# RIDE MECHANICS

IMMERSIVE AMUSEMENT PARK ATTRACTION
Thumbelina Thrill Ride - Group 2

## Ride mechanics subsystem

A rollercoaster is a complicated product with many physics based attributes which all need to work perfectly. The task of this subsystem is to design parts of the roller coaster in such a way that the rollercoaster will function as intended.
A lot of similarities can be found with the subsystem ride design, however the difference between our group and theirs is the primary goal. We provide tools which the ride design team can use to create an experience, after which we can check if all components for this experience are feasible.

## Requirements

At the setup of the subsystem we set up a list of requirements, found in *ridemechanics_handout §1*, which the rollercoaster needs to fulfill. The most important ones are:

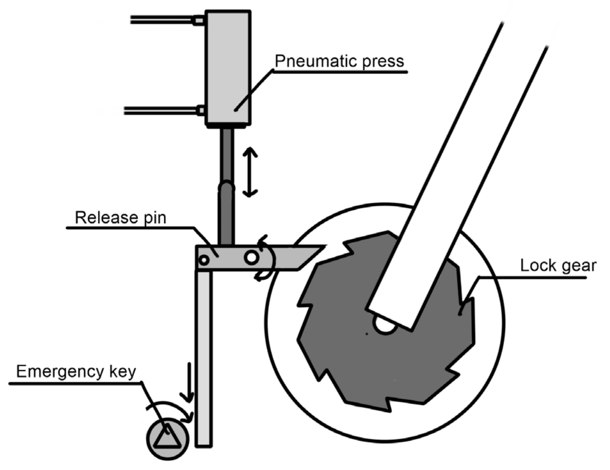
- The ride has to be completed with minimum and maximum capacity.
- Carts should open the seatbelts automatically at the load platform, but it should also be possible manually by an employee
- Stop the carts in an emergency situation in a safe location.
- The rail is able to measure the exact position of the carts on specific parts during the ride

These requirements, and those unlisted, will be evaluated using the test plan stated below.

## Cart mechanics

### Safety bar

A T shaped safety bar will be used in the carts. As we are not making loopings, shoulderguards are not necessary. U-safety bars would consist of more parts and are thus also not chosen. Safetybelts will not be implemented as this will cost time at loading and unloading and will not give any significant safety, as the passengers are already inside a cup. Opening and closing of the safety bars will happen pneumatically by a signal given by the rails to the cart. In case of emergency the employee can remove the lock using a key.



Pneumatic release system of the safety bar

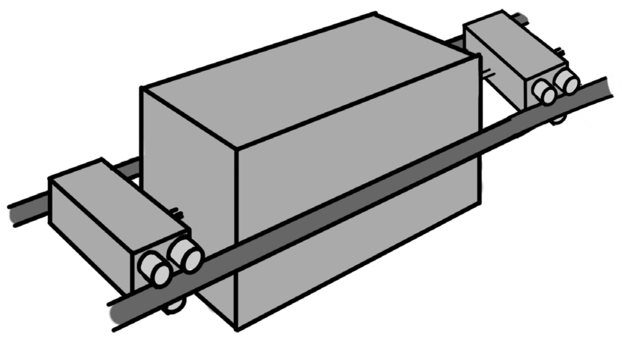
### Capacity

Initially, the requirement was to have a capacity of 1400 passengers per hour (p/h). However, it was calculated that this is a highly unfeasible amount since there need to be 5 trains with 28 passengers simultaneously on the ride to fulfill this requirement. Therefore it was decided to decrease the capacity to 1042 p/h. This capacity can be managed with 3 trains on the ride each of which consists of 7 separate carts which can hold 4 passengers. The exact calculations for this can be found in *ridemechanics_handout §5*.

## Track mechanics

### Rails

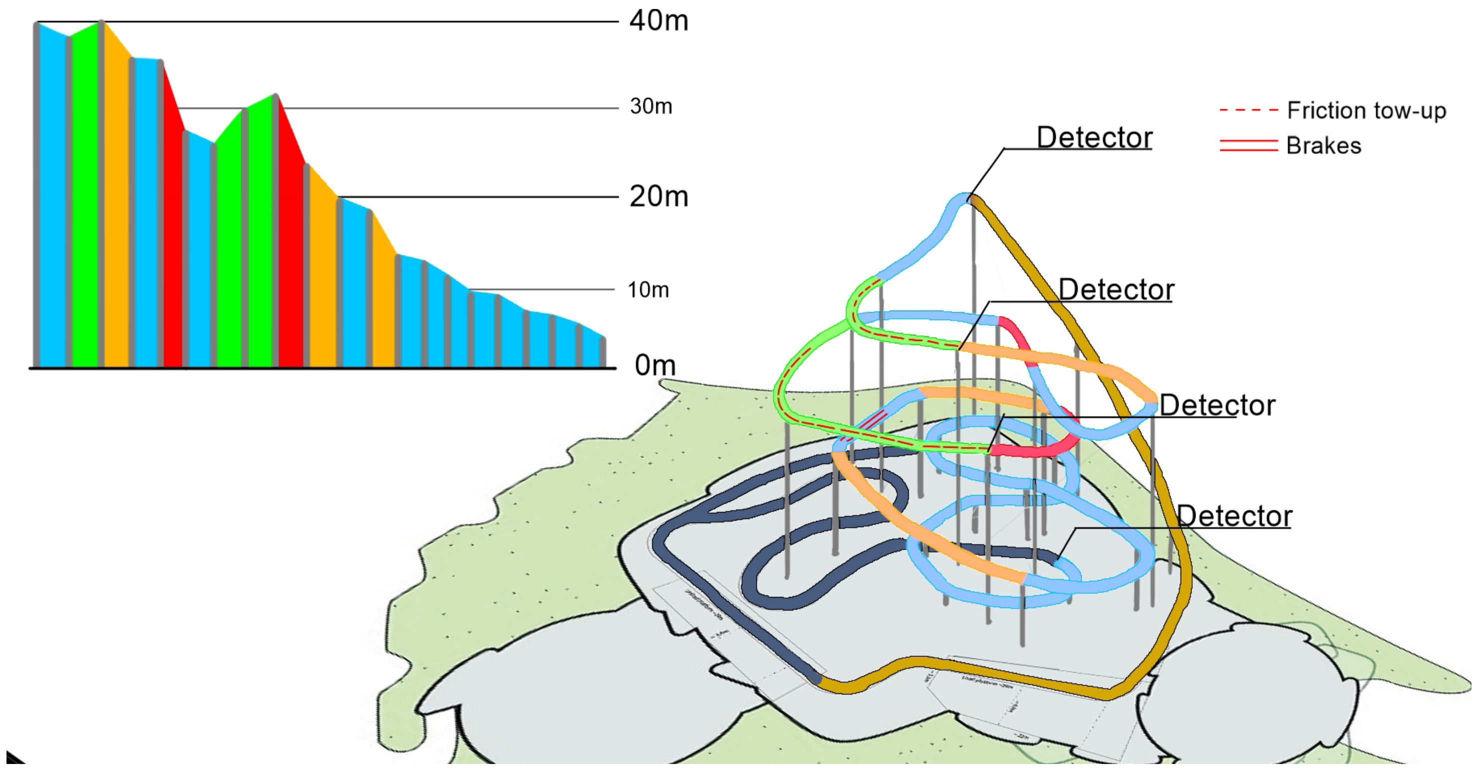
To support the emerging in the story a nonconventional rail type was used: the tube-rollercoaster. With the rails on the same height as the chairs it gives yet another feeling of being smaller than normal.



### Turn radius

This rails design comes with its share of problems. One of the bigger ones is the minimum turn radius, as the cart is inside the rails and should not hit the rails itself. Thus, mathematics was used to calculate the smallest curve the cart could make fully horizontal which resulted in a circle with a radius of 3,7 meters measured from the middle of the track. The calculations can be found in *ridemechanics_handout §8*.

### Technical track design



After giving the minimum radius of the curve to the ride design subsystem, they created a track design. It was up to us to calculate if and how the train will get to the end station. The track contains four main sections: entrance/exit, lift, fast section and slow section. We focussed on the fast section as it is the only section not fully supported by either friction wheels or a chain lift, which could mean that the cart could involuntarily stop halfway through.
To make sure this would not happen the fast section was divided into 21 parts spaced 20 meters from each other. These were scaled on their intensity, and an estimated acceleration was calculated as can be seen in the table on the right. The precise calculations can be found in *ridemechanics_handout §7*.

| Section color | Height difference (m per section) | Acceleration without resistance (m/s per section) | Estimated acceleration (m/s per section) |
|---|---|---|---|
| 🟩 | +3 | -7,8 | -12,1 |
| 🟦 | -1 | 4,4 | 0 |
| 🟧 | -5 | 9,9 | 5,5 |
| 🟥 | -10 | 14,0 | 9,6 |

With these calculations it was determined where friction wheel tow ups and brakes should be placed. The friction wheel tow ups also gave the opportunity to stop the cart from continuing to its next section without needing emergency brakes, as the tow up would just stop if the train had not yet been detected to go to the next section. The calculations show a top speed between 55 to 61km/h depending on the intensity of the brakes and mass of the cart.

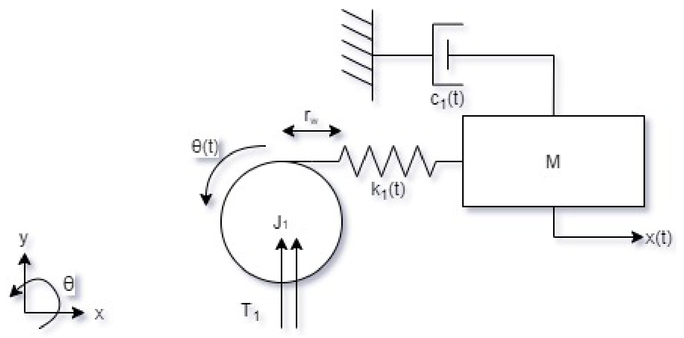
## Internal- & external interfaces

There are 5 internal components all with interfaces towards and from each other, these sections are: the cart, the rails, the control room, the ride and the safety system. Almost all information is first sent to the safety system which after a green light from the control room will start the ride. This safety system also checks if the safety bar is locked everywhere or if there is a train in front of another train on the track and acts accordingly. Find this internal n2 diagram in *ridemechanics_handout §2.*

Externally, there is an interface with 2 subsystems, the loading platform and the ride design. The train control on the loading/unloading platform communicates with the rails and safety system. The decor only has 1 output to the safety computer showing the status. Find this external n2 diagram in *ridemechanics_handout §3*
Besides information, the interface between ride mechanics and ride design becomes a lot more blurry. As for example the cart mechanics and safety belt and cart design work together.

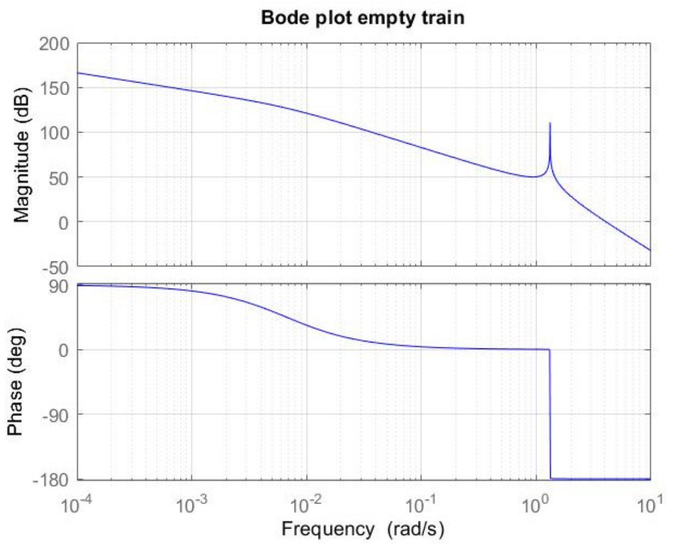
### Mechatronics

The application of a mechatronics system will be present in the braking system of the train. The train needs to comfortably stop at exact locations at both loading and unloading platforms however, the deceleration of the train changes based on mass of the train. This can be optimized with mechatronics by creating an ideal physical model (IPM) of the real world, which can be reduced to a 4th order IPM. Using the equation of motions, the corresponding transfer function was calculated. The reduction from a 10th to a 4th order model can be found in *ridemechanics_handout §6.a*.



Transfer function:

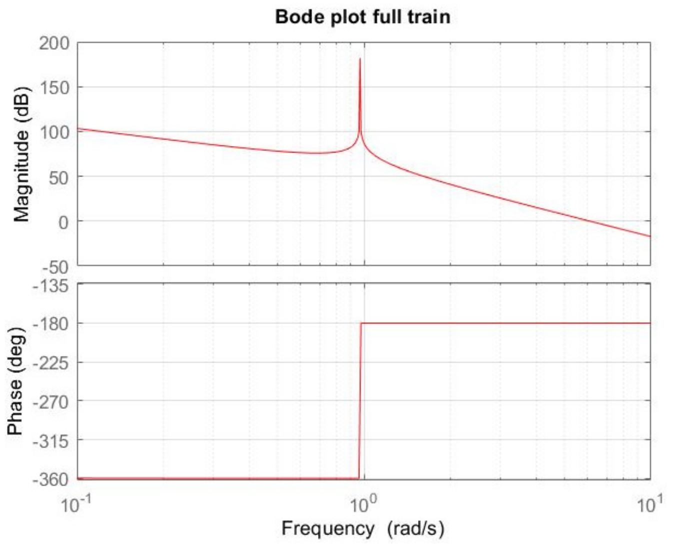
$$\frac{X(s)}{T(s)} = \frac{-\frac{k_1 \cdot r_w}{J\cdot m}}{s^4+\frac{c}{m}\cdot s^3+\frac{J+m\cdot r_w^2}{J\cdot m}\cdot k_1\cdot s^2+\frac{k_1\cdot r_w^2\cdot c}{J\cdot m}\cdot s}$$

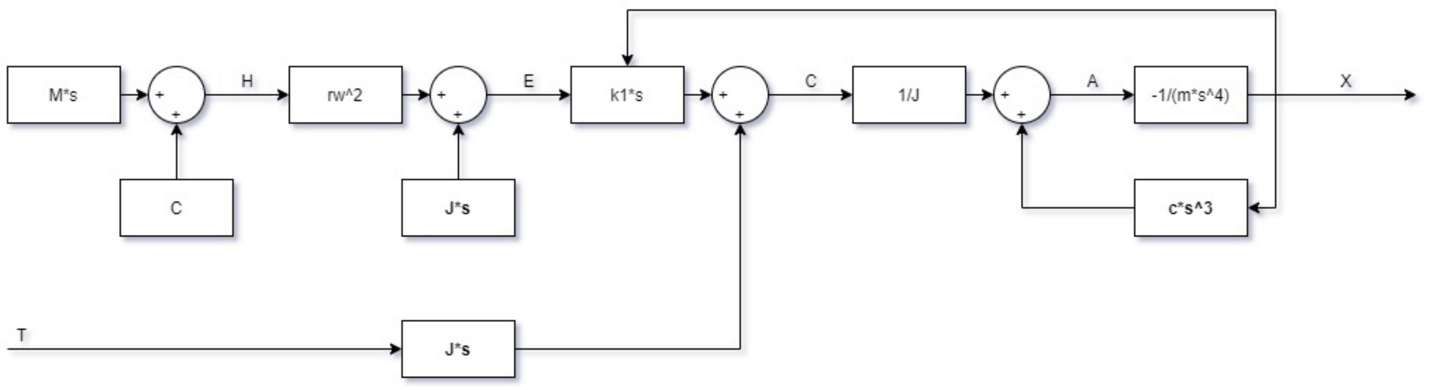


In order to create bode plots, the variables needed to be filled in by guessing realistic minimum and maximum values. This resulted in two bode plots for which the one on the top represents the train when completely empty and the one on the bottom when completely filled.

For this system, a PI controller is desired since a slow reaction speed is not a problem. Moreover, the reduction of overshooting is the primary focus, this is something that the PI controller excels at.

Furthermore, a block diagram was created to visualize the system and from which the steady state error could be defined. A complete overview of the mechatronics calculations can be found in *ridemechanics_handout §6*.





## Testplan

In order to check whether all requirements are met, a future test plan was created. The test plan is divided into three phases. First, for each interface the verification method is determined which confirms if an interface is ready to be tested. Second, it is determined what components will be tested, this is based on the list of requirements. The last phase is the validation where a plan is set of what needs to be done in case certain tests fail. If the subsystem is then fully approved, the next step is to move on to the whole system integration. This all is put into a table and can be found in *ridemechanics_handout §4*.

## Reflection

The next step in our process would be to start simulating. With all the rough calculations done it should be looked into what the mass of the train will really be and how well the train gets to its destination.
Two things were on the agenda but have not been explored: the G-forces and the support beams. Using the smallest radius curve and the highest speed we calculated that the G-force will not exceed 7.5G, this is too large for a good conclusion and thus every curve should be separately looked into to make sure that the G-force will not exceed too many Gs for too long. Using G force it would be then possible to determine the maximum force which would come onto the support beams. Lastly, the strength and overall design of the support beams could be calculated.

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