riders to swing side to side as the train races along the track. Due to the swing designs, these roller coasters cannot invert riders.

History

One of the earliest suspended roller coasters was known as *Bisby's Spiral Airship*, built in Long Beach, California in the early 1900s. Riders on *Bisby's Spiral Airship* rode in square gondolas suspended from the track above, which were then carried via lift hill to the top of a tower. The gondolas then rolled down the track, which spiraled down the tower back to the loading platform. The attraction operated at least until the mid 1910s.

In 1975, German aircraft manufacturer Messerschmidt debuted *Alpenflug* at the annual Oktoberfest fair. Featuring multi-car trains and a 2700-foot twisting, spiraling layout, *Alpenflug* was a hit during the 16-day fair. However, the design was scrapped after analysis revealed significant stress in the track, whose curves were not banked, and in the wheel assemblies, as the train's brake fins were located at the bottom of the train's gondolas instead of near the track itself.

The first permanent modern suspended roller coaster was *The Bat* at Kings Island. Built by Arrow Dynamics, *The Bat* opened April 21, 1981, but it was soon plagued with problems. The problems included: excessive stress on the support springs due to the unbanked curved track sections and stress on the wheels because the brakes were mounted at bottom of the swinging cars. Kings Island's USD \$3.8 million ride closed in 1983 and was later scheduled for demolition. *The Bat's* former site is now occupied by the Arrow-designed looping coaster *Vortex*.

Arrow Dynamics continued to refine its suspended roller coaster design, culminating in the debut of *The Big Bad Wolf* at Busch Gardens Williamsburg and *XLR-8* at Six Flags Astroworld in 1984. Since 1984, Arrow manufactured ten suspended roller coasters, including *Iron Dragon* at Cedar Point and *Ninja* at Six Flags Magic Mountain.

Other manufacturers have also constructed their variations on the suspended roller coaster. Dutch designer Vekoma manufactured a suspended model dubbed "Swinging Turns," of which three copies were constructed. Vekoma offers both traditional car designs as well as a new "floorless" car with seats similar to those found on an inverted roller coaster like on the Arrow-designed Vampire (roller coaster) at Chessington World of Adventures. Caripro, another designer based in The Netherlands, manufactured twelve suspended roller coasters and American designer Setpoint manufactured four.

List of suspended roller coasters



An Arrow Dynamics suspended roller coaster, Big Bad Wolf at Busch Gardens Europe



A setpoint suspended roller coaster, Roller Soaker at Hershey Park



Trains swinging on an Arrow Dynamics manufactured suspended roller coaster Flight Deck at Kings Island



Trains swinging on an Arrow Dynamics manufactured suspended roller coaster Iron Dragon at Cedar Point

Wooden Roller Coaster



The Texas Giant, a large wooden roller coaster at Six Flags Over Texas in Arlington, TX



Colossos, one of the world's largest wooden roller coasters at Heide Park, Germany.



Thunderbird in the PowerPark amusement park

A **wooden roller coaster** is most often classified as a roller coaster with laminated steel running rails overlaid upon a wooden track. Occasionally, the structure may be made out of a steel lattice or truss, but the ride remains classified as a wooden roller coaster due to the track design. Due to the limits of wood, wooden roller coasters in general do not have inversions (when the coaster goes upside down), steep drops, or extremely banked turns (overbanked turns). However, there are exceptions; Son of Beast at Kings Island has a 214-foot-high (65 m) drop and originally had a 90-foot-tall (27 m) loop until the end of the 2006 season, although the loop had metal supports. Other special cases are Hades at Mount Olympus Water and Theme Park in Wisconsin Dells, Wisconsin, featuring a double-track tunnel and a 90-degree banked turn, The Voyage at Holiday World (an example of a wooden roller coaster with a steel structure for supports) featuring three separate 90-degree banked turns, Ravine Flyer II at Waldameer Park which has a 90-degree banked turn, and T Express at Everland in South Korea with a 77-degree drop.

Decline and revival

Once a staple in virtually every amusement park in America, wooden roller coasters appear to be on a slow decline in popularity for a number of reasons. Steel roller coasters, while having larger up-front costs, cost much less in ongoing maintenance fees throughout the years of operation. Wooden roller coasters, on the other hand, require

large amounts of devoted funds annually to keep the ride in operating condition through regular re-tracking, track lubrication, and support maintenance.

Wooden coasters are also becoming less marketable in today's media-driven advertising world. Superlative advertising in which the "biggest", "tallest", or "fastest" ride is what brings in crowds often cannot apply to new wooden roller coasters, especially since a large majority of record-holding rides are steel. Amusement parks are always looking to add attractions which can be presented in commercials and ads as incredibly tall, fast, or extreme which eliminates many wooden roller coasters.

However, the arrival of several new wooden coasters has bucked the downward trend. In 2006, a trio of giant wooden coasters opened in the United States: The Kentucky Rumbler at Beech Bend Park, The Voyage at Holiday World, and El Toro at Six Flags Great Adventure. Another wooden coaster, Renegade at Valleyfair!, opened in 2007. It remains to be seen whether or not these new coasters mark the beginning of a wooden coaster revival, but they do indicate that amusement parks continue to show interest in wooden roller coasters. This may be owed to the fact that rides like El Toro at Six Flags Great Adventure actually feel like steel coaster, due to prefabricated track.

Golden Era

It is agreed on many that the Golden Era of coaster design was the 1920s. This was the decade many of the world's most iconic coasters were built. Some of these include Santa Cruz Beach Boardwalk's Giant Dipper, the Coney Island Cyclone, and the Big Dipper at Geauga Lake. This decade was the design peak for some of the world's greatest coaster designers, including John A. Miller, Harry Traver, Herb Schmeck, and the partnership of Prior and Church.

Unfortunately, the great depression ensured destruction of many of these great classics, but a few still stand as ACE classics and landmarks.

The popularity may have come to a short closing, but that didn't stop certain amusement parks from building scream machines again and again. Cedar Point built Blue Streak in 1964, a Philadelphia Toboggan Company manufactured coaster designed by John C. Allen. This dead age of coaster design was brought to an end by The Racer at Kings Island.

Revival



Dorney Park and Wildwater Kingdom's Steel Force and Thunderhawk roller coasters in Allentown, Pennsylvania. Thunderhawk is one of the longest-standing wood roller coasters in the U.S.

Wooden roller coasters slowly became larger over the course of time. By the end of the 1970s, Kings Island came back to the scene with *The Beast*, which currently holds the record for the longest wooden roller coaster in the United States (*The Beast* was also the longest roller coaster in the world overall until 1991, when *The Ultimate* at Lightwater Valley opened). Judge Roy Scream, a wooden roller coaster with a 71' drop, opened at Six Flags Over Texas in 1980, Grizzly, a wooden roller coaster patterned after the Cincinnati Coney Island Wildcat, opened in 1982 at Kings Dominion, and Raging Wolf Bobs (inspired by The Riverview Park Bobs) opened at Geauga Lake Park in 1988.

The 1980s would continue with *The Beast* leading the way for many new wooden coaster designs. In the 1990s, the popularity of large wooden twister roller coasters would come to the scene. With rides built by the Dinn Corporation such as Mean Streak at Cedar Point and Texas Giant at Six Flags over Texas, many wooden roller coasters have become as big as possible.

The popularity of traditional out-and-back designs also became popular throughout the 1990s, except they could be made bigger and better with new technology. Custom Coasters International (CCI), is responsible for creating a large number of out-and-back

and twisting coasters such as Shivering Timbers at Michigan's Adventure, GhostRider at Knott's Berry Farm, The Raven at Holiday World, and its sister coaster, The Legend.

Modern Designs

After CCI went bankrupt in 2002, the designers from the design team came together again to found The Gravity Group coaster manufacturing company. Intamin AG, another well-known roller coaster company, came to the scene with their Prefabricated Wooden Roller Coaster. And a new company named Great Coasters International has come to the scene with their new breed of wooden coaster designs, including Wildcat at Hersheypark, the Lightning Racer (also Hersheypark), Gwazi at Busch Gardens Tampa Bay, and Evel Knievel at Six Flags St. Louis.

Also in 2000, Kings Island premiered the world's tallest and fastest wooden roller coaster, the Son of Beast. Until 2006, it was also the only wooden roller coaster with an inversion. Following an accident with the structure, the loop was removed before the 2007 season.

Newer wooden roller coasters often break the rules and restrictions traditionally associated with the type. Many new wooden roller coasters feature extremely steep drops, 90-degree turns, and normally feature trains other than Philadelphia Toboggan Trains. Great Coasters International usually run their coasters with their signature Millennium Flyer trains. The Gravity Group has developed Timberliners to compete with Millennium Flyer trains. They are scheduled to be added to The Voyage later this year.

At Upper Clements Park in Nova Scotia, a wooden roller coaster was built in 1980 that today still wins awards for the terrain that was used in dictating its design and the terrain that it still covers. Built using a natural setting beside the sea, the Tree-Topper curves its way over a river, through a marsh, up onto hills and into a forest. The coaster is one of the premier attractions at this park.

Prefabricated track

One of the most significant recent developments in wooden coaster design is Intamin AG's use of prefabricated track. This design essentially applies the principles of steel coaster manufacturing to wood.

Traditional wooden coaster track is built on-site. It is nailed layer-by-layer to the support structure, then it is smoothed to the proper shape and steel running plates are mounted on top. Prefabricated track, on the other hand, is manufactured in a factory. It is made of many thin layers of wood that are glued together and then laser cut to the exact shape needed. The track is made in 25-foot (7.6 m) sections which have special joints on the ends that allow them to snap together like K'Nex pieces. This process allows for far higher precision than could ever be achieved by hand. In addition, the trains for a prefabricated wooden coaster have wheels with polyurethane tires, just like a steel coaster. In contrast, traditional wooden coaster trains have bare metal wheels.

This design results in a ride that is nearly as smooth as the smoothest of steel coasters, and much smoother than any traditional wooden coaster. However, some coaster enthusiasts may find this smoothness to detract from the experience, as it would not have the same character as a traditional wooden coaster. Despite this, all four existing prefabricated wooden coasters are consistently rated among the best wooden coasters in the world.

Prefabricated wooden coasters also benefit from faster construction and reduced maintenance compared to a traditional wooden coaster. The track is simply bolted to the structure, which takes an insignificant amount of time compared to actually building the track. The track also stays smooth much longer than traditional track, which becomes rough rather quickly and eventually must be replaced.

Wooden versus steel

Wooden roller coasters provide a very different ride and experience from steel roller coasters. While they are technically less capable than a steel coaster when it comes to inversions and elements, wooden coasters instead rely on an often rougher and more "wild" ride as well as a more psychological approach to inducing fear. Their shaky structures and track, which usually move anywhere from a few inches to a few feet with a passing train, give a sense of unreliability and the "threat" of collapse or disregard for safety. Of course, this assumption is purely mental and wooden roller coaster supports and track systems are designed to sway with the force. If the track and structure are too rigid, they will break under the strain of the passing train. The swaying of the track reduces the force applied per second, like a shock absorber.

Like steel roller coasters, wooden roller coasters usually use the same three-wheel design, pioneered by John Miller. Each set of wheels includes a running wheel (on top of the track), a side friction wheel (to reduce side to side movement known as "hunting") and an upstop wheel (beneath the track to prevent cars from flying off the track). Some wooden coasters, such as Leap-The-Dips, do not have upstop wheels, and are therefore known as side friction roller coasters. As a result, the turns and drops are more gentle than on modern wooden roller coasters. Scenic Railway roller coasters also lack upstop wheels, but rely on a brakeman to control the speed. A handful of wooden coasters use flanged wheels, similar to a rail car, eliminating the need for side friction wheels.

The debate rages as to which type of coaster is better: wood or steel. This is unlikely to ever be settled, however, because each category distinguishes itself from the other in a number of ways, in addition to also providing a substantially different and unique ride.